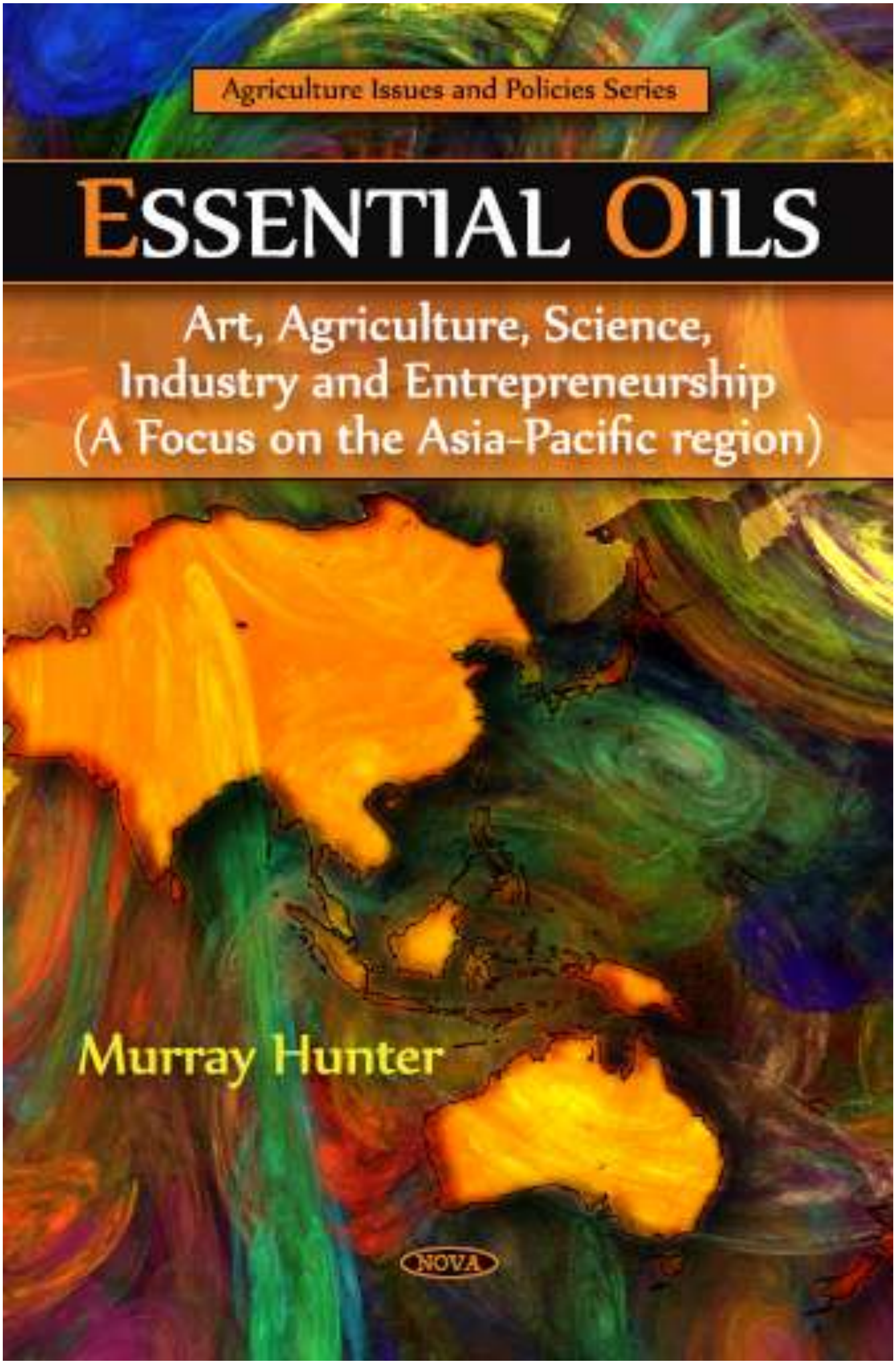
Agriculture Issues and Policies Series
ESSENTIAL OILS
Art, Agriculture, Science, Industry and Entrepreneurship (A Focus on the Asia-Pacific region)
Murray Hunter
NOVA

ESSENTIAL OILS: ART, AGRICULTURE, SCIENCE, INDUSTRY AND ENTREPRENEURSHIP (A FOCUS ON THE ASIA-PACIFIC REGION)

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In memory
of
my grandfather
Leonard David Hunter
(1911-1973)
A self-made chemist
A pioneer of essential oil based products
in Australia
A great entrepreneur and mentor to all

Contents

PREFACE

The essential oil industry is under threat from numerous issues at present. Rising agricultural input costs, particularly petrochemical based fertilizers and fuels are squeezing farmers' profit margins. Rising food prices and the increasing value of housing and industrial land prices is creating competition for land, particularly around populated areas. Adverse weather conditions and changing climate are creating both short and long term problems. Poor crop yields are occurring much more regularly than before because of unusually heavy rain, hail, floods, heat-waves and cold snaps. Climate change is affecting long term yields due to increasing plant stress caused by warmer temperatures. As many temperate areas are becoming drought affected, crop cultivation is becoming more difficult as irrigated water is becoming extremely scarce. This is threatening the very survival of many enterprises and industries in their present locations.

Industry change through takeovers is increasing buyer concentration, making it more difficult for small firms to survive in the industry. Technology change requires continuous learning and development of new techniques which change the way products are manufactured. Increasing consumer scrutiny, changes in taste and increasing sophistication in developing markets are creating shorter product lifecycles, requiring companies to spend more on product development. Last but not least, a rapidly tightening regional regulatory environment is increasing the costs of introducing new materials and products into the marketplace.

However, notwithstanding the threats and challenges mentioned above, opportunities still exist in the essential oil industry. In fact, the issues mentioned above can increase the propensity of opportunities to evolve inside the industry, if one knows where to look and how to evaluate their potential.

The essential oil industry is far from being monolithic. It can be seen more as a group of overlapping segments of other industries, which are related by the nature of the product – natural aromatic compounds. Its agricultural component would include the collection of biomass from the wild, the cultivation of selected flora in the field or the collection of by-products from other activities like timber logging or citrus fruit production. Manufacturers in the essential oil industry use essential oils and other natural aromatic materials to produce a number of value added products which include flavours and fragrances, fine fragrance, cosmetics, household, pharmaceutical, agro-chemical and aromatherapy products. These products are promoted, marketed, sold, transferred, shipped and consumed through various levels of the supply and value chains. Finally, the public sector component plays a role in both research and regulation at a local, national and international level, both on policy and specific issues.

Yet with all the attention that has been given to essential oils in the past, the reality must be stated – essential oil production will never become a major crop or contributor to any agricultural economy. It is a niche industry, an alternative crop to any mainstream agricultural portfolio in any country. Also, in the flavour and fragrance, cosmetic, household product, pharmaceutical *(although nearly 70% of pharmaceuticalactive compounds have been synthesized from the inspiration of natural compounds)*, and agro-chemical industries, essential oils in an aggregate sense only play a minor part in the composition and formulary of products in those industries. Only in aromatherapy are essential oils the main ingredient in product formulatory. This scenario will never change. The importance of essential oils lies in the role they play in linking industries, which makes their economic contribution substantial – as ingredients in flavours and fragrances, as ingredients in cosmetics and household products, and as starting materials of prime active ingredients in pharmaceuticals and agro-chemicals like pesticides and fungicides. There is no doubt however that essential oils lead to great passion and take on a major role in the branding of many products.

This leads to another point. There is a vast amount of misleading and wrong information about essential oils and the industry. This can be widely found in media articles, the internet, papers presented to conferences and even books. There are a number of *"consultants"* around that base their advice on sometime misinformed premises and old industry paradigms. Some of the organizations involved in the essential oil industry, particularly those representing traders, sometimes appear to be contributing to *industry mythology* and have encouraged an elitist approach to those considered *"outsiders"* to the industry.

Many people who are attracted to some part of the essential oil industry, whether production or application is based on passion, emotion and infatuation, rather than business logic and sense. This can be a dangerous and delusional footing.

The failure rate of those setting up essential oil production ventures is outstandingly high. It is also sad that many of these failures involve community groups, led by some consultant's advice. For far too long essential oil markets been analysed on an economic basis, rather than a niche entrepreneurial opportunity.

Although business failure rates have been high among producers, a number of success stories exist. These are usually about companies producing cosmetics and aromatherapy ranges utilizing essential oils. Many new aromatherapy, cosmetic and agro-chemical pesticide and fungicide products are being launched onto market. A number of companies within a short space of time have grown into international suppliers of essential oil based products. These companies have been at the innovative forefronts of their respective industries.

Thus innovation would appear a prerequisite of success, especially with changing consumer tastes, lifestyles and product expectations. This certainly supports the argument that the essential oil industry should be viewed in the entrepreneurial paradigm to see if more sense and understanding can be gained – which is what this book will try to do.

With the term *technology* taken simply to mean *a way or means to do something*, then *new technology* means *a new way or means to do something*. In that light, it is certainly worth examining how things are done at farm level to produce essential oils, i.e., propagation, planting, crop maintenance, harvesting and extraction. Becoming competitive and developing a source of competitive advantage in essential oil production may have more to do with new technology introduction than with labour cost advantages. Many methods of propagation, planting, maintenance, harvesting and extraction have been developed with knowledge built more upon learning from trial and error on the part of entrepreneurial farmers than taking stock solutions off a shelf somewhere. Through the observation of operational essential oil ventures, successful technology would appear in many cases to be homegrown solutions in response to specific farm level problems. Add to that the rapid growth of biotechnology and the emphasis on the molecular level with *nano-technology* - technology issues are going to continue in their importance. An entrepreneurial approach may help to understand and manage this.

There have been many books written on essential oils which have placed the word *art* in their titles. This has been in recognition of the creativity needed to construct a fragrance or perfume, sometimes paralleled with the artist or the musician. However the concept of art can be extended to the business of essential oils. Business commentators now tend to call business an art, rather than a science. In business there are many ways to achieve an end or objective and a multiplicity of strategies that can be used in any particular situation. The metaphor of *the art of strategy* is maybe more applicable. Agriculture can also be an art form in that there are also a number of ways to achieve an end. If we view landscapes, which are part of an eco-system as art, then utilizing the land in a sustainable way may also be considered an art form. Sustainable solutions to agricultural problems would seem to be much more important than before. Hopefully this book will provide the reader some insights into the art of essential oils in the wider, rather than the narrower sense.

The development of essential oils and related products requires some knowledge in botany, natural product and phyto-chemistry, analytical chemistry, agronomy, thermodynamics and chemical engineering, agricultural and mechanical engineering, economics, supply chain management, accounting, finance, organization, marketing, new product development, cosmetic, household product, and pesticide chemistry, farm and industrial management, human resource and project management. In addition skills in the areas of opportunity identification and evaluation, strategy selection, development and enactment are required. An ability to negotiate and present ideas to various stakeholders is also important. Thus developing essential oils or an essential oil related product requires a true multi-disciplinary approach. The entrepreneur in this industry must be a *'jack of all trades'* to understand and find solutions to the issues he or she will encounter. It is through inter-disciplinary thinking that new products will come to the market.

At the product level where changing consumer tastes, expectations and lifestyles influence what is required, coupled with more distribution channel avenues and a dramatic increase in new regulation around the world, new product forms, branding linkages, organizational form, and channel utilization requires new knowledge to be applied. These changes require new thinking in the industry and this may not be based on the same conventional thinking of the past. This would seem to be of advantage to small companies, where the larger multinationals have tended to follow and take ideas onboard, once someone else has proven them successful.

I have been lucky and privileged to have had the opportunity to be involved in as so many aspects of the essential oil industry as I have. Discovering new compounds in plants was an exciting time, requiring a massive and focused effort with only a remote chance of finding something that may be commercially interesting. Domesticating plants from the wild presented a number of challenges as well researching the ability of selected aromatic crops in adapting to different geographical locations and climates. There was great excitement about designing and developing harvest and distillation systems, especially when they are fully commissioned in working condition. As equally challenging was designing suitable field drainage and irrigation infrastructures for farms that can handle the quantity of water falling during a tropical storm without carrying away the top soil or able to irrigate a field during the dry months. One of the most important and satisfying challenges of late with the high cost of diesel was designing and commissioning alternative fuel systems to power steam generation for a distillation operation in a sustainable way. Learning how to construct a fragrance, responding to fragrance brief and having *my creation* selected by a customer always brought a great sense of pride and satisfaction. Developing new products for consumer markets through the process of nurturing the concept, finding the materials, evaluating packaging concepts and designing the method of production, and finally turning it into the reality was at the envelope of excitement and satisfaction. The *'sell in'* and the drama of waiting for the consumer to give their approval on the product through their purchases is something no one forgets. Traveling, meeting people, attending conferences, visiting markets and walking around a farm are all fulfilling activities for those involved in essential oils.

Having been in and around the essential oil and allied industries for many years and knowing many of the *legendary people* within it encouraged me to write about the industry. I recognize that this book will bring some criticisms from some quarters, but if criticism is feared and prevents ideas being put forward, then there will be no advance in knowledge.

This book reflects much of these experiences and it is written as I understand the issues – sometimes as a layman and sometimes as an expert, but always within the theme of being *a jack of all trades*, with an attempt to inject interdisciplinary insights into issues and challenges that development, production, marketing and management bring forward. As such, this book has attempted to look at product, market, industry and technical issues involved to assist the reader in their situation overcome their specific barriers to entry, so that they can create something of value to the industry – a trait that is needed to survive in any sustainable way in business today. Hopefully this book helps the reader make sense of things.

I hope that students undertaking subjects like business and entrepreneurship, agriculture, bio-systems engineering and chemistry are able to benefit from this book. I hope that this book can assist farmers and potential farmers make decisions about what aromatic crops they invest in. I hope this book provides some insights to researchers in the natural product chemistry and agronomic areas. I also hope this book can assist those wishing to develop aromatherapy, cosmetic, household, pharmaceutical and agro-chemical pesticide and herbicide products. I hope this book can assist the reader understand the industry better, the business involved, the challenges that it brings and develop ideas to help solve some of these problems.

The structure and content of this book is as follows:

Chapter One introduces the definitions relevant to crude products produced by the industry. The size of the market is calculated and apportioned between each product/market segment. The rest of the introduction sets the background of the industry and discusses some of the contemporary problems and issues associated with it.

Chapter Two discusses the structure and interrelationships of the industry. This is undertaken more from a macro point of view so that concepts like derived demand and the influence of synthetic materials can be understood by the reader. This chapter also looks at world essential oil production centres and the various types of essential oil production. The role of essential oils and flavour and fragrance materials in the market typology of consumer products is also introduced. Finally the chapter looks at the essential oil value chain.

Chapter Three takes a closer look at essential oil production in the South-East Asia-Pacific region, focusing on Australia, New Zealand and South-East Asia. Recent international published research undertaken in each country is also outlined.

Chapter Four and Five are two technical chapters which introduce phyto-chemistry and the theory behind the extraction of essential oils. These are important technical areas where any potential practitioner should have some understanding of the basic principals. Chapter Four explains the role of essential oils in plants as secondary metabolites. The various classes of essential oils are explained with a number of examples of natural aroma chemicals found in plants. Chapter Four also introduces the basic methods of essential oil analysis. Chapter Five explains the basic theories of distillation, solvent and CO_2 extraction and the traditional method of enfluerage.

The next three chapters (Six, Seven and Eight) are concerned directly with the concepts of screening potential essential oils for viability to develop commercially and create a development plan. Chapter Six specifically looks at the issues involved in developing a new crop to a farmer or potential farmer, emphasizing what specific information is required to make decisions. The chapter also introduces the concept of risk and challenges. The potential reasons for success and failure are outlined, as well as showing the range of possible development strategies for a project to pursue. Finally this chapter looks at potential products that can be developed for different levels in the value chain, with corresponding potential entry strategies.

Chapter Seven is primarily concerned with the screening and evaluation process and discusses the regulatory environment in detail. Chapter Eight returns to an industry analysis to assist in the development of a strategic plan, using a number of tools. This chapter integrates both the business and technical aspects of the project together so that a comprehensive overall operational plan can be created.

Chapter Nine is concerned with the field issues of essential oil development. Agriculture is first introduced as a system and the issue of climate change and the potential consequences are discussed. The chapter then outlines the project preparation phase, the selection of genetic material, seed collection, the improvement of genetic material, land selection, propagation and planting, field development, crop maintenance, harvesting and extraction. The chapter finishes off with a discussion about Good Agriculture Practice (GAP) and financial modeling of the project.

Chapter Ten examines the organic production of essential oils. The size and growth of the organic industry is examined and the various continuum of farming are discussed. The rest of the chapter looks at the basic organic farming concepts and practices including crop rotation, cover crops and green manures, animal manures, intercropping, composting, mulching, crop diversity, natural fertilizers, minerals and supplements, insect and disease control, weed control, tillage and farmscaping. The planning and site selection issues are looked at before briefly examining the certification process and extent of organic farming in the Asia-Pacific region.

Chapter Eleven looks at the application of essential oils. The chapter begins with an overview of the classification of odours and flavours. The structure of a fragrance and the development of perfumes are described. The process of developing flavours is briefly discussed. The chapter then goes into the new product development process in detail, exploring the concepts of a systems approach to product development, creativity, innovation and opportunity required in ideation, the development of the product concept and prototype, market and product planning, the development of the formulation and manufacturing system and the eventual product launch. The chapter then looks at each product/industry segment utilizing essential oils including cosmetic and personal care products, natural perfumery, household products, agricultural products, pharmaceuticals and natural aroma chemicals and other isolates. The next part of the chapter examines potential distribution strategies, Good Manufacturing Practice (GMP), HACCP, Standards, Occupational Health and Safety (OSHA), environmental compliance and certification schemes. Finally the concept of the holistic and focused enterprise is introduced.

Chapter Twelve integrates enterprise viability with new crop potential, arguing that the type of production organisation will influence what type of crop is viable to select. The concept of opportunity within the framework of personal goals is re-examined. The remainder of this chapter and book looks at criteria to examine new essential oils and finishes with a number of mini-monographs on plants of interest to the author.

Most books tell the reader how to cultivate essential oil crops. This book attempts to help the reader select what crops to develop.

I would have liked to elaborate and explore a number of issues in more detail than I had, but size of the manuscript led to making choices and my own research into these issues is still in its infancy. These issues include exploring alternative energy sources for extraction of natural materials from plants, including solar distillation, boiler design and fabrication, the modification of existing farm equipment to perform new roles particularly in the harvesting area, the development of low cost micro-propagation facilities, and the utilization of enzymes in agronomy, extraction and transformations. I hope sometime in the future further contributions can be made by the writer.

I hope this book leads to a better understanding of the issues involved in developing new essential oil ventures. Certainly I have tried to emphasize the need for innovation at both the technical and business model level to assist in creating product differentiation for the potential practitioner.

Please note the author has not followed strict botanical nomenclature where names familiar to the industry have been used. For any incorrect and misleading material in this book I do sincerely apologize and welcome correction. I also apologize for any grammatical errors in the manuscript.

Murray Hunter
Hat Yai
Songkhla
Thailand

10th February 2009

ACKNOWLEDGEMENTS

Life is often considered a journey, where knowledge, experience and insights are gained through where you are, what you are doing and who you meet up with. I have been lucky to have a long fulfilling journey, which has made it possible to complete this book.

I was born into an entrepreneurial family in Melbourne Australia late in 1958. My grandfather, Mr. Len Hunter Senior was a '*self made'* chemist, inventor and entrepreneur extraordinaire. He invented the product *Pine 'O' Clean*, a pine oil based disinfectant in the 1930s and was given an exemption to import American pine oil during the Second World War to supply the US troops stationed in Australia at the time. Len sold *Pine 'O' Clean*, along with Oxford Shoe Polish to Reckitt and Colman in 1956 for the sum of One Million Pounds. This was an extremely large figure at the time for the family and part of this money was invested to form Hunters Products Pty Ltd, which manufactured household cleaning, personal care, gardening, pool care and institutional products up until the 1980s when again the company, a household name in Australian cleaning, was sold again to Reckitt-Benkaiser.

During the height of the family era, the household division of the group was run by my father Mr. Alan Hunter, who had great influence upon me. My father took me under his wing, always taking me to the factory during the weekends and in latter years during my teens to sales calls all over the country. It was with my father I first came into contact with top executives and even owners of companies like Dragoco, Drom, Monsanto, ICI, Haarman & Reimer, Kao, The Andrew Jergens Company, Kiwi and many others. This was a period of great excitement for me, which opened up many different aspects of the industry.

Two of the people I very fondly remember from that time were Mr. Eric Floyd, the Southern Sales Manager of Dragoco and Mr. Hans de Jong, the Victorian Sales Manager of Haarman & Reimer. Both of them gave me very firm ideas about essential oils and fragrances.

With Hunters household division going to Reckitt-Benkaiser I went out on my own forming a company called *New Approach Products Pty Ltd* in Melbourne during 1988. This company manufactured toilet cleaners, soaps, garden insecticide and air fresheners. In seeking to create greater competitive advantage for our air freshener range, mainly sold under generic supermarket brands, the concept of blending our own fragrances came to mind and we were in the flavour and fragrance business. At that time I met with Mr. Brian Brennan of Brennan Aromatics and developed a close relationship with him as a shareholder of his company. It was with Brian I picked up some of the practicalities of creating fragrances.

It was around the same time that my interest of producing essential oils developed. I learnt a lot from Fred Bienvenu of the Ovens Research Station, Victorian Department of

Agriculture during our time together developing *Polygonum odoratum* as a new essential oil crop. I also thank Professor Glywn Jones of the Department of Food and Nutrition, Deakin University, Geelong, Victoria for inviting me to join their research group on basil oils at the time.

During the early 1990s, not only did I see South East Asia as a potential market, but a source of essential oils. It was Dr. Erich Lassak who encouraged me to be bold in introducing new crops to South East Asia. John Reece took me under his wing and we travelled all over Australia and South East Asia together visiting plantations, attending conferences and trying to set up projects in Malaysia. I also thank the late Djohan Napati, President of PT Djsula Wangi in Jakarta for opening up his plantations and business to me. I also thank the Late Mr. Karim Yaacob for the time we spent together travelling around Malaysia looking at potential new essential oil crops.

I would like to greatly thank Tan Sri Dr. Yusof, the former Director General of the Malaysian Agricultural Research and Development Institute (MARDI) and Tan Sri Dr. Hamid Bin Pawan Teh, the former Chief Minister of Perlis (now President of the Malaysian Senate) for giving me an opportunity to develop a tea tree plantation in the Northern part of Malaysia during the early 1990s. I also remember the time Mr. Mansor Puteh and myself spent on convincing people to try tea tree as a serious crop in Malaysia. I am also indebted to other members of the team including Mr. Malik and Tunku Kassim of MARDI and Mr. Hasnan Abdul Kudus of the Perlis State Economic Development Corporation.

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I would like to thank the Vice Chancellor of University Malaysia Perlis Brig. General Professor Dato' Dr. Kamaruddin Hussin, who had faith in me to become an academic and supported my activities and writing this book. Finally, thanks to Ms. Suraya Binti Mat Ros, my secretary, who ran the SME Unit while I spent countless weeks and months writing this manuscript.

Chapter 1

INTRODUCTION: THE DEVELOPMENT ISSUES

Chapter one presents a basic introduction to the issues of essential oil development. The chapter begins with a discussion about the difficulties of estimating the aggregate farm-gate value of global essential oil production. The various types of natural aromatic materials are defined. The chapter then goes onto a discussion of some of the major issues facing essential oils, including global warming, the food, rural and financial crisis, market turbulence, wild collection and threatened plant species, the bargaining power of producers, the regulatory environment, and the templating of natural molecules for synthesis rather than for cultivation and extraction. The chapter then turns to outlining the factors that contribute to success or failure in essential oil development and the importance of making accurate project assumptions and estimates. These include planning and opportunity issues, management and organizational issues, financial issues, technical issues, marketing issues, fate and nature. Finally, a model outlining the potential strategic success factors is presented.

INTRODUCTION

Good Essential oil cultivation is based on a knowledge intensive production system. The essential oil sector within any country's agricultural base will never become a major industry in value terms, but it is one of the most complex ones. Although the essential oil industry is very small in aggregate terms, its influence stretches far beyond the agricultural sector. Essential oils are materials used in a number of dynamic consumer and niche industrial markets. The industry is undergoing rapid structural transformation from a craft orientated base to a modern multi-national orientated industry with very sophisticated supply chains. Essential oil usage has also widened into a number of smaller fragmented applications, which include natural perfumery, aromatherapy and bio-active agricultural chemicals. Both production geography and operational practices are changing, influenced by a number of factors that will be explained in this chapter.

Today, new essential oil based ventures usually start in one of two major ways. The first case is where private entrepreneurs find and respond to market opportunities. Their responses to these opportunities can be quite complex and very different from traditional producers. Private entrepreneurs may not be satisfied just producing a crude oil. They may involve themselves in the higher value product/market activities along the supply chain. The second case is where the government through an agency may initiate research and development of an essential oil crop for the purposes of disseminating technology, planting stock, operational methods and market connections to local farmers to exploit. A variation on this could be a community development project funded by an NGO. In both cases, the initiator will promote the formation of farmer alliances and/or cooperatives to improve the chances of success.

Unfortunately, many community projects fail to develop their full potential or even collapse. This occurs for a number of reasons. Reasons outside the farmers control include competition, weather and collapses in prices. Other causes of failure may develop because of structural faults, *i.e., issues not properly considered when the project was conceptualised*. These may include failure to continue production in a sustainable manner once external assistance has ceased, reliance on external people for motivation with no local champion to continue momentum in the farmer group, failure in dealing adequately with external competition, or failure to maintain collaborative links with other stakeholders such as research institutions. Reasons for failure within farmers control include poor management or diverging objectives and agendas by stakeholders.

Agriculture is traditionally considered an activity undertaken within a static system that is very slow and resistant to change. The reality is that agriculture is in a state of flux and transformation like many other industries. Agriculture is transforming itself from a commodity driven to a consumer and market driven activity. A recent World Bank report on agricultural innovation identified six areas of change that will drive agriculture in the coming decades. The report cites;

1. That future development will rely on market and not production orientated approaches to the agricultural sector,
2. Changes in production methods are now rapid and unpredictable, due to changing technologies and ease of technology transfer,
3. Agricultural supply chains are now very dynamic, where there is a greater propensity to create direct producer- retailer or producer-user relationships,
4. The private sector is the driving force of new knowledge and technology into the sector,
5. Information and communications technologies are having profound affects upon communities taking advantage of knowledge generated in other places, technology transfer and producer-customer relationships, and
6. Agricultural venture development is being increasingly undertaken with globalised, rather than local orientations [1].

This implies that selecting essential oil crops can be better undertaken through a market driven crop selection process, based on product development and customer driven management, rather than a commodity approach.

THE SIZE OF THE ESSENTIAL OIL INDUSTRY

Any accurate assessment of the aggregate size of the international essential oil industry is extremely difficult. World production of essential oils is very fragmented, much of it in tropical equatorial regions that are not easily accessible to transport. Communications infrastructure is weak or even non-existent. A large quantity of essential oils are produced at subsistence level and collected from farms by individuals who sell the oil onto wholesalers. Producers are remote from the major towns and cities of Government administrations, where organization is poor. Language is yet another barrier to communication, where all the above factors combined hinder any accurate measurement of essential oil production.

The difficulty in measuring essential oil production is further complicated by the differing statistical classification systems various countries use to tabulate production. The harmonized system of customs codes only identifies around half a dozen individual essential oils. Where essential oils are small, production figures may be grouped together with other miscellaneous activities, thus not showing up directly in statistics. Essential oil production will most likely be aggregated with herb and other natural product production.

Accurate counting is also difficult because of the unstable nature of production, where production figures may differ greatly from year to year. This occurs from poor weather, natural disasters, insurgencies, wars, and other national disturbances, crop disease and droughts, which only make the accounting of aggregate supply figures more difficult. Essential oil traders hold stocks and can distort the market through the selling of their inventories in times of shortage and buying up extra product in times of production surpluses. Most agreements between producers and traders at farm-gate level are confidential and undisclosed.

Doubt exists whether essential oil sales through the internet are statistically recorded. Most oils sold and sent through the postal system are high value/low volume oils, which will only have nominal values attached to customs forms. For example, one kilogram of *rose Otto* may be sold for a few thousand US Dollars, but the nominal value recorded may only be a few US Dollars.

Finally, currency values will also distort production values due to fluctuating exchange rates and parities between different producing countries. As most essential oil production occurs outside of the United States, currency conversions have to be made, where the final figure will be greatly influenced by the exchange rate at the time. For example, if aggregate essential oil farm-gate production in Australia is valued at AUD 25.0 million in June 2008 at an exchange rate of 1.04, Australian aggregate farm-gate production would be valued at USD 24 million at that time. However if the conversion was made at the end of November 2008 at a rate of 1.55, Australian aggregate farm-gate production would be valued at USD 16.20 million, almost one-third less than June in the same year, even though physical production is the same.

The author's estimate of the farm-gate aggregate value (in USD) of World essential oil production was USD 1,480 in 2008. Essential oil usage can be divided into a) flavour and fragrance, b) aromatherapy, c) pharmaceutical, d) intermediates, e) agrochemicals and f) cosmetics. This is shown in Figure 1.1. Aggregate essential oil production is increasing, but each sector is growing at different rates. Aggregate growth is around 8-10.0% per annum.

Even with major consumer product manufacturers espousing *"natural products"* in their marketing campaigns, the use of essential oils in fragrance compounds, as a percentage of the formula, has declined over the last several decades [2]. This is partly the result of US manufacturers being allowed to call synthetic aroma chemicals *"nature identical"*, if they are chemically the same to those found in nature. This is a factor preventing more essential oil usage in flavour formulations. However, there is still growth in the aggregate volume of essential oils supplied to the flavour and fragrance sector because of overall growth in worldwide demand for perfumed and flavoured products.

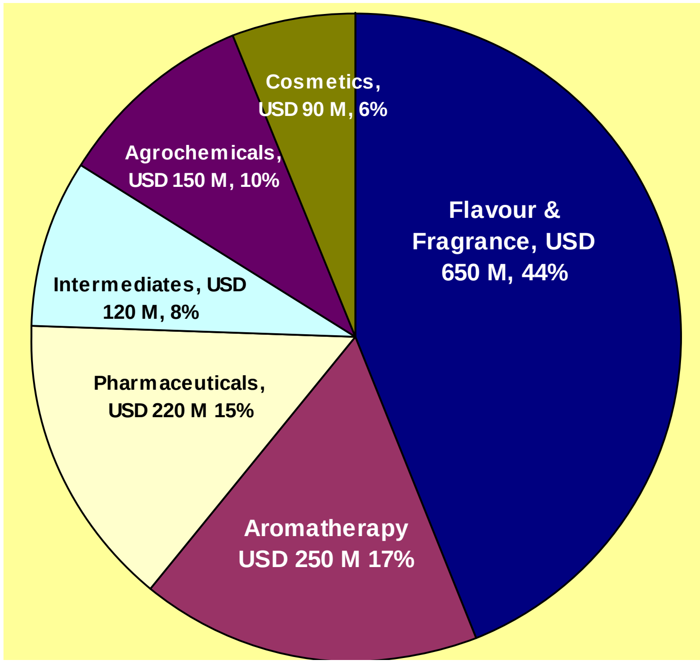

Figure 1.1. Estimate of the World Farm-gate Value of Essential Oil Production (USD) in 2008.

The aromatherapy market had enjoyed rapid growth until it stalled in the beginning of the 1990s. Aromatherapy has become much more closely aligned with cosmetics, natural perfumery and other traditional medicines, which has brought this sector into growth again. Some cosmetic categories, including cosmoceuticals and organic products are enjoying very high growth rates. Some pharmaceutical products now fit into cosmetic categories, as pharmaceutical and cosmetic companies regularly compete against each other. It is now much harder to distinguish the differences between many cosmetics and pharmaceuticals as both types of products provide the same consumer benefits. Another sector enjoying very high growth is the agricultural chemical market, where new companies are developing fungicides, pesticides and herbicides using essential oils as active ingredients.

Although the essential oil production is increasing, the growth of individual oils may bare little relationship to the overall trend. Within a given year some essential oils will drastically decline in production because of adverse weather conditions, natural disasters or political events, only to return to production levels a season or two later. Other essential oils will slowly decline in production over a long number of years because of the availability of cheaper substitutes, the exhaustion of supply from wild collection and restriction of use through increasing regulation.

As supply patterns change and materials become unavailable, users are forced to make compensatory changes to the oils they use, thereby changing demand patterns. Shortages will force users to switch to substitutes. When a shortage is overcome users may be very hesitant to return to the original oil, due to the effort involved in changing back product formulations. Demand also changes as the relative prices of substitutes move in relation to each other.

Verlet pointed out that production tends to cluster in areas because of three basic reasons. Firstly some production centres have a long history of production with a supportive social structure. This is the case in Morocco, Turkey and Egypt in the production of rose, jasmine and cumin oils. Secondly, large multi-national companies have intervened and promoted the development of an industry. This was the case with patchouli production in Brazil. Thirdly, production serves a large domestic market, which enables it to sustain itself. This is the case of some essential oil production in China, India and the US [3].

A large number of essential oils are produced by a) small-holder farmers usually at a subsistence level, b) the gathering and processing of wild plants by subsistence farmers, c) small scale plantations, and d) large scale plantations. Other essential oils are produced as by-products of other primary products. Examples include eucalyptus and pine oils from the timber industry, and citrus oils from the processing of fruit juices in the citrus industry. Other small farms and plantations may incorporate activities like agro-tourism into their sites to improve profitability [4]. Long periods of low prices can bring volatility to the global industry, encouraging countries like China, India and Vietnam to increase production at the expense of less competitive countries like Tanzania, Ivory Coast and Madagascar.

Some companies may move up the supply chain and scale down their farm operations to focus on higher value products. For example, Thursday Plantations in Northern NSW ceased tea tree production to focus on agro-tourism and the marketing of tea tree oil based personal care products. Today Thursday Plantation became a major buyer of tea tree oil and now sells their products in over 40 countries [5].

Differing sources of competitive advantage underlie production in different regions, which enables industry viability.

Countries like Brazil, China, India and Indonesia have large domestic markets. Their competitive position is supported by a low production cost regime based on low cost labour and/or high levels of mechanization to make them efficient. These countries control more than half the world's production in some of the oils they produce. Long established logistic and trading infrastructure assists in maintaining a strong market position.

Producers in countries with a small domestic market are forced to focus on exports. Production is limited to a small number of oils. Small existing industries develop with financial and research support. Effective research allows them to develop optimum methods of production to develop market competitiveness. These industries are usually located in ideal physical and climatic conditions for the chosen crops.

Some producing countries have been able to maintain their position as a preferred producer by producing exceptional quality oils. These oils become *'benchmarks'* in the Flavour & Fragrance industry, such as *Haiti Vetiver* or *Comoros Basil.* This is reinforced long term links with major trading companies or International flavour & fragrance houses.

Many distinct trends are occurring at the same time in the essential oil industry supply chain. Ownership and management of flavour and fragrance houses is becoming very concentrated. This has changed the *craft orientation* of most companies to a much more corporate multi-national outlook on the business and the way of doing things. Products are being standardised, eliminating various grades of essential oils in the quest for efficiency. New perfumers are trained to construct fragrances from proprietary bases to save on inventories. Chemical production is also moving away from Europe and the United States to India and China, partly to save on costs and partly to escape much stricter environmental laws.

Table 1.1. Worlds Top Twenty Essential Oils and EU Regulatory Threats in 2006 [8]

Essential Oil	Botanical Name	Volume (Tonnes)	Under Threat Cosmetics	Under Threat Biocides	Under threat Fragrance
Orange	*Citrus sinensis*	**26000**	X		X
Cornmint	*Mentha Arvensis*	**4300**			
Eucalyptus	*Euc. globulus*	**3728**	X	X	X
Citronella	*Cym winterianus*	**2830**	X	X	X
Peppermint	*Mentha piperita*	**2367**			
Lemon	*Citrus limon*	**2158**	X		X
Euc. Citriodora	*Eucalyptus citriodora*	**2092**	X	X	X
Clove Leaf	*Syzygium aromaticum*	**1915**	X	X	X
Cedarwood (US)	*Juniperus virginiana*	**1640**			
Litsea cubeba	*Litsea cubeba*	**1005**	X		X
Sassafras (Brazil)	*Ocotea pretiosa*	**1000**	X		X
Lime	*Citrus aurantifolia*	**973**	X		X
Spearmint	*Mentha spicata*	**851**			
Cedarwood (China)	*Chamaecyparis funebris*	**800**			
Lavandin	*Lavandula intermedia*	**768**	X		X
Sassafras (China)	*Cinnamomum micranthum*	**750**	X		X
Camphor	*Cinnamomum camphora*	**725**			
Coriander	*Coriandrum sativum*	**710**			
Grapefruit	*Citrus paradis*	**694**	X		X
Patchouli	*Pogostemom cablin*	**563**	X		X

At the same time there are a number of new emerging markets. This is encouraging the creation of new companies with committed *natural product* philosophies. Organic cosmetics, pharmaceuticals and aromatherapy products are being merged together to form new product groups called cosmoceuticals. Small companies specializing in the creation of natural perfumes are emerging. New companies producing organically certified bio-active products based on essential oils are growing in size exponentially. In the biotechnology sector, new companies are producing natural aroma chemicals through bio-transformations. Totally new supply chains based on new paradigms are developing like the Fairtrade movement.

The new markets mentioned above have attracted a number of new traders in essential oils, with very different backgrounds to established traders, which served the market for many years. Many new traders specialise in trade to the aromatherapy market and organics. For sellers this has opened up the market somewhat more than was the case two decades ago. Many traders are now developing direct links with producers, creating their own closed supply chains. New market segments driven by new ideas are nurturing new entrepreneurs who successfully interpret consumer wants and successfully develop and commercialise new products. Established companies are also feeling the pressure to change so they remain relevant to changing market expectations. Multi-national companies, usually not as innovative as pioneering entrepreneurial enterprises are purchasing some of these emerging *'new theme'* companies outright, so they can enjoy this new market growth.

Retail chains over the last decade have become very powerful. Retailers, equipped with modern point-of-sale scanners have first hand information about consumer tastes and preferences and decide their product ranges and positioning on the information they collect. Retailers work closely with manufacturers to produce product ranges that aim to maximise sales and profitability [6]. Chain retailing in developed countries controls up to 95% of retail sales and 50-70% in developing countries. Many chains operate on a trans-market basis and exert great influence over multi-national manufacturers. Some essential oil producers already supply products directly to these retail chains with retail oil packs and consumer products, either with their own brands or as private labels. This is expected to grow much larger in the near future.

E-commerce has been another revolutionary influence on the way business is being undertaken in the marketplace. Essential oil users now issue *e-tenders* and *invitations to supply* electronically. More mid sized producers are turning to the internet to market their essential oils. Many producers have their own websites where they offer their products. This has not been successful as a primary marketing strategy, but is successful when used as a support tool for other marketing strategies, *i.e, distributing these products through physical distributors in different geographical markets.*

The essential oil industry is not without factors that will inhibit future growth. European regulatory authorities like REACH[1], SCCP[2] and BPD[3] are challenging the safety of many essential oils [7] and asking producers to put up a case as why they should continue to be on the market without safety warnings on labels. Table 1.1. shows the top twenty essential oils produced in the world and their status under EU regulation. This leaves an unanswered question of who will represent subsistence producers in developing countries to prove the safety of essential oils they have been producing for many years?

DEFINITIONS OF ESSENTIAL OILS AND OTHER NATURAL AROMATIC EXTRACTS

The word essential oil is often used as an umbrella term to cover a number of different natural volatile aromatic materials, although strictly speaking not all of these materials are essential oils. Natural aromatic materials can be extracted from the roots, rhizomes, wood, bark, leaves, stems, fruits, flowers and seeds, from a wide variety of plant, shrub and tree

[1] Registration, Evaluation and Authorisation of Chemicals.

[2] The Scientific Committee on Consumer Products – previously called the SCCNFP: Scientific Committee on Cosmetic & Non Food Products) is an expert committee set up under the EC Health and Consumer Protection DG. SCCP reports to the EC H&CP Scientific Steering Committee on matters relevant to the EC countries in their defined area. The committee comprises a diverse range of experts in toxicology from industry, the medical fields and tertiary institutions.

[3] Biocidal Products Directive.

species. Different parts of the same plant may contain compounds which differ in their chemical composition, and may or may not require different methods to extract these compounds effectively. Primarily, the extraction method used determines whether the aromatic extract is called an essential oil, concrete, absolute, tincture, pomade, oleoresin, or balsam. These methods are summarized in Figure 1.2.

Essential oils result from extracting volatile compounds, mainly terpenes and oxygenated compounds, through a form of distillation. The constituents of essential oils are synthesized in the plant through the melavonic and shikimic acid pathways as secondary metabolites, stored in glandular trichomes, oil cells or ducts in plant tissue. The specific method of distillation used will depend upon the characteristics of the aromatic materials present in the plant, the structure of the plant material and the economics of extraction. Three basic types of distillation exist, hydro-distillation, water and steam distillation and steam distillation.

Other specialized methods such as vacuum distillation, high pressure distillation and destructive distillation are used in certain cases, where specific conditions are required. For example, low temperatures are sometimes needed to prevent highly volatile materials from being destructed or lost during distillation, so vacuum distillation would be used. Where greater heat and pressure is needed to extract high boiling volatile materials from the plant, high pressure distillation can be used. Where the plant material itself must be destroyed to remove volatiles, destructive distillation can be used.

Oils are also produced from citrus fruits through a process called cold expression. Orange, lime or other citrus peels are pressed until a fine spray of aromatic oil is released. This is specifically called an *expressed oil*. Cold expressed oils can be distilled under vacuum to remove the terpene hydrocarbons from the rest of the oxygenated components to produce what is called a *terpeneless oil*. The other resulting product is known as a *terpene oil*, *terpenes* or *terpene tails*.

Where aromatic materials are susceptible to chemical changes from heat processes and this is undesirable, extraction can be undertaken through washing the plant material with a solvent in a method called solvent extraction. Petroleum ether, acetone, hexane or ethyl acetate can be used to wash out specific plant materials, usually volatiles, pigments and waxes into the solvent. Once the solvent has been evapourated off through vacuum distillation, the remaining material is called a *concrete* or in some cases a *resinoid*. The volatile materials can be further extracted from the concrete through washing the material with alcohol and then removing the alcohol through vacuum distillation. The remaining material is called an *absolute*.

Enfleurage is an old method of extracting aromatic materials from plants, which is being revived in aromatherapy. Enfleurage involves laying plant material on specially prepared fat and lard to absorb the volatile materials. After a period of time the odourous material is extracted from the fat by heating. The material is then filtered from the solid particles, leaving a *pomade*. When the ethanol is distilled off through vacuum distillation, the resulting product is called an *absolute.*

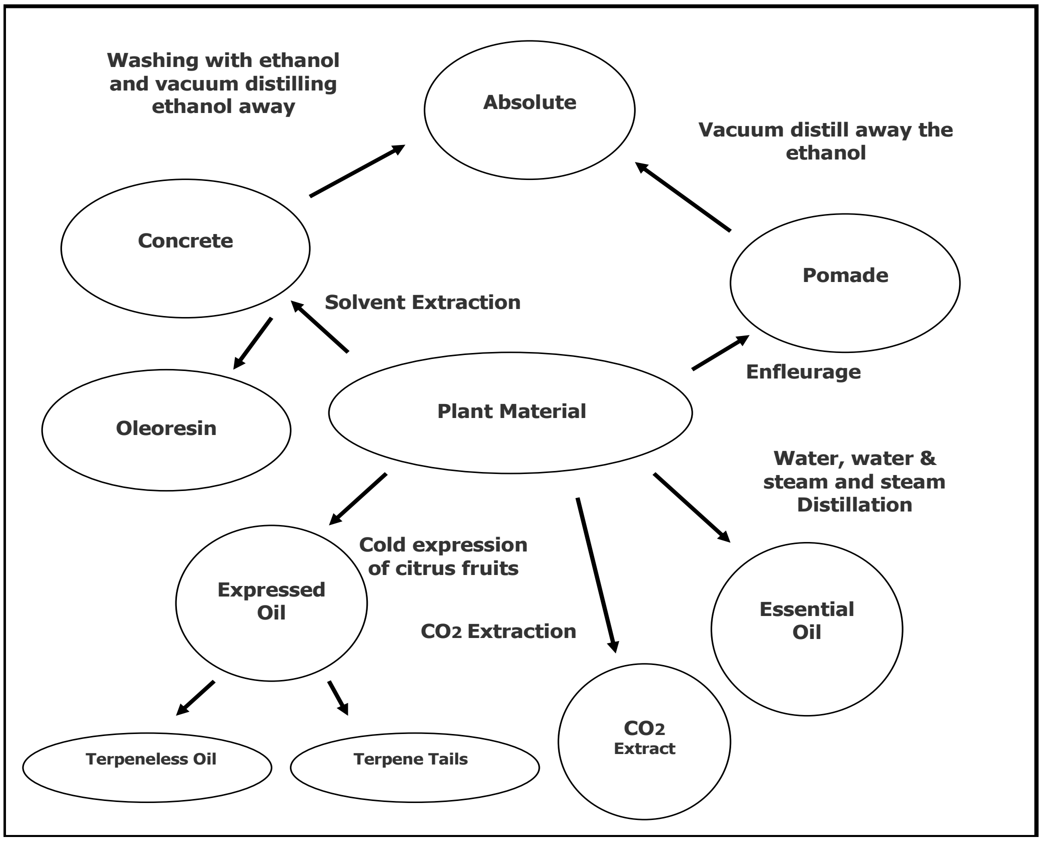

Figure 1.2. The Various Methods of Natural Material Extraction and Products.

The use of liquid carbon dioxide as a solvent under pressure to remove volatile plant substances is one of the newer methods of extraction. Products produced from this process resemble nature very closely as there is no heat involved. Carbon dioxide is an inert material which doesn't promote any undesirable chemical reactions. Natural materials extracted in this way are called *CO_2 extracts*.

Very low and non-volatile aromatic materials that are present in woods are extracted through a more complex form of solvent extraction, which yields an *oleoresin*.

PRODUCT STRATEGY CHOICES

The development of essential oil crops previously focused upon the production of the crude oil as the venture's final product. Developing a product for entry higher up the supply chain was rarely considered. The focus was on producing an essential oil which met certain physical specifications, where the venture would accept the prevailing market prices at the time. The product would be marketed like a commodity, *i.e., sold to a trader or large single purchaser as a price taker.*

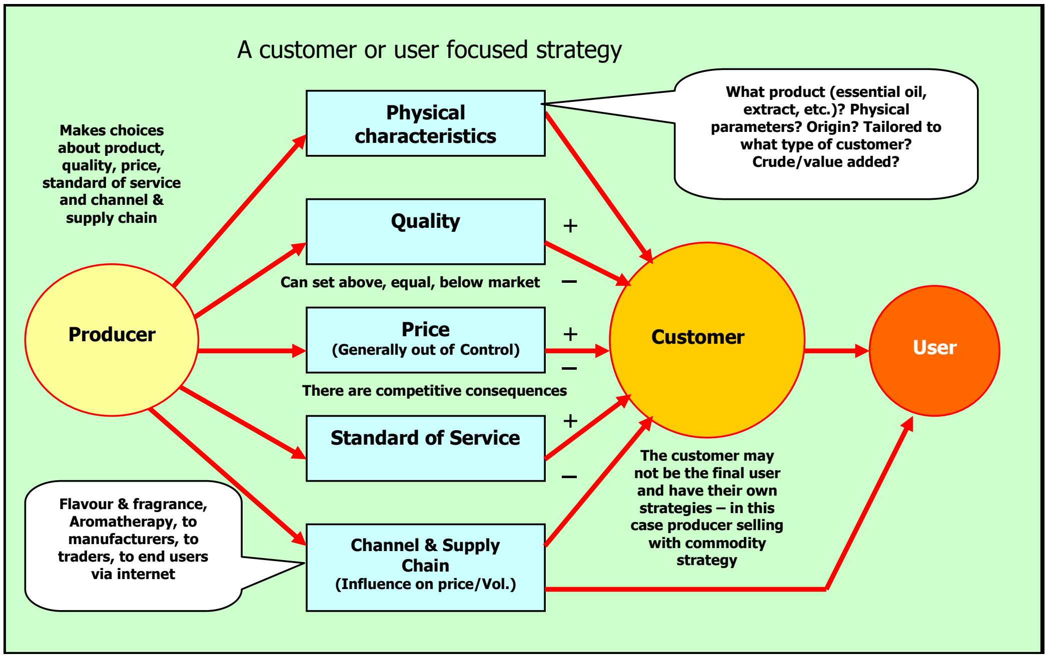

Figure 1.3. The Product Strategy Choices Open to a Producer.

Generally as a commodity item, there are three basic choices; to sell at a par with competitors, at a discount or at a premium. Selling at a par to the competition can be a disadvantage to a new supplier, as potential customers do not yet trust the new supplier. Selling at a discount, could result in competitive retaliation. Selling at a premium price is possible on a basis of product differentiation, *for example as customer perceived superior quality*.

Value added products can be sold higher up the supply chain where better financial returns can be obtained from the market. Through developing a value-added product, more marketing variables like quality, branding, price, service, channel, promotion and market presence take on importance. Value-adding the essential oil is one method that many ventures utilize to grow their business.

Higher up the supply chain where the producer can offer the product in value added forms *(i.e., shampoo, cosmetics, medicines, etc)*. There is much more flexibility for price setting. The producer will have to make the decision at which industry and part of the supply chain that development and marketing efforts should be focused, *i.e., flavour and fragrance industry, aromatherapy industry, pharmaceutical industry, cosmetic, agricultural chemical industry, etc*. The part of the supply chain the producer targets to operate within will influence and define the type of products they can produce. The product/strategy options open to a producer is shown in Figure 1.3.

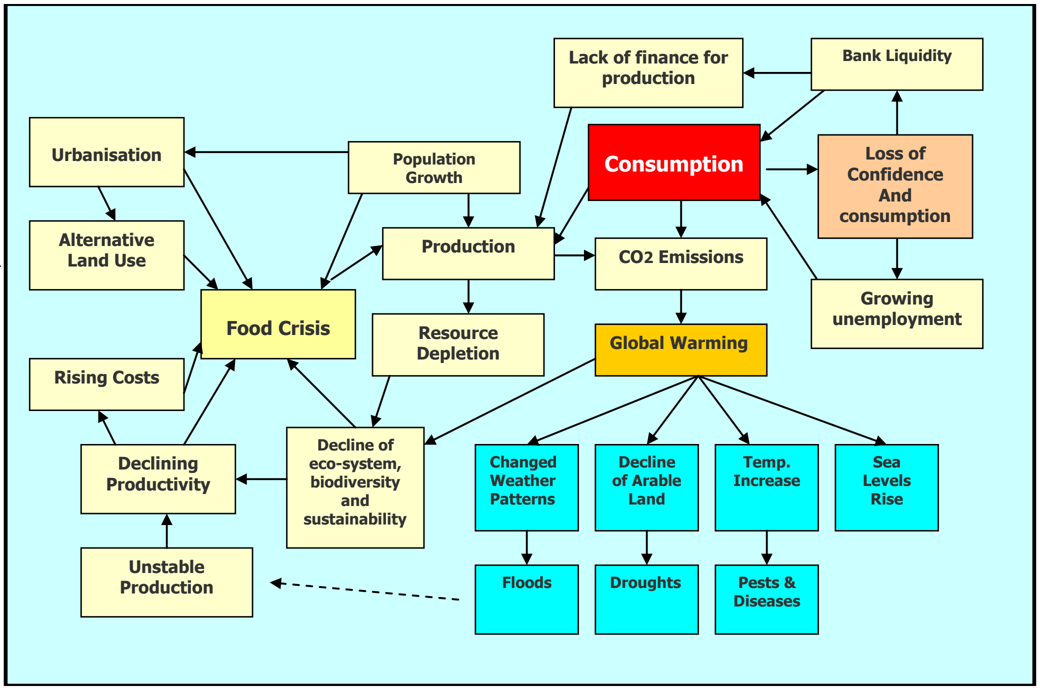

Figure 1.4. Some of the underlying challenges on the essential oil industry from climate change, the food and economic crisis.

THE DEVELOPMENT ISSUES

The essential oil industry faces a number of major issues and challenges including climate change, the food and economic crisis. Other important issues the industry is facing include wild plant collection, the bargaining power of producers, the regulatory system, the rural crisis, the templating of natural aromatic molecules and patents, research and sustainability. These issues are discussed briefly in the following sections.

Global Warming, the Food and Financial Crisis

Three major issues, climate change, the food and economic crisis form a great part of the underlying general environment that the essential oil industry must exist and operate within. Issues generated by climate change, the food and economic crisis are extremely complex and subject to intense debate and analysis, both scientifically and politically. Figure 1.4. depicts some of the underlying issues and challenges to the essential oil industry from climate change, the food and economic crisis.

Some of the basic issues are summarized very simply below.

Population growth requires a corresponding increase in the production of goods and services to meet growing consumption demands (needs and wants). Rapid population growth is increasing consumption, leading to higher rates of production, which increases carbon dioxide emissions. The growing carbon dioxide traps UV radiation in the atmosphere, rather than allowing it to escape back into outer space. This creates a condition where the atmospheric temperature will slowly rise. The increase in atmospheric temperature creates a number of secondary effects which include altering weather and tidal patterns, which in turn cause floods, droughts, heat waves, cold snaps. These secondary effects give rise to changing pest and disease cycles, faster loss of top soils due to adverse weather and the increase of arid land area. Continued warming is melting the polar ice caps which cause rising sea levels. The results of these environmental activities are an increase in the incidence of crop failures.

Mankind's unsustainable production practices at our current state of technology is leading to the depletion of the Earth's natural resources. This is also leading to the decline of bio-diversity. This causes the cost of production to rise due to the need to use more inputs per unit of output. There are also increasing levels of outright crop failures. Food costs are further heightened through the rising costs of land due to greater urbanization and industrialization, the shortage of labour and increasing operational costs.

During 2008, US housing prices rose to the point where they reached a peak and began to collapse. Prices started to decrease to the point where housing mortgage equity was not supported by equity in the house values. When many borrowers defaulted on their repayments and banks could not recover their loans through mortgage auctions, a liquidity crisis began. Banks cut lending to manufacturers and retailers which need liquidity to operate. This led to a loss of confidence, decline in consumption and corresponding decline in production and worker lay-offs. The loss of confidence, increasing unemployment and corresponding credit squeeze started a downward spiral in demand, production and consumption, potentially leading the World into recession.

Through the interrelated World economy the effects of the US liquidity and confidence crisis is spreading to Europe, Japan and Australia. European banks have lent money to banks in the US and Eastern Europe where there is risk of major loan defaults due to these economies shrinking in economic activity. Decreasing consumption in developed countries is leading to lower product orders from Asian manufacturers. The crisis is now spreading to the Asian region as well, where unemployment is beginning to rise. Recovery in Asia will depend upon how well domestic markets sustain demand and growth.

There are concerns that because of the wide extent of this global economic crisis, the issues of climate change and food scarcity will be put into the background by governments at a time where many believe they cannot be ignored.

Global warming, the food and economic crisis are already affecting the essential oil industry in a number of ways. Global warming increases the incidence of risk in general agricultural production. As regions become warmer, droughts set in and seasons change, some areas will become unsuitable for the production of certain essential oils, while other areas will become suitable. Agronomic practices will have to take account of the technical issues brought about from the effects of global warming. The global economic crisis will challenge the stewardship of business. The marketing of essential oils will take place in markets that are declining, rather than growing. The raising of funds for essential oil research and production will also be expected to be more difficult because of the financial crisis.

Some of the basic issues underlining the food crisis are also relevant to essential oil production. Essential oils will have to compete for land against other potential land uses. This means that essential oils must make a higher return per unit of land than food crops for farmers to be enticed to cultivate them. This will mean higher prices for essential oils in years to come.

Market Turbulence

Like other commodities, essential oils are subjected to price fluctuations. This is the result of mismatches in supply and demand, particularly the supply side. As essential oils are agricultural products, they are affected by adverse weather, especially heat, droughts, natural disasters, pest and diseases, labour shortages and competition for land use. The attraction of other crops also causes supply problems, *(i.e., sugarcane production in Brazil)*.

The situation for a number of essential oils over the last few years has proved no exception, where a number of oils have suffered supply problems. There have been shortages of aniseed oil *(weather)*, bergamot oil *(weather)*, coriander oil *(seeds used for spice as prices more attractive)*, dill and fennel oils *(excessively warm weather)*, geranium oil *(farmers switched to growing food crops)*, lavender and lavendin oils *(excessively warm weather)*, lemon oil *(weather)*, litsea cubeba oil *(shortage of labour)*, and rose oil *(shortage of labour during harvests)*.

Sometimes price fluctuations and supply shortages are enough to force customers to switch to substitutes. This has happened to a number of essential oils, which became priced out of the market or the shortage forced cessation of product use. Tea tree oil was discontinued as a product line in some European retail chains in 2005, when there were chronic shortages of supply [9]. Patchouli oil was replaced by many users in fragrance formulations with the development of synthetic aroma chemicals that are cheaper and stable in price. Shortages of litsea cubeba oil encourage the use of synthetic citral. The rising price of sandalwood will encourage the use of synthetic alternatives, which may leave only a small remaining market for fine fragrance use, if confidence is lost in supply by the majority of users. There has also been a drastic decline of essential oils that are reliant on wild collection. Essential oil price fluctuations can threaten the long-term usage of an essential oil and force substitution to low cost mix of stable synthetic substitutes.

Other factors that cause market turbulence include the rise in the price of petroleum which increases the costs of distillation. Some oils like Ylang ylang require over 20 hours of distillation and clove bud requires 48-50 hours. Thus diesel and bunker fuel is not a minor cost in the production of the oils. Steel prices are increasing, making the costs of drums to go up, China is tightening environmental regulations and urbanization is creating shortages of rural labour. Adulteration of essential oils is still of great concern. There are still a number of cases of adulteration of essential oils, which cause concern and loss of integrity in the marketplace.

Wild Collection and Threatened Plant Species

There are between 300-400 natural aromatic materials, including essential oils, concretes, absolutes, resins, oleoresins and balsams available commercially in the market. Almost 50% of these materials are extracted from trees that are hundreds of years old or rare plants that cannot be easily domesticated [10]. These are collected from the forests, jungles and bush lands around the world. This raises the issue of sustainability. Over the last few decades a number of flora species have become threatened with potential extinction, due to over harvesting.

The pricing mechanism heavily influences what happens in wild plant collection. When prices are high, two major things can happen.

The initial response is often a frenzy of collection by various collectors, which results in harvests well above demand levels. This reckless manner usually occurs because of lack of law enforcement in remote areas that fails to preserve stocks of the species for future harvesting.

Secondly, if the plant can be domesticated entrepreneurs will commence planting of the crop. For example, supply shortages and continued high prices have encouraged a large number of people to cultivate both *Aquilaria* and *Santalan* species. This will most likely lead to a massive oversupply situation in the future.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), is an intergovernmental agreement ratified by 189 nations under the International Union for the Conservation of Natural Resources (IUCN), which compiles a list of threatened species that should not be traded. Table 1.2. shows a list of potentially endangered species relevant to the aromatic trade. Listing plant species as endangered is one issue, enforcement is another as many of these endangered species are still traded in significant quantities [11].

Table 1.2. A List of Potentially Endangered Aromatic Flora Species

Common & Botanical Name	**Location**	**Status**	**Use and Comments**
Chinese Rice Flower *Aglaia odorata* (Lour.)	China, Cambodia, Laos, Myanmar	IUCN Red list of threatened species of threatened species in 2007	A flower oil and absolute used in fine perfumery
West Indian Sandalwood *Amyris balsamifera* L.	Florida, Belize, Costa Rica, Haiti, Honduras, Nicaragua, Cuba, Jamaica, Puerto Rio, Venezuela, Colombia, Ecuador	Predicted to disappear because of over-exploitation [12]	Limited use in soap and deodorant perfumery
Aniseed Myrtle *Backhousia anistata*	Australia, in North East NSW	Species has a very small geographic range of 100km [13].	Very minor quantities sold for aromatherapy use. Some small cultivation is going on.
Agarwood Various *Aquilaria* Spp.	Over the forests and jungles of South-East Asia	Most species listed on CITES appendix II [14]. *A. banaensae, beccariana, crassna, cumingiana, hirta, malaccensis, microcarpa, rostrata,* and *sinensis,* on IUCN Red list of threatened species in 2007.	Sold as an incense material and essential oil for fine perfumery. Large plantations being developed in Vietnam, Thailand, Laos, Malaysia and Indonesia. Human infected wood said not to be as good quality as naturally infected wood.

Wormwood, Various *Artemisia* species	Europe	Considered rare	Essential oil of *A. gracilis* used as a flavour in a local European liqueur *genipi*.
Asafoetida, *Ferula assa-foetida* L.	Iran	Stocks deteriorating due to unsustainable exploitation	Used as a material in savoury flavours.
Boldo, *Peumus boldus* Molina	South America	Local authorities restricting exploitation	Leaves produce an essential oil used in flavours (FDA approved).
Buchu Leaf, *Agathosma betulina*	South Africa	Vulnerable stocks in the wild, due to harvesting for oil and tea, diminishing habitat [15].	Essential oil used in flavouring for blackcurrant flavours. Also used in fine perfumery. Now a cultivated crop.
Holy Weed, *Bursera glabrifolia*	Mexico	Over harvesting threatening existence of species [16].	Now an essential oil of minor importance.
Calamus, *Acorus calamus* L.	Widely distributed throughout Europe and India, also in South-East Asia	Becoming rare in India [17], but variety of opinion as to whether should be restricted due to wide distribution.	Essential oil from rhizome. Employed as a traditional incense oil. Also used as a flvour ingredient, although restricted use by EU Food Regulations [18].
Candeia Plant, *Eremanthus erthropappus* (DC) MacLeish, *Vanillosmopsis arborea* (Aguiar) Ducke	Found in the Atlantic Brazilian rainforest.	The tree is becoming rare due to exploitation	The wood is a source of *(-)-alpha-bisabolol* [19].
Canarium zeylanicum (Retz.) Blume	Sri Lanka	IUCM Red List of Threatened species 2007	Used as an oleoresin for incense.
Cedarwood Atlas, *Cedrus atlantica* (Endl.) Manetti ex Carr	At 1500-2500m altitude in Atlas Mountains, Morocco	IUCM Red List of Threatened species 2007. Production has declined substantially.	Essential oil produced from waste wood. An absolute is also produced.
Cedarwood Himalayan, *Cedrus deodora*	Above 2000 m on the slopes of the Himalayan Mountains from Afghanistan to Pakistan.	IUCN Red List of threatened species in 2007	Crude and rectified oils from sawdust and wood shavings, an absolute and a fir needle oil available. Production has decreased dramatically to almost nothing. Also used in aromatherapy, perfumery and a product extracted through destructive distillation as a veterinary medicine.

Table 1.2. Continued

Common & Botanical Name	Location	Status	Use and Comments
Cedarwood Kenyan, *Juniperus procera* Hochst ex Endl.	1000-3000m range along the mountains of Kenya, and Ethiopia. Also in other African countries and Saudi Arabia, Somalia.	IUCN Red List of threatened species in 2002	A now almost unattainable essential oil. Species suffered from insect infestations and dieback [20].
Cigar Box Wood, *Cedrela odorata* L.	South and Central America	Illegal export in many countries but trade continuing [21].	A wood essential oil.
Cinnamomum Spp. *Cinnamomum camphora* L. var. *linaloolifera, cinnamomum camphora* Sieb var. *glavescens Hayata* (Ho Wood)	China and India	IUCN red list, Chinese authorities ban harvesting.	Rectified crude oil produces ho wood oil, which is used as a source of linalool, acetylated oil produced through esterfication with acetic anhydride used to reconstitute some essential oils and extend lavender oil. Also used a natural linalyl acetate.
Cinnamomum parthenoxylon (Jack) Meisn.	Vietnam and China	IUCN red list of threatened species in 2007, Chinese authorities ban harvesting.	As a source of safrole (>95%), which is used to produce piperonyl butoxide.
Cinnamomum tamala, Tejpat oil	Northern India	Over exploitation of species.	Essential oil from steam distillation of the leaves.
Commiphora Spp., Opoponax	Ethiopia, Eritrea, Kenya, Somalia, also species in India	IUCN red list of threatened species in 2007	A source of opoponax, resin exudes from the bark naturally, but can be collected through making incisions. Also has numerous medicinal uses.
Copaiba Spp. *C. reticulate, C. guianensis, C. multijuga*and *C. officinalis.*	Rainforests in Brazil.	Threatened by logging [22].	Used as a fixative in perfumery.
Costus, *Saussurea lappa* C.B. Clarke	India, and China	Critically endangered and listed as a negative export by the Ministry of Commerce, India. Some cultivation occurring [23].	Essential oil of roots and plant, concrete and resinoid from roots. Material banned by IFRA for use in cosmetics. Now used for aromatherapy.
Elemi, *Canarium luzonicum*	Indonesia, Philippines, Pacific Islands and Papua New Guinea.	IUCN red list of threatened species in 2007	Essential oil distilled from the pathological resin of the tree. Also CO_2 extracts produced, probably in Europe. Used in

			perfumery.
Canadian Fir Balsam, *Abies balsamea* (L.) Mill.	Canada	IUCN red list of threatened species in 2007	Essential oil distilled from the needles and twigs of the tree. Used in perfumery and as a varnish.
Silver Fir, *Abies alba* (L.) Mill.	Northern Europe	IUCN red list of threatened species in 2007	Oil distilled from cones, needles and twigs and used for pine type fragrances.
Galbanum, *Ferula gummosa* Boiss	Pakistan, Turkmenistan, Iran, and India.	Over-exploitation	Gum exported to Europe, oil distilled from gum for perfumery use.
Gaultheria fragrantissma Wall. (Wintergreen)	India, Himalayas, China, Java.	Over exploitation	Medicinal and perfumery use.
Gentiana Spp. *Gentiana lutera* L.	Central Europe, also France, Spain, Turkey, Albania and Romania.	Over-exploitation, wild harvesting banned in Spain.	An absolute developed from the roots for flavouring.
Ginger lily, *Hedychium coronarium* Koenig	Himalayas, throughout South-East Asia, India, China and Hawaii	Over collection in India.	Used as an essential oil in perfumery.
Gonystylus Spp.	South-East Asia	IUCN red list 2 of threatened species in 007	These trees produce a lower quality of gaharu than the *Aquilaria* Spp
Gurjun, *Dipterpcarpus* Spp.	A number of species throughout South-East Asia	Logging has dwindled tree populations extensively. IUCN red list of threatened species in 2007.	Essential oil obtained from steam or vacuum distillation of the resin.
Hinoki Wood, *Chamaecyparis obtuse* (Siebold & Zucc.) Endl.	Japan	Protected by Japanese Government, IUCN red list of threatened species in 2007.	Essential oil from sawdust, waste, and off-cuts. There are also root and leaf oils.
Spanish Juniper, *Juniperus trurifera* L.	Morocco, Algeria, Spain and Corsica.	IUCN red list of threatened species in 2007	A rare oil used for leathery notes in perfumery.
Juniperus Spp. *J. oxycedrus*	Mediterranean Europe, Portugal, France, Morocco, Iran	IUCN red list of threatened species in 2007	Cade oil is obtained from destructive distillation of the wood and branches of the shrub.
Kaempferia Spp., *K. galangal* and *rotunda*	Throughout East and South-East Asia	Becoming over exploited and facing extinction [24]. On negative export list of Ministry of Trade, India.	Essential oil of *K. galangal* used locally in hair washes, etc [25].

Table 1.2. Continued

Common & Botanical Name	Location	Status	Use and Comments
Spiked Ginger-lily, *Hedychium spicatum* Smith	India, Nepal, Malaysia and Japan.	Over exploited	Essential oil produced from the dried tuber roots, used in limited amounts in perfumery.
Brazilian Sassafras, *Ocotea pretiosa* (Nees) Mez.	Brazil and Paraguay	Logging seriously threatening this species.	As a source of safarole now largely replaced by exploitation of *Cinnamomum parthenoxylon* in Vietnam.
Olibanum, *Boawellia carterii*	Somalia, Oman and Yeman.	Over exploited and damaged due to unskilled collection, result of clearing for agriculture. IUCN list of threatened species 2007	Trees tapped for resin where essential oil is distilled from dry resin. An absolute and resinoid also produced. Used in fine perfumery.
Pine Spp. *P. cembra* L., *P. roxburghii* Sarg., *P. merkusii, P. Radiata, P. Menziesii, P. pumila, P. silvestris, P. sibirica, P. eeliotii, P. strobus,*	Europe, Russia, USA, Canada, India, Pakistan and Himalayas.	IUCN red list of threatened species in 2007	Gum oleoresins and turpentine oil. Also twigs, needles and cones of some species distilled for pine needle oils, similar to *Abies* oils.
Prostanthera Spp., *P. rotundifolia, P. granitica, P. askania, P. hindii, junonis, P. palustris*	Tasmania, Victoria and New South Wales in Australia and New Zealand.	IUCN red list of threatened species in 1997.	Very small production in Australia for aromatherapy.
Ravensara anisata	Madagascar	Threatened by over production (damaged done by removing bark)	Essential oil distilled from bark.
Rosewood, *Aniba* Spp., *A. rosaeodora, A. fragrans, A. canelilla, A. parviflora*	Brazil, Colombia, Ecuador, French Guiana, Guyana, Peru, Suriname, Venezuela.	Gross over exploitation [26]. IUCN red list of threatened species 2007.	The wood chips are steam distilled. Used in perfumery.
Australian Sandalwood, *Santalum spictum*	Northern and Western Australia	Exhausted through wild collection [27].	Used in perfumery but not of same quality as East Indian Sandalwood.
East African Sanadalwood, *Osyris lanceolata* Hochst & Steud.	Tanzania, Algeria, Zimbabwe, Swaziland.	Protected species in Tanzania sine 2005.	Essential oil and CO_2 extract used in perfumery.
East Indian Sandalwood, *Santalum album*	India, Timor Leste, Some Indian Ocean Islands, Indonesia, Philippines, Australia. Aslo	IUCN red list of threatened species 2007.	Essential oil used in fine fragrance. Availability has dropped dramatically.

	introduced into China, Sri lanka and Taiwan.		
New Caledonian Sandalwood, *Santalum austrocaledonicum* Viell. var *austrocaledonicum*	New Caledonia	Nearly depleted, some production under control [28].	Used in cosmetics and fine fragrances.
Shorea robusta Gaertn.f.	Nepal. Also other species in India, Thailand, Cambodia and Laos, Indonesia and Malaysia.	Harvesting banned in Nepal	A gum is exuded from the stem. Sawdust and resin from the tree used to manufacture joss sticks.
Siam Wood, *Fokienia hodginsii*	China, Vietnam, Laos	IUCN red list of threatened species.	Used as a wood source for furniture. Essential oil is distilled from off-cuts and sawdust.
Spruce, *Picea albies and P. mariana*	*P. abies* distributed over Central and Northern Europe, *P. mariana* over USA and Canada.	IUCN red list of threatened species 2007	Needle and twigs distilled for essential oil used in perfumery.
Styrax, *Liquidambar styraciflua,*	USA, Belize, Guatemala, Honduras, Mexico, Nicaragua.	IUCN red list of threatened species 2007.	Oleoresin produced in Honduras and vacuum distilled to produce styrax oil. Resinoid used as a fixative in perfumery.
Thymus Spp.	Mostly collected from the wild in Spain.	Protected under Spanish law and quantities produced are declining, but doesn't include all species.	Used as a flavour material.

The harvesting of wild plants often involves traveling over difficult terrain to collect material and process it into an essential oil or aromatic extract. The supply of wild plant material is unstable and subject to both natural interventions and regulation. Wild collection in the majority of cases is difficult to regulate [28] and ensure sustainability.

Bargaining Power of Producers

Approximately 55% of the World's essential oils come from developing countries [30], particularly those countries along the tropical belt. The vast majority of producers in these regions are subsistence farmers who suffer from poor yields, poor quality, unfavourable economics and markets outside of their control. The power of producers to influence price in the market does not exist, particularly where producers of one geographic region also compete against producers from other geographical regions. To survive subsistence farmers must skillfully decide which crops to cultivate, so their income is maximized. However when large numbers of farmers receive the same information, aggregate over responses usually occur through dramatic increases or decreases in production. This creates large price fluctuation and variances in income. Where crops are perennial, producers have no choice but to continue in the market and take what price is offered, unless they decide to get out of production completely.

The longer the supply chain the less influence the producer will have over it. Traders act on behalf of a large group of fragmented producers from remote locations, thus exercising great power over producers. The supply chain can be manipulated by hoarding stocks and waiting until prices rise, allowing the sell off stocks at large profits. How widespread this practice is unknown. There are few organizations that represent the true interests of the producer, most represent the interests of traders.

The ethics of purchasing from primary producers in the supply chain is now an important issue amongst many companies. Some large companies have set up community projects in developing countries with ethical supply chains. A number of Non-Government international agencies have put in large efforts to shorten the supply chains so that sellers can deal directly with buyers or with intermediaries on agreed buyer/seller charters through programs like *Fair-trade*. These moves are aimed at bringing equity into buyer/seller relationships.

Large essential oil producers focus their business development strategy on finding ways to develop product differentiation to strengthen their bargaining power over customers in the marketplace. These strategies involve developing isolates, fractions and specialty materials from essential oils, which other producers don't have. Producers try to convince the customer that these isolates have benefits or efficacy that is superior to the crude essential oil and worth paying a premium for. Other producers, *although very few have been successful*, have developed and marketed their own consumer product ranges around the world in attempts to get away from the price swings of a commodity product.

The Regulatory Environment

The regulatory environment is cited as the most difficult barrier to overcome in the development of a new essential oil. The regulatory environment is currently undergoing great change. It is governed by a number of organizations with regional and product category jurisdictions. These are described in some detail in chapter Seven. Many see these regulatory bodies as taking *'an over the top'* approach to ensure consumer safety through material restriction, far beyond the actual threat availing society from the usage of aromatic materials in everyday life [31]. Examples of some issues facing the industry today include;

- Limonene, a monoterpene constituent of many essential oils, including citrus oils is under consideration for classification as an acute hazard to the environment. This means that products containing this ingredient in specified proportions [32] will be required to follow EU hazard labeling rules. As it is proposed to designate limonene as R50/53 under the environmental regulations. This will disallow the certification of any product containing limonene in eco-certifications.
- The EU Scientific Committee on Consumer Products (SCCP) gave an opinion in April 2008 that oakmoss extract use be limited to where atranol and chloroatranol do not exceed >2ppm in products [33]. This will potentially limit natural chypre and

fougere accords in perfumery and promote more synthetic substitution for natural materials in this area.

- According to EU Directive 2003/15/EC, amending Council Directive 76/768/EEC [34], any product containing above specified limits of amyl cinnamal, benzyl alcohol, cinnamyl alcohol, citral, eugenol, hydroxyl-citronellal, isoeugenol, amylcin namyl alcohol, benzyl salicylate, cinnamal, coumarin, gernaiol, hydroxyl-methylpentcyclohexenecarboxalde-hyde, anisyl alcohol, benzyl cinnamate, farmesol, 2-(4-tert-Butylbenzyl) propionaldehyde, linalool, bezyl benzoate, citronellol, hexyl cinnam-aldehyde, *d*-limonene, methyl heptin carbonate, 3-Methyl-4-(2,6,6-tri-methyl-2-cyclohexen-1-yl)-3-buten-2-one, oak moss extract and treemoss extract, (all constituents found widely in essential oils), will require toxicity warning labels on consumer products.
- The SCCP in 2004 formed the opinion that the use of undiluted tea tree oil is unsafe and it is unsuitable for use in cosmetics [35].

Under proposed legislation small cosmetic cottage industry hobbyists and micro-companies will be required to register with the US Federal Drug Authority like any other cosmetic manufacturer. Under the proposed FDA Globalization Act 2008 [36], small companies will be required to pay the same fees as their larger counterparts, operate production and goods storage in separate locations, undertake the same paperwork requirements, register their formulations and advise the FDA of any changes in product formulation. If this act is passed, it will heavily curtail home and hand-made cosmetic and aromatherapy production in the United States.

The major consequence from the changing Worldwide regulatory framework is that all essential oils must fulfill regulatory requirements, including existing ones because there are no *'grandfather'* provisions in the EU regulations. This will dramatically increase the cost to producers who are not organized as a representative group and increase the costs for any new essential oil development.

New markets and opportunities are opening up for essential oils. The organic cosmetic market is reported to be growing 39% per annum [37]. No published market or growth figures exist for organically certified agricultural pesticides and fungicides, but growth is exponential according to those in the industry. There are also innovations in the household insecticide market. Companies like EcoSmart® have launched *knock-down* household insecticides utilising essential oils as the major active ingredients [38].

The use of the term *natural* in the cosmetic industry has become misleading. Many multi-national companies are moving into the organic cosmetic segment, previously served by smaller specialist niche manufacturers. There is a lot of confusion as consumers are often given the impression that ingredients as 100% natural, when this is often far from the truth. There is currently lack of regulation in this area which is allowing companies to portray their products as natural, when they are really not. Natural does not mean sustainable and the use of some materials may actually harm bio-diversity, rather than preserve it, as discussed in the previous section on wild plant collection. The use of diesel to distill essential oils can be substantial. Ginger takes 20 hours, linaloe 25 hours, vetiver 30-90 hours and Ylang ylang up to 48 hours of distillation time. This creates a large carbon footprint, especially with diesel and bunker fuels that have to be carted long distances.

Various organic certification bodies exist to audit and appraise cosmetics, but these certification schemes at present, are not uniform in their standards and are voluntary, without any legal sanction. Generally these organic certification programs require only 95% of materials in the product be of natural vegetable origin, processed through physical methods. Therefore it is possible that the fragrance in the product is synthetic and not from a natural source. The sustainability of production is also not adequately assessed, leading to criticism of these certification schemes. Until these certification schemes are developed further, there is little incentive for manufacturers to increase their use of essential oils. This will be discussed in more detail in chapter 11.

The Rural Crisis

As we are completing the first decade in this new Century much of the Asia-Pacific region is suffering a rural crisis. Australia is hit with a long drought which is slowly grinding rural regions to a halt. With tightening credit, many rural families are being forced off the land. Chronic shortages of labour are affecting harvests and production. Declining services and infrastructure is lowering the quality of life for rural families. Another aspect of Australian rural society is the inequality of educational pathways between rural and urban youth [39]. This could potentially inhibit the ability of rural people to scan for opportunities and exploit them in the next generation.

To the North in Papua New Guinea, economic and social inequality is increasing between the rural and urban population. Rural population has fewer opportunities from limited economic activity. Disadvantages include, remoteness from urban markets, the high cost and deterioration of transport services, poor access to services, lack of private and Government investment and environmental pressure on the eco-system due to illegal activities such as logging. In Papua New Guinea nearly half of the people living in rural areas live under the poverty line [40].

Through South-East Asia, rural areas are facing similar problems as Australia and Papua New Guinea. Many rural areas lag behind in national development unable to benefit from the high levels of growth in the region. Some governments are focusing on building infrastructure in urban areas due to the very rapid urban population growth, at the expense of the rural areas. Lack of rural investment is leading to higher rural unemployment rates where a large percentage of the rural youth population is leaving to the cities for job opportunities [41]. This leaves an aging farmer population in rural areas with low education levels, resources and capital. In some parts of the region, there is a feeling of powerlessness, with a lack of ideas, opportunities and matching skills, so very few are willing and able to embark upon new agriculture ventures [42].

Templating of Natural Aromatic Molecules

Many natural perfumes from the scents of flowers in the forests and jungles of the World are examined each year by flavour and fragrance companies [43]. This results in a thorough analysis of these oils and an investigation of the biological pathways that leads to their natural synthesis. From this data, thousands of new molecules are synthesized each year, their odour properties evaluated and tested in potential applications and the synthesis process for promising molecules patented [44].

The discoveries of new aromatic compounds have led more to the development of specialty aroma chemicals than to the development of new essential oils. The newly discovered aromatic molecules become *molecular templates*, where economic routes of synthesis can be designed and developed on a commercial scale. With advances in bio-fermentation, this trend is likely to continue because many newly discovered natural molecules come from plant species where the target molecule exists in the plant in trace amounts and too costly to extract. With very few exceptions, flavour and fragrance companies have been reluctant to invest and develop the production of new essential oils due to the ease of synthesis as an alternative. The process of finding new molecules and synthesizing them is shown in Figure 1.5.

The patenting of aromatic materials found in nature is the way that many companies have protected specialty aroma chemicals with novel notes they have developed. This allows companies to exclusively offer these materials to the industry on a monopoly basis. The issue of synthesis raises the debate about intellectual property. These claims and rights in many cases are based on indigenous knowledge and medicine, although this is sometimes hidden. Companies hide the original source of knowledge and true ownership through not using the correct botanical nomenclature and specifying individual chemicals from the plant, without specifically mentioning the plant, and referring to a number of plants. The effect of these patents in a number of cases is to prevent the development of a specific essential oil as a single party has been awarded the exclusive rights, preventing others from exploiting a known and public domain natural resource.

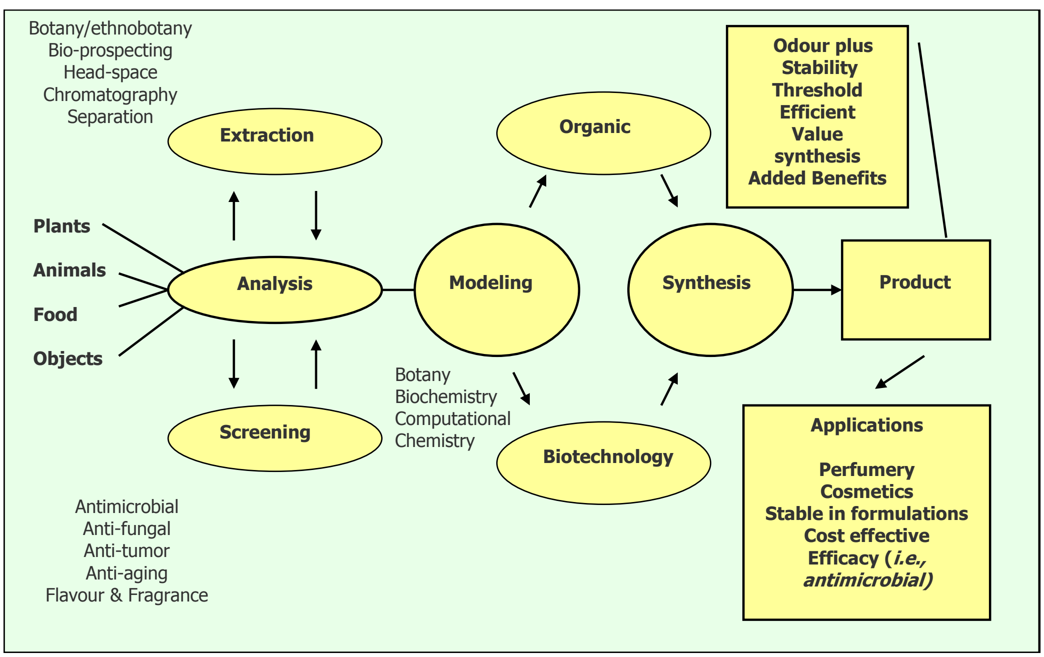

Figure 1.5. The process of finding, analyzing and synthesizing an aroma molecule from nature.

Companies that have the analytical equipment and laboratories to compile the data needed for an expensive patent application are advantaged over individuals and community groups who are usually not organized and lack the needed resources [45]. The *Cropwatch* website argues that these patents represent misallocations of public domain knowledge and occur because the patent authorities lack the expertise required to scrutinize these issues [46]. Nevertheless, a number of these patents have been challenged and revoked by patent authorities. For example, WR Grace European Patent on Neem extracts *(Azadirhta indica* A. Juss) was revoked and a tumeric *(Curcuma long* L.) patent held by the University of Mississippi Medical Centre was revoked in 1995.

Research

Most crops need considerable research before they can be commercialized. Research plays an important role in essential oil development and maintaining competitive advantage of an existing industry. Essential oil research covers the disciplines of botany, ethno-botany, entomology, natural product chemistry, analytical chemistry, mirco-propagation, agronomy, agricultural engineering, distillation engineering, biotechnology, bioprocess engineering, cosmetic chemistry, perfumery, flavours and industrial chemistry. However, the majority of research undertaken in these fields by universities and research institutions tends to be academic rather than practical research. Academic researchers tend to be more concerned about maintaining the rigour of science, judged by their peers in journals and conference proceedings, rather than research that contributes directly to the exploitation of essential oils and development of the industry [47].

According to Malcolm, the last fifty years of Australian agriculture research was largely irrelevant to the farming community [48]. Public funding is decreasing and this is forcing the role and organization of research into new paradigms. In the future strategic alliances will need to be created, like for example the strategic alliance between the University of Tasmania and Essential Oils of Tasmania. Other commercial research and development arrangements are being implemented places like New Zealand, where a corporate research institution (SCION) is collaborating with the existing kanuka oil industry to improve the value of production through creating specific isolates useful to industry, under a commercial arrangement [49].

Future essential oil research cannot rely on public research funding to assist in the establishment of new essential oils. Farmers will need to empower themselves and lead their own research in what is called *farmer driven research* [50]. This research approach escapes the irrelevant research provided by public institutions and focuses on the real needs in developing a new crop [51]. Many research models involve the farmer in their own crop trials, without the same rigour as academic research to achieve useable data that can be utilised by farming communities. This approach is called *participatory action research, farmer participatory research, participatory technology development* and *on-farm research.* Although these models were originally developed for Third World farming communities, they are quickly being adapted to problems of farming in developed countries [52]. The shift from traditional based research to participatory action research is shown in Figure 1.6.

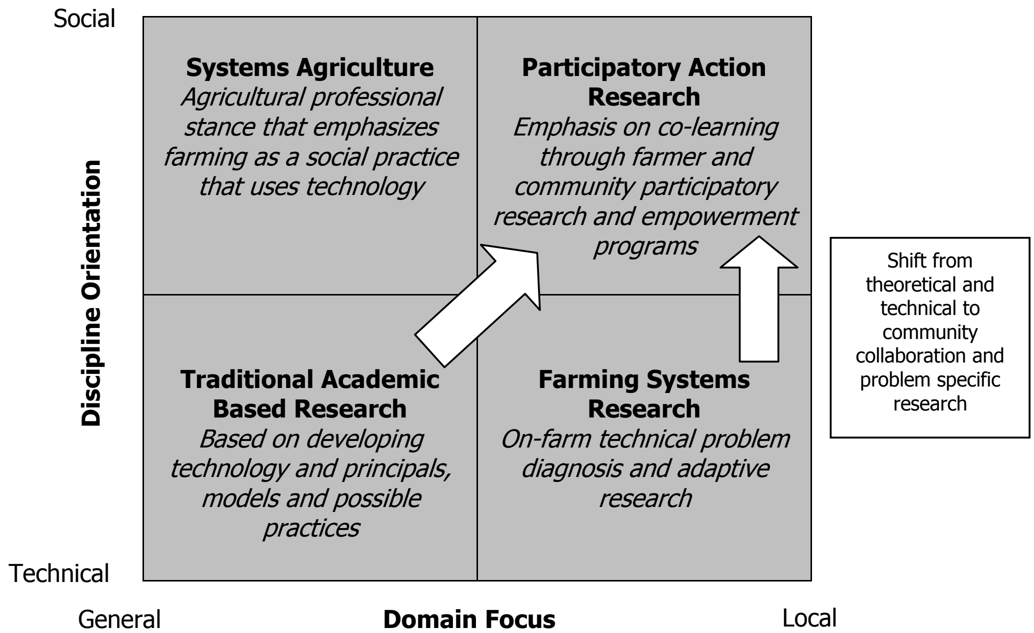

Figure 1.6. A typology of Various Farming Research Management Concepts.

Research in the future is most likely to be corporate based focused on the development of highly valued isolates and fractions of existing essential oils. This will be sponsored and dominated by research orientated enterprises, the flavour and fragrance industry, cosmetic and pharmaceutical companies. Growers in the Asia-Pacific region will have to rely on collaboration with other individuals [53] and commercial organizations, or go down the road of participatory action research [54].

From a sustainability standpoint, research without a strong component of innovation that provides some form of competitive advantage, or is based on some external unique factor like climate, may not always benefit the emerging industry. Research that doesn't create a strong entry barrier to others will not stop an industry declining in one country and emerging in another. Examples to support this proposition is the loss of the Australian eucalyptus industry to Europe, Africa and South America, the loss of the Australian tea tree industry to China and the move of floral oil production from Europe to Asia.

Sustainability

The concept of sustainability is elusive, difficult to define and even more difficult to know whether the enterprise is really operating in a sustainable way. Although there are now many conflicting definitions of sustainability, most include elements of both the socioeconomic and natural systems [55]. Theoretically, sustainability is about integration of the enterprise with the environment, where the environment includes natural, social, economic and strategic aspects. A sustainable enterprise is one that maintains productivity in the long-term [56]. Immediate needs should be able to be met, while ecosystems and biodiversity are preserved for the future. However, it must also be accepted that everything has a limited lifecycle, and this increases the complexity of the meaning of sustainability. Sustainability needs consideration on all aspects of an enterprise. These areas include;

a) the agricultural aspects, where long term production and preservation of resources are balanced out,
b) the surrounding ecological aspects, where the eco-system and bio-diversity is not depleted,
c) the management aspects, where the management system supports individual employees and the community,
d) the financial and economic aspects, where the benefits of new crops can be sustained without having to continually subsidize and financially support them with external funding, and
e) interactions with the socio-economic environment and the community, where both have mutual benefits.

The concepts of sustainability in agriculture are discussed further in chapter 10.

FACTORS LEADING TO SUCCESS AND FAILURE

Before proceeding further into this book, it is important to have a look at the factors influencing success and failure. Robert Cooper in his book *Winning at New Products* suggests that looking only at the factors of success will not give as an informative picture as looking at the factors of failure, as well. This is because, not all factors we equate with the success, actually contribute to that success. Therefore, the study of the factors resulting in failure is in many ways a more important key to understanding what factors are critical [57].

Table 1.3. Physical Requirements, Competencies and Market Needs for a Potential Crop

Physical Requirements	Competencies	Market Needs
• Genotype • Chemotype • State of maturity/time • Part of plant harvested/method • Temperature • Light duration • Water • Nutrients	• Propagation • Planting/maintenance • Harvesting/processing • Operational • Marketing • Financial	• Quality • Volume • Value to user • Delivery • Service • Assistance to user • Market development

Planning and Opportunity Assessment

Assessing potential opportunities should be undertaken in a manner that considers and exposes the potential risks in development. Risk can be minimized when the requirements to exploit the crop successfully *(i.e., major consideration factors and resources required)* are matched by the available physical characteristics, existing management and technical competencies available to enable the fulfillment of market needs. Each crop should be screened against criteria set out in Table 1.3.

A good assessment of the issues involved in development will help those involved gain a good understanding of what knowledge is required to make the project succeed. Making good assessments of the issues involved is a way to deal with potential future problems that could pose challenges to the project. A good assessment of the issues will negate the possibilities of the unexpected occurring, as these have already been factored in with potential contingencies, should they arise. When a project progresses without surprises, it is much easier for all stakeholders to maintain their patience and commitment. The loss of patience and commitment by stakeholders can quickly shut down a project. Incorrect assessments can lead to underestimations of the technical, management and market requirements that could be critical to success or failure.

Making good assessments during screening will lead to the setting of sound assumptions from which good development plans can be set. Many essential oil projects fail outright because of wrong assumptions made in the early planning of the project. Incorrect assumptions could be related to market, customer, price, cost, yield, cultivation time, or operational costs. The very assumptions that a development plan is based upon must be realistic, and contingencies developed for any variances of these assumptions. Identifying the correct stakeholders that have the ability to enhance and improve competencies is important.

Paramount to making sound opportunity assessments is the quality of information used. There are numerous sources of information available ranging from totally unreliable to very reliable. For example, at the time of writing there is great excitement about cultivating lemongrass, as a source of citral. Many websites are claiming that citral is a newly found cure for cancer. Some companies are buying up lemongrass and manufacturing products with claims that cannot be scientifically supported and without any pharmaceutical registration [58]. When products don't meet pharmaceutical regulations, they will eventually be forced off the market by the authorities. Some farmers will suffer as their customers will disappear. The reliability of information will be discussed in more detail in chapter Six.

Management and Organisational Issues

Management is a crucial factor in the success of any project. Management will lead the project implementation, appraise progress, and strategise ways to solve any arising problems. This will be much easier if potential problems were anticipated and contingencies developed to settle them as discussed in the last section. Management should be flexible and open to changing approaches to deal with arising issues. The project management must have the identified skills and competencies required to undertake the project, or have outside assistance available where these skills do not exist internally. This is where collaboration with research institutes and customers are important.

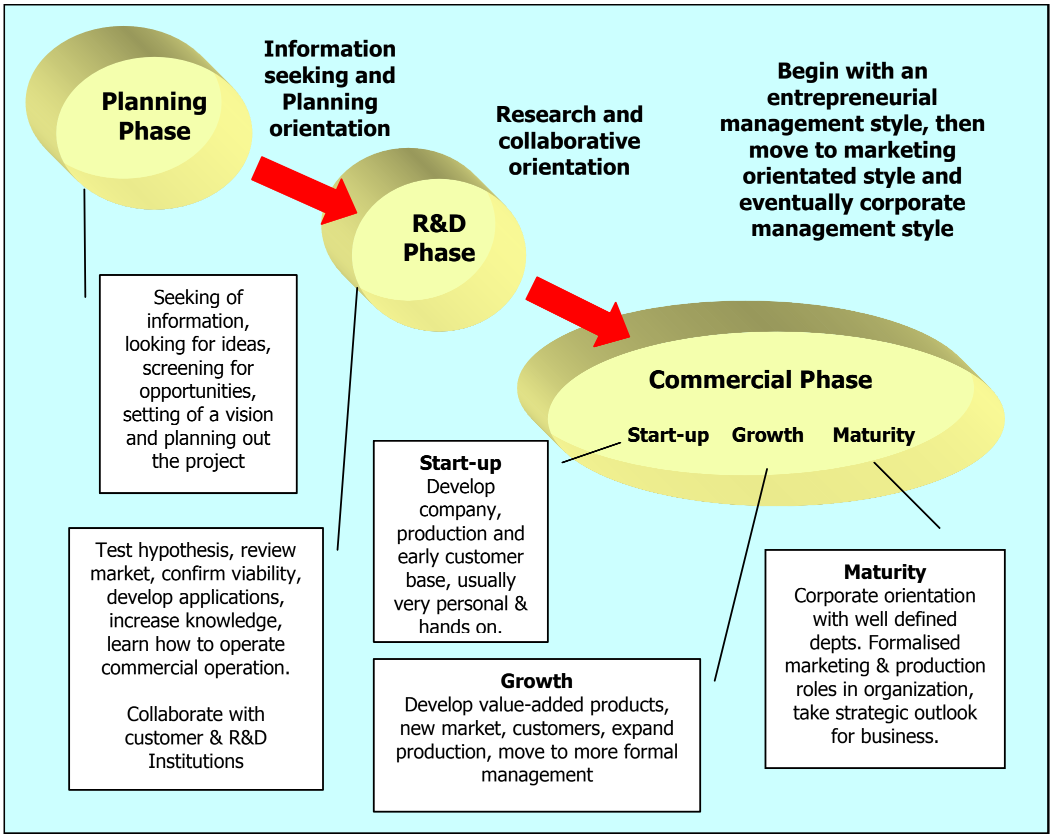

Figure 1.7. The Various Stages, Management Styles and orientations Required during Project and Enterprise Development.

During a project, different types of management style are required. Firstly, in the initial phase, a planning stance is necessary. After the planning phase, a research and development phase at field and market level is required. This is the time where collaboration with outside stakeholders will be critical. The third phase is where the enterprise moves from the research and development phase into the commercial phase. The commercial phase will involve start-up, growth and maturity sub-phases, which also require different areas of strategic focus and styles of management. For example, planning style will be no good during the research and commercial phases, etc. Different people will have different strengths or competencies during each phase and the enterprise may require different people to lead it through these different stages. The various stages in project and enterprise development are depicted in Figure 1.7.

Successful enterprises are ones that find opportunities that add value to the commercial operations. This could be in waste management, the production of by-products or some form of horizontal integration. Enterprises with multiple sources of revenue will generally have better chances of becoming sustainable and successful.

Factors that can lead a project to failure include activities and attributes that are dysfunctional to the enterprise. This can start in the strategic arena where important stakeholders do not share a common vision and see different directions for the enterprise. This is common in many government-private enterprise ventures. Disagreement over vision can degenerate into straight politics, greed, deception or dishonesty, all destructive forces for a project. Other factors that detract from potential success are mismatches of skills to technical, management and marketing requirements and the failure to find and develop extra value-added horizontal diversifications that can supplement income.

Financial Issues

Sound budgeting depends upon correct time assumptions with good contingency planning. This ensures that all stakeholders know what to expect and will be supportive of the project throughout its progress. Over-estimates of income and under-estimates of costs will result in insufficient cash-flows. This will bring doubts and questions upon the management that drew up and is implementing the plan. This can lead to loss of confidence and the demise of the project. Likewise, underestimates of development and operational costs leads to a project that has difficulty moving forward due to financial constraints.

Funding issues should be intelligently worked out before operations commence. Financial support from banks and other financial institutions cannot be assumed especially in regions where essential oil production is an unknown or little known concept. Banks are usually very reluctant to extend funds into enterprises involving new crops. Alternative funding sources should also be considered in a conservative manner. Venture capitalists and business angels are important sources of funds in Europe and the United States, where ventures raise 4.9% and 2.7% of GDP respectively. However in Australia capital raised in this way accounts for only 0.62% of GDP, and this is considerably lower in South-East Asia [59].

A successful venture's size should have a certain 'critical mass' to have any economies of scale and be viable. Therefore the investment must ensure that all the necessary equipment is available to ensure the smooth operation of the venture when needed. Machinery and equipment should be an optimal size (discussed in chapter 9). Over-capacity equipment requires over-investment into a project and this can jeopardize returns on investment (ROI).

Technical Issues

Successful projects are those where the technical issues of propagation, planting, cultivation, nutrition, harvesting and extraction have been thoroughly investigated with a well planned out research program. The results of the program should lead to and understanding of what are the best practices required for the commercial phase. The initial research phase should include the selection of a suitable cultivar for the project site, the development of specialized equipment to handle, planting, crop maintenance, harvesting and extraction, and the audit systems required to meet regulatory and market requirements.

Projects often fail from simple technical mistakes. Common mistakes include the selection of the wrong plant chemotype, failure to look into the regulatory issues, failure to develop infrastructure like irrigation, failure from pest or disease attacks, using land that is not suitable for the crop, *i.e., infertile, no source of water, etc.*, selecting crops which require manual labour to plant, maintain and harvest in areas where there is a labour shortage, and poor worker attitude to best possible practices. Many potential mistakes can be foreseen if past research work is examined to find out the reasons why it wasn't commercialized previously.

Land Issues

Land is one of the most important influences on project success and is often poorly considered, as in many cases it is taken as a given, *i.e., it is already owned, it is the only piece of land on offer and available, or it has been allocated for the project.* Therefore in a number of cases, projects fail because the land may not be suitable for the crops selected, *i.e., land poor for annual crops, but maybe more suitable for long-term perennial crops, with some research and development of practices.* The primary aspects of land that influence success or failure include;

- The biophysical aspects of the land; soil, climate and terrain,
- Existing physical capital, *i.e., access, water sources, irrigation, other basic infrastructure,*
- Socio-economic aspects, including,
  a) the existing knowledge and cultural practices of the community,
  b) access to farm inputs,
  c) access to markets, and
  d) access to credit.
- The current and potential degradability of the land and its influence on productivity.
- Labour availability and quality issues, *i.e., will it be likely that there will be labour shortages during critical times like planting, weeding and harvests.*

These combined factors will influence the input/output ratio of the land which is the ultimate determinant of land suitability. Any deficiencies in the above land aspects can seriously impair success of the project.

Marketing Issues

Sound market research is an important success factor. Many projects have not succeeded simply because essential oils without markets have been developed. Any market research should seek to interview potential customers at all levels in the supply chain for their views. Potentially important strategic customers should be invited to collaborate and even jointly participate in the project. Having potential customers involved in a project from the outset is a very important positive factor. Customer involvement should provide a good environment for stakeholder support and commitment. Market research for existing crops of commerce should also focus upon potential competitors and their potential reactions.

The type of product developed, whether a crude essential oil, an isolate or a consumer product, together with the part of the supply chain the venture will focus upon, *i.e., traders, manufacturers, wholesalers, retailers or directly to consumers,* should be evaluated. Information and knowledge gained through market research should assist in developing a differentiated product to other producers, if this can potentially create some advantage. Differentiation can be achieved through linking the essential oil with the geographical area where the project will take place, organic production, producing an isolate and/or through community participation/Fairtrade certification.

Effective marketing depends of good relationship with both direct and indirect customers throughout the supply chain. Time and effort should be put into market development, and manpower with a budget is required to fulfill this function. Many projects fail to allocate funds for these activities.

Many ventures fail because the marketing function is ignored or not understood. One of the first mistakes made by new ventures is to see a single customer as a potential market and develop a project on that basis, only to find out that the potential customer has disappeared or even ceased to exist. Other mistakes involve not having an idea of who the customers will be, or relying on third parties to sell the product. Many projects did not even allocated any funds to finding customers and marketing, have no idea about how to go about the marketing function, and lack any personnel to do it. Other market issues where new ventures fail involve the essential oil not meeting market requirements and standards.

Issues facing the producers of consumer products include;

1. Lack of innovation resulting in the creation of products with little differentiation from their competition,
2. Failure to create enough products to have a critical sales mass that can generate revenue above the break-even point,
3. Trouble gaining large retailer acceptance of the product, and
4. Failure to find wholesalers and distributors and rely on only a few selected stores in the local area to sell their products.

Strategic Environmental Issues

The most advantageous environment is a farming community that shares the same aspirations and works together through the pooling of resources on aspects of research, propagation, harvesting, extraction and marketing. However developing a successful clustering arrangement is difficult if the individual farmers have little resources to share. Situations where there is industry disunity tend to be counter-productive and can weaken seller bargaining power. Other strategic issues include the competitive environment and the influence on the market by competitors.

Issues of Fate and Nature

Issues of fate and nature cannot be ignored in agriculture. Adverse weather conditions and natural disasters can lead to crop failures. Over the last few years weather patterns have been in a state of flux with abnormal conditions. Past patterns for predicting future patterns cannot be relied upon like in previous times. Prices, exchange rates and the prices of substitutes are mostly outside of control and influence success or failure. The only approach to these types of risks is to plant and develop a portfolio of crops and develop other venture diversifications.

A summary of the factors influencing success and failure are listed in Table 1.4.

Table 1.4. A summary of the factors influencing success and failure

Factors Influencing Success	**Factors influencing Failure**
Planning & Opportunity Assessment	
• Selection of the right essential oils to develop • Understanding of the issues and requirements to develop and commercialise the crop and the venture • Realistic assumptions used • Good contingency planning • Correct identification of the required stakeholders to make the project successful, *i.e., university, venture capitalist, potential customers, etc.*	• Making the wrong planning assumptions – *market, customers, prices, costs, yields, cultivation time, operational costs, etc.* • Lack of patience and commitment *(often comes from poor planning and not knowing what to expect)*
Management and Organisational Issues	
• Flexibility in project implementation • Required competencies and skills for the venture acquired • Take up opportunities to value-add	• Stakeholders in the project not sharing the same vision • Politics, greed, deception and dishonesty • Poor match of technical, management and marketing requirements and skills (competencies) • Failure to develop value-added, horizontal diversifications that supplement income
Financial issues	
• Good budgeting, time assumptions with contingency planning. All stakeholders know what to expect • A critical mass from which to operate and cover costs, (however too large an investment and equipment size, etc, can lead to over-capitalisation)	• Overestimate of revenue coming in (price assumptions) • Underestimate of costs (cost assumptions) • Insufficient cash-flow to carry out necessary farm, operational and marketing tasks • Lack of funding to undertake necessary research and crop development work • Over-capitalisation for venture revenue volume, *inability to make significant ROI*
Technical Issues	
• Issues requiring research and development clearly identified and research undertaken • Good cultivar selection, good constituent levels and yields • Planned research and development provides information and knowledge to assist in increasing yields and quality • Farm and harvesting equipment is partly/wholly built on-site, rather than purchased. • Product integrity through certifications,	• Planting and cultivating the wrong chemotype • Failure to research regulatory situation sufficiently, *i.e., no GRAS listing, a chemical constituent under scrutiny by EU SCCP, etc.* • Failure to develop all necessary infrastructure *(i.e., irrigation)* • Failure due to pests and disease • Developing the project on land that is marginally fertile and unsuitable due to lack of rain and/or irrigation

GAP, HACCP, etc.	• Crop selected cannot be mechanized for harvest, etc, where there is a lack of labour and/or labour costs are high • Poor appreciation of crop cultural practices required, *worker resistance to new cultivation techniques* • Past work on the potential crop not reviewed
Land Issues	
• Favourable biophysical attributes, soil, climate and terrain • Socio-economic aspects a) knowledge and cultural practices b) access to inputs c) access to markets d) access to finance • Input/output ratio • Positive motivational factors: *i.e., govt. incentives*	• Unfavourable biophysical attributes, soil, climate and terrain • Labour shortages during critical times, *i.e., planting, weeding, harvest, etc.* • Derogated land
Marketing Issues	
• Potential customer(s) involved from the outset of the project • Sound market research, especially supply side • Development of a sound product differentiation strategy • Branding and market presence • Good relationships through the supply chain • Effective market development program	• Mistaking the wants of a single customer as a market • Not having specific customers in mind when developing the project • Relying on third parties to market and sell the essential oil • No allocated marketing budget • Failure to have required quality of product • Failure to find profitable outlets for the product • Don't know how to go about the marketing • Don't have the personnel • Failure to invest in market development
Strategic Environmental Issues	
• Develop clusters with other producers to take advantage of research, economies, marketing and other resources	• More efficient producers as competitors • Price downturn as come on-line commercially • Lack capital at industry, as well as at farm level • Industry disunity
Issues of Fate and nature	
• Exchange rate variations that enhance the competitiveness of the price (cost) to the customer	• Adverse weather conditions • Natural disasters leading to crop failure • Venture dependent on new product for viability *(i.e., no crop portfolio or existing support income to reduce risk)*

Development success depends on basing a project on the correct fundamental assumptions. These include market size and potential, price, volume, quality, yield, costs and time. The consequences of getting any of these critical premises or assumptions wrong will most likely lead to a failure. Table 1.5. summarizes the consequences of getting any premise wrong.

Table 1.5. Potential Consequences of Getting a Basic Project Premise Wrong

Basic Premise	Comments	Consequence
Market	*Does the structure and dynamics of the market, i.e., the competitive environment, certifications and other legal issues, the nature of buyers and rival competitors enable the enterprise to enter into this market? Can the product produced really meet the specifications of what is really required in the market? (essential oils are all different even if they are from the same botanical source: colour, odour, chemical constituents levels), Is the market a local, regional or international one? Even with a potential market established, what is the possibility of getting access to potential customers, can they be serviced, what is the competition and how will they affect market strategies and what is the cost of each sales? (this is often ignored in project studies). What extra volume can the market absorb?*	Failure to enter market and gain customers – **unsold oil and no revenue**. Failure to meet market requirements- **unsold oil and no revenue** Underestimate of costs of servicing customers **– higher costs**
Price	*Wrong assumptions about product quality, the level of demand and supply from other producers will lead to wrong price assumptions. Making price assumptions are more risky for a new essential oil than an existing essential oil of trade.*	Achieve price under the assumptions – **Lower revenue**
Volume	*The volume produced is related to the yield. The volume must be enough to sell so that all costs and overheads of the project can be met. The production of low volumes may affect the enterprises ability to sell to large companies, as quantities may not cover their demand. Low volumes also require relatively more funds to market, as costs are amortised over smaller volumes. The production of very high volumes may be too much for the market to absorb, leading to the holding of stocks. It is thus very important to know how large the volume of the market is and how much is currently being supplied. Calculating this figure is very hard and will rely on a lot of informal and fragmented information.*	The production of low volume may **exclude opportunity to sell to large customers** Large production volumes **may lead to excess stocks**
Quality	*What essential oil characteristics are important to buyers and the use buyers utilize the product for? Is the*	Failure meet customer

	product a real substitute for what is already in the market, or is it different? (for example, the whole cultivated sandalwood in Australia has assumed that Australian sandalwood oil is a direct substitute for East Indian Sandalwood oil [60]*)*	requirements in quality – **unsold oil or oil sold at huge discounts**
Yield	*The yield is very important in determining the volume of oil for a particular lay out or spending of funds for the production of the crop, extraction of the oil and the other costs in undertaking those activities. Yields can be expressed in cost per kilogram produced, etc. Making the right assumptions about yields is critical to outlays and returns, most importantly the surplus. Yields per hectare are important in meeting break-even cost point in production.*	A lower than assumed yield will **increase costs in relation to revenues.** If yields bring revenue below “break-even” point then project will continue to **require external funding**
Costs	*Cost assumptions include the cost of nursery, planting, cultivation, harvesting, extraction, marketing, transportation, maintenance and administration. The results of agronomic research and development will confirm the cost assumptions. The early results and feedback from marketing efforts will determine the actual costs, once the organization is in commercial operations. Product costs are also directly related to yields, where operational costs that will occur regardless of sales are referred to as fixed costs. Adding the fixed costs with the variable costs per unit of production volume will give the break-even point. Enterprise size must be large enough to be able to cover fixed costs adequately, in what is referred to as the ‘critical mass’.*	Under assumptions of costs **will raise potential break-even points for the enterprise.**
Time	*Times aspects relating to a project concern a number of aspects. 1. The time of research & development. R&D costs money and the longer the R&D phase the higher the project set up costs. 2. Crop cycle time is critical to annual spending costs, underestimates will increase costs. 3. Harvest and processing times will affect the processing costs of the crop, and 4. The time it takes to sell the oil once it is harvested is rarely calculated in project papers. (it should be noted with some essential oils, stocks from season to season may be held by producers, tying funds up).*	Time overruns – **increased costs and potential loss of stakeholder support**

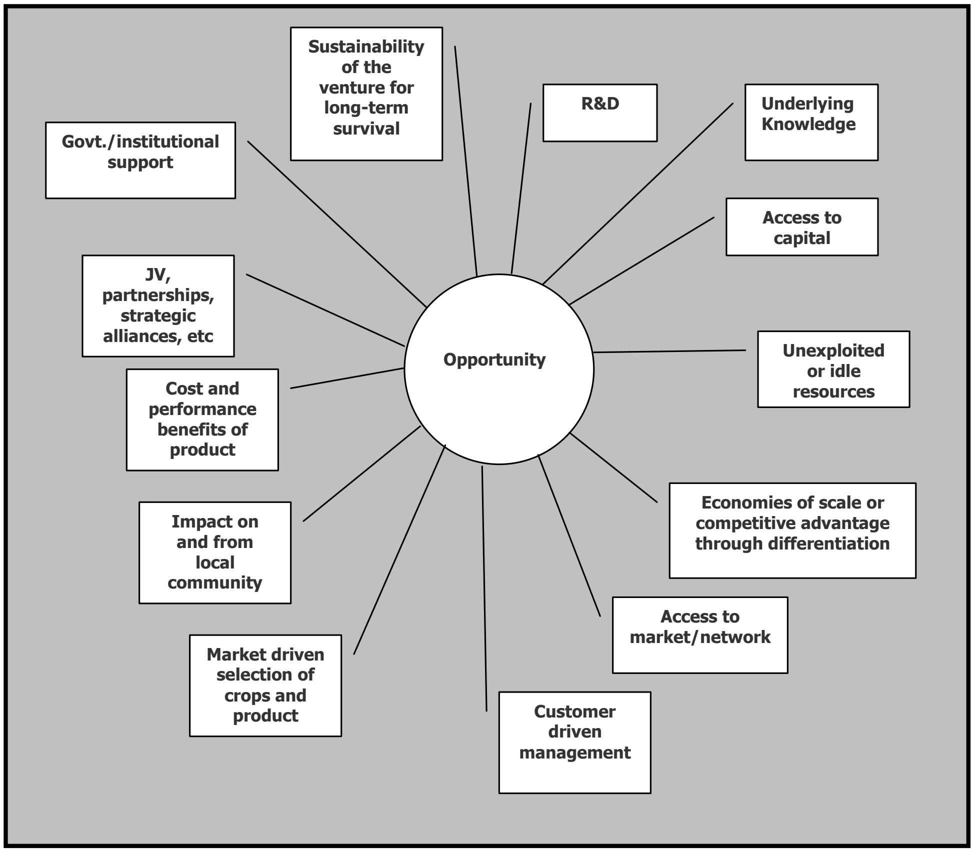

Figure 1.8. Some Potential Strategic Success Factors.

Few agriculture sub-sectors will escape the impact of advances in biotechnology, chemical technologies, process engineering and increasing consumer demands for a better quality of life. The management of agricultural enterprises will be presented with challenges in how to utilize new technologies, cater to stakeholder demands while creating better quality with improved productivity at the same time. Value-added enterprise expansion will become a must for future survival. Scientists have to become market driven and focus research upon areas which have potential benefits in industrial application. Community based production organizations will be presented with both challenges and opportunities from changing supply chains and industry concentrations. Producers will have to work through the rules set by regulatory regimes around the World, which themselves are undergoing transformation.

The growth of essential oils is constrained by increasing regulation, price fluctuations, and the cost conscious industry. Organic certification systems have to be further enhanced so that manufacturers are compelled to use organic essential oils in their formulations. There is still a lack of reliable organic essential oil producers today and organic oil price premiums need to drop so that more consumption is encouraged. The way in which entrepreneurs approach industry issues will determine how essential oils grow in the coming years.

Improved farm management is still needed in the industry, especially in the planning, technical, cultivation, extraction and supply chain management. Farmers in different geographical areas have different opportunities based on their experience, knowledge, capital, networks and local conditions. The way in which agricultural enterprises, R&D institutions and local governments respond to opportunities will have a profound effect on the size and structure of their agricultural sector in the future. In general there still needs some institutional collaboration with farmers to assist in the development of new crops and supply chains through partnerships and strategic alliances. Figure 1.8. shows some potential success factors.

The rest of this book will try and assist the reader to identify potential essential oils crops through a number of tools, assist in developing both an enterprise and crop management framework and assist in identifying the part of the supply chain that the enterprise should focus upon and operate within.

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Chapter 2

THE NATURE OF THE INDUSTRY

Basic success or failure in any part of the essential oil industry depends upon a thorough understanding of its nature and dynamics. This chapter introduces and describes the industry and the various interrelated sub-sectors. The chapter briefly introduces the various essential oil production units, traders, aroma and chemical specialty manufacturers, flavour and fragrance houses, consumer product manufacturers, retailers and consumers. The regulatory system, research institutions, government and standards associations are also introduced. A brief outline of the cosmetic, pharmaceutical, aromatherapy and agrochemical sub-sectors is given before introducing the concept of the industry value chain.

INTRODUCTION

The essential oil industry can be viewed from many different perspectives, depending upon one's position within it's hierarchy and orientation. At the base of the hierarchy, the industry is primarily agricultural, where trade has its historical roots and traditions, yet at the same time being modern and discerning, utilising the most up to date supply chain techniques. The selection and use of essential oils are based on art, science, and in many situations antidote. Essential oils are selected on desired efficacies to achieve particular characteristics and effects in end products. Essential oils may be classified as commodities, but they are also specialist products, usually playing some intermediary role in product creation. To all involved in the industry, including users, essential oils have always created fascination and passion in people. This is an important aspect of the nature of the essential oil industry.

The essential oil industry can be classified by the nature of activity. This covers the wild collection of natural resources, agriculture, chemical synthesis, trading, research, regulatory assessment, monitoring and control, flavour and fragrance creation, development and compounding, consumer and industrial product manufacture, supply chain distribution, mass and niche marketing channels and last but not least, consumerism. The essential oil industry can also be classified according to final application, which includes flavour and fragrance, cosmetics, aromatherapy, pharmaceuticals, agro-chemicals, and all types of food products. This chapter will look at the various segments of the industry in more detail.

THE FLAVOUR AND FRAGRANCE INDUSTRY

Interdependencies between various sub-sectors, patterns and trends that influence the situational environment are complex. Understanding the flavour and fragrance industry is critical for anybody who wishes to operate within some part of it. Many essential oil production ventures have failed because they have simply misunderstood the nature of the industry [1]. Essential oil producers must understand the structure of the flavour and fragrance industry and the nature of derived demand in order to competently identify potential opportunities and analyse any corresponding threats.

At the beginning of the 20th Century essential oils were the prime building blocks of flavour and fragrances. Until the 1950's essential oils, concretes, absolutes, resins, tinctures and balsams, along with a few animal products, made up the composition of the whole palette that the perfumer and flavourist had at his or her disposal to create flavours and fragrances. The development of the petrochemical industry and the discovery of novel ways to synthesise synthetic aroma chemicals led to the decline of essential oils as the prime ingredients of flavours and fragrances. Flavour and fragrances became largely constructed from synthetic materials because of the rising costs of natural materials. This was spurred on by external World events like the Second World War and the end of colonialism, advances in science, and society's fascination with synthetics at that time. Today, natural materials only make up approximately 7% of flavour and fragrance formulations, with the bulk made up of synthetically derived aromatic materials, fixatives, extenders and solvents. Figure 2.1. shows the break up between the percentage of natural, synthetic and solvent materials utilised in flavours and fragrances today.

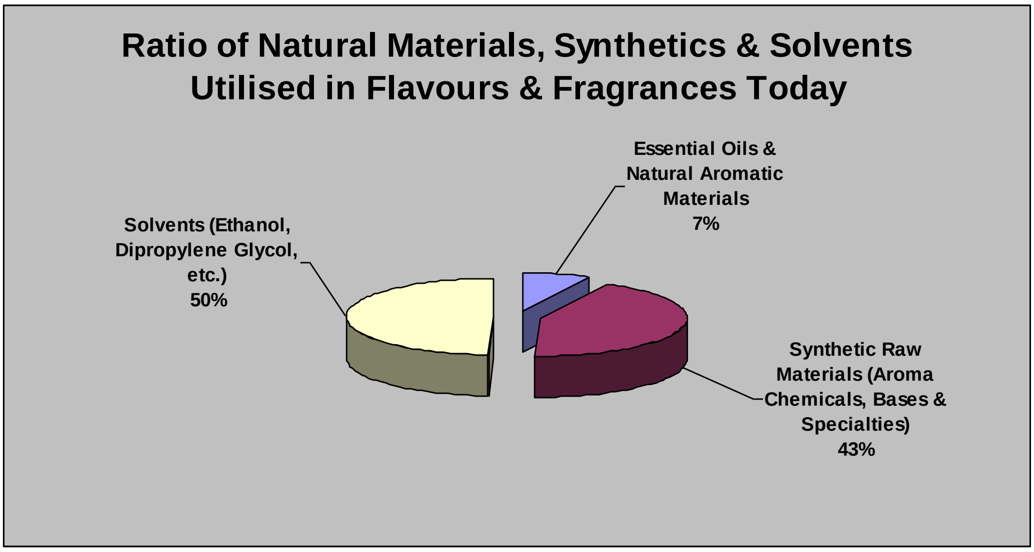

Figure 2.1. The Ratio of Natural Materials, Synthetics & Solvents Utilised in Flavours & fragrances Today.

The food, cosmetic, flavour and fragrance industries evolved largely in parallel. The food industry evolved from a small home cottage industry using local herbs and spices, to a large integrated industrial processing base that utilise materials from all around the World and markets products on a global basis. The flavour and fragrance industry once incorporating the cosmetic industry, started as a cottage industry, utilising traditional skills where the finest craftsmen would produce soaps, eau de colognes, aromatic waters and candles, making use of locally available plant materials for fragrance. This is a major reason why some essential oils in Europe are produced where they are today. Essential oils were an integral part of the craft. Both the cosmetic and food industries have become mass consumer product industries today where all but a few small companies have abandoned the production of essential oils to focus on product manufacturing and marketing.

The flavour and fragrance industry must be seen as a combination of overlapping industries and cannot be considered monolithic, due to the diversity of activities undertaken with links to essential oils. The flavour and fragrance industry is largely hidden behind the higher profile food, beverage, cosmetic, personal care and household product industries. Very few people realise the scope and diversity of the industry and the vital role it plays in supplying reinforcement to the desired images consumer product manufacturers portray through products marketed to the consumer. However, to some degree, even today the flavour and fragrance industry still has some remnants of the old craft and artisan ways, even though it has become a truly international industry [2], which relies on raw materials from all over the World, where most companies operate multi-nationally.

COMPONENTS OF THE FLAVOUR AND FRAGRANCE INDUSTRY

Recording the structure of the flavour and fragrance industry in an accurate manner is a difficult task due to the interactions and interdependencies between its various parts. Many organisations operate across the different functions and parts making them difficult to define. Mapping the industry according to function avoids the issues of who owns who which has been very fluid over the last few years, as there have been a large number of mergers and takeovers. Figure 2.2. shows a basic outline of the industry structure [3].

Figure 2.3. depicts some of the input/output relationships between the sub-sectors in the industry.

ESSENTIAL OIL AND OTHER NATURAL PRODUCT PRODUCERS

The diversity of natural products used in the flavour and fragrance industry is considerable. Essential oils and natural products are obtained from a wide variety of plants, shrubs, and tree species from various parts of the plant anatomy. These parts can undergo specific processes (distillation, expression, solvent extraction) to extract the aromatic material in a way that produces an essential oil, expressed oil, concrete, absolute, balsam, oleoresin, tincture or pomade.

Essential oil and aromatic extract production is a specialised agro-industry, where production is undertaken by farmers and agricultural enterprises, which are not part of the flavour and fragrance industry. Individual essential oil production trends are not homogeneous and must be studied and viewed separately because of the different production origins, varied importance of different oils to users in the industry, differing odour and performance characteristics [4] and many uses of each material [5]. This is well seen in the case of many high volume low value oils produced in developing countries. For example, the decline of essential oil production in countries like Indonesia is partly due to the low exit barriers of farmers and their ease in switching to food crops to seek better financial returns [6]. This is a structural factor that will ensure the return on essential oil production to farmers will always be higher than the return on food production.

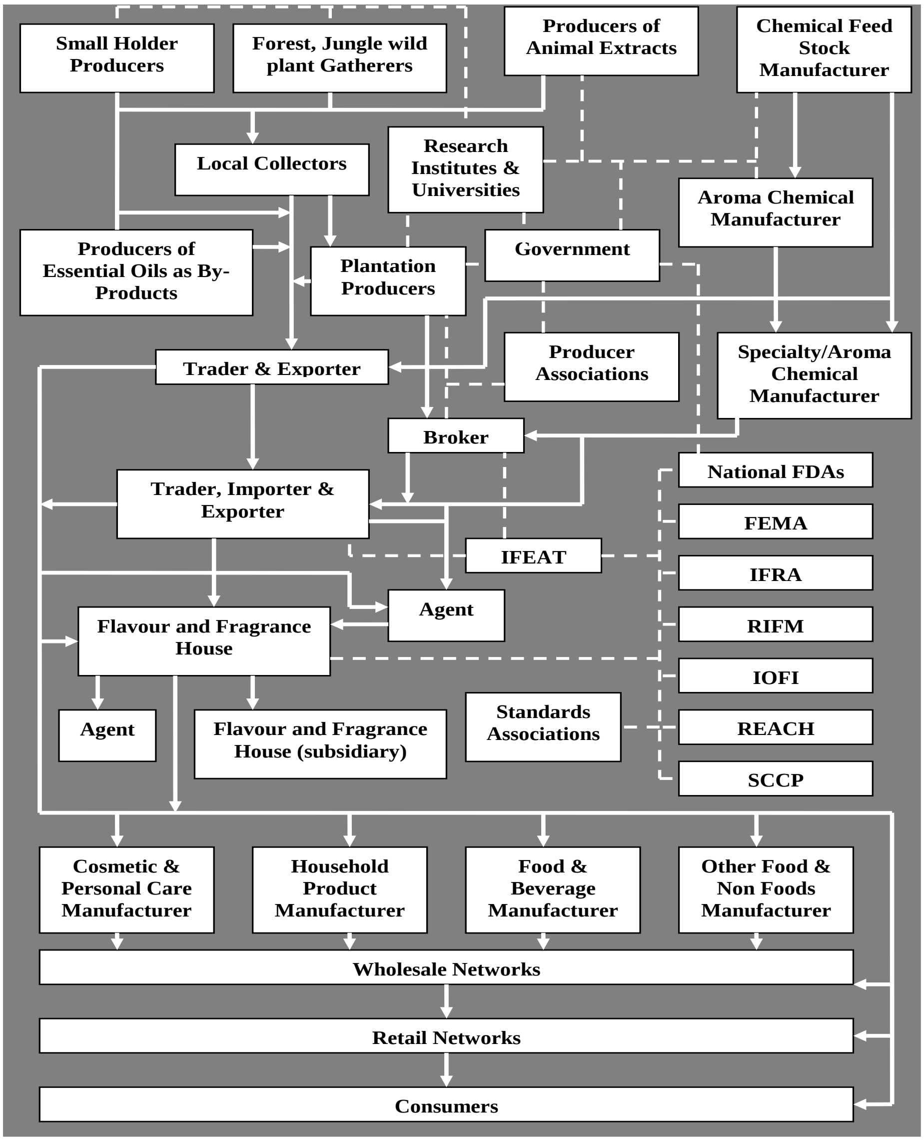

Figure 2.2. The Structure of the Flavour and Fragrance Industry.

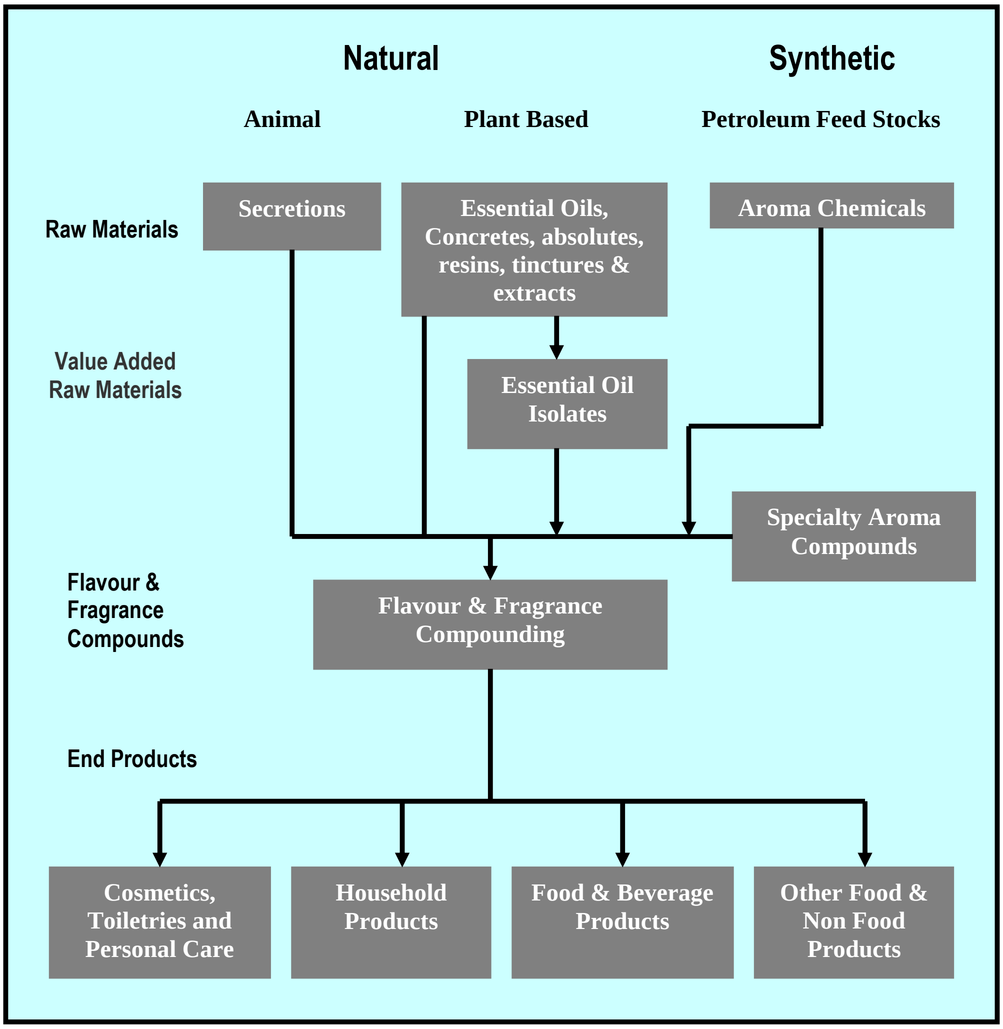

Figure 2.3. The Inputs and Outputs Interrelating Each Sub-Sector in the Flavour and Fragrance Industry.

Traditionally, centres of essential oil production tended to develop in regions where specific plants originated. However, cultivation spread outside these traditional regions after World War II due to the end of colonialism, wars, natural disasters, and the increasing cost of producing essential oils in Europe [7]. Today, modern professionally managed plantations exist alongside subsistence, small holder production and wild harvesting of plants for essential oils, in both temperate and tropical regions. Lawrence reported that of some 300 essential oils produced commercially, 50 percent are still obtained either as a by-product of another agricultural or forestry activity or harvested in the wild [8]. Table 2.1. shows the production methods for the top 20 essential oils of trade [9]. Figure 2.4. shows the geographical distribution of the World's major essential oil production areas [10].

Table 2.1. The Top 20 Essential Oils and Method of Production

Essential Oil	Scientific Name	Volume (Tonnes)	Method of Production
Orange Oil	*Citrus sinensis*	26,000	Produced in extensive plantations. Oil is a by-product from cold expression from peels after juice pulping.

Cornmint Oil	*Mentha arvensis*	4,300	Produced in extensive plantations exclusive for essential oil production. Steam distillation of wiltered foliage.
Eucalyptus Oil	*Eucalyptus globulus*	3,728	Mainly harvested from open dedicated forest areas and plantation. Oil extracted through steam distillation.
Citonella Oil	*Cymbopogon winterianus*	2,830	Both plantation and small holder but still wild collection in Java. Oil distilled by both hydro and steam distillation of the leaves.
Peppermint Oil	*Mentha piperita*	2,367	Produced in extensive plantations exclusive for essential oil production. Steam distillation of weltered foliage.
Lemon Oil	*Citrus limon*	2,158	Produced in extensive plantations. Oil is a by-product from cold expression from peels after juice pulping (some distillation).
Eucalyptus Citriodora Oil	*Eucalyptus citriodora*	2,092	Mainly extensive plantations. Steam distillation of the leaves.
Clove Leaf Oil	*Syzygium aromaticum*	1,915	Mainly from plantations, hydro and steam distillation.
Cedarwood Oil (US)	*Juniperus virginiana*	1,640	Waste wood from mainly wild collection is steam distilled.
Litsea Cubeba Oil	*Litsea cubeba*	1,005	Mainly plantations, steam distillation of the leaves.
Sassafras Oil (Brazil)	*Ocotea pretiosa*	1,000	Mainly wild collection, wood is chipped down and distilled.
Lime Oil	*Citrus aurantifolia*	973	Produced in extensive plantations. Oil is a by-product from cold expression from peels after juice pulping (some distillation).
Spearmint Oil	*Mentha spicata*	851	Produced in extensive plantations exclusive for essential oil production. Steam distillation of weltered foliage.
Cedarwood Oil (China)	*Chamaecyparis funebris*	800	Waste wood from mainly wild collection is steam distilled.
Lavandin Oil	*Lavandula intermedia*	768	Mainly Medium sized plantations, hydro distillation of the flowers and leaves.
Sassafras Oil (China)	*Cinnamomum micranthum*	750	Mainly wild collection, wood is chipped down and distilled.
Camphor Oil	*Cinnamomum camphora*	725	Mainly wild collection, wood is chipped down and distilled.
Coriander Oil	*Coriandrum sativum*	710	Plantation, Distilled from the fruits.
Grapefruit Oil	*Citrus paradise*	694	Produced in extensive plantations. Oil is a by-product from cold

			expression from peels after juice pulping (some distillation).
Patchouli Oil	*Pogostemom cablin*	563	Mainly plantation and small holder cultivation. Steam distilled under pressure after storage leaves for some months.

WILD COLLECTION FOR ESSENTIAL OIL PRODUCTION

Many natural products of importance to flavours and fragrances are not cultivated, but collected from the wild in many parts of the World. Boronia flowers are collected each year in Western Australia under rights granted to forest gatherers by the State Authorities. Pimmento leaves are collected by gatherers for distillation in Jamaica. Other essential oils produced from wild harvest include rosemary, armoise, thyme, amyris, cistus, galbanum, Spanish sage, Texas cedarwood, cedarleaf, sassafras, camphor and citronella. Wild collection of feed-stocks for essential oil production has been a controversial issue of late with over harvesting and unsustainable practices forcing many Governments to regulate or even ban wild collection. A number of companies are also making statements on product labelling that materials used in the product originate from sustainable production.

The convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), under the World Conservation Union (IUCN) came into effect in July 1975 and has been ratified by over 160 countries [11]. These countries have banned international trade on species deemed endangered. This has led to a sharp decline in the trade of many essential oils produced through wild collection. However these regulations are criticised for being easily avoided through smuggling, avoiding documentation, under reporting traded volumes, not using the correct scientific name on documents, passing off the item as another item that is unrestricted and using the restricted material to produce another value-added item that is not restricted *(i.e., plant banned but not essential oil)* [12].

SMALL HOLDER ESSENTIAL OIL PRODUCTION

Small holder production is a particularly important form of organisation in developing countries. The tea tree oil industry in Australia was also organised in this manner before the mid 1980s. This sector generally relies on family manual labour, employing varying levels of technology and mechanisation. Countries like India and Indonesia rely heavily on the small holder sector for the bulk of essential oil production.

Map Key

1. France: Anise seed oil, Angelica root oil, Artemisia Oil, Basil oil, Carrot seed oil, Celery herb oil, Celery seed oil, Clary sage oil, Roman chamomile oil, Clary sage oil, Cognac oil, Cypress oil, Fennel oil, Lavender oil, Neroli oil, Petitgrain oil, Rose oil, Rosemary oil, Spearmint oil, Tarragon oil, Thyme oil, Broom absolute, Mimosa absolute, Orange flower absolute, Tuberose absolute, Violet leaf absolute, Rose oil, Jasmine concrete and	**27: Seychelles:** Cinnamon leaf oil, Lavandin oil, Lemon oil, Neroli oil and Origanum oil.

absolute.	
2. United Kingdom: Angelica root oil, Basil oil, Celery seed oil, Chamomile oil, Clary sage oil, Coriander oil, Lavender oil, Rosemary oil, Sage oil, Spearmint oil, Hop oil and Thyme oil.	**28: South Africa:** Buchu leaf oil, Calendula oil, Coriander oil, Eucalyptus oil, Tagetes oil, Tangerine oil and Jasmine concrete and absolute.
3. Germany: Angelica root oil, Artemisia oil, Birch tar oil, Chamomile oil and Cognac oil.	**29. Comoros**: Basil oil, Cananga oil, Palmarosa oil and Ylang ylang oil.
4. The Netherlands: Anise oil, Angelica root oil, Bergamot oil, Caraway oil, Clary sage oil, Coriander oil, Cumin oil, Eucalyptus oil, Fennel oil, Lavender oil, Lemon oil, Marjoram oil, Rosemary oil, Tangerine oil, Thyme oil and Hyacinth absolute	**30. Madagascar:** Basil oil, Cananga oil, Clove oil, Palmarosa oil, Ylang ylang oil and Vanilla resinoid.
5. Spain: Anise seed oil, Bergamot oil, Cade oil, Clary sage oil, Cumin oil, Eucalyptus oil, Bitter fennel oil, Sweet fennel oil and Orange flower absolute.	**31. Guinea:** Bergamot oil and Bitter orange oil.
6. Austria: Birch tar oil	**32: United States:** Angelica root oil, Basil oil, Cedar leaf oil, Cedarwood oil, Celery seed oil, Chamomile oil, Clary sage oil, Coriander oil, Dill weed oil, Fennel oil, Fir balsam oil, Grapefruit oil, Lemon oil, Lime oil, Lemon balm oil, Melissa Oil, Olibanum oil, Orange oil, oregano oil, Peppermint oil, Pennyroyal oil, Pine oil, Sassafras oil, Spearmint oil, Rosemary oil, Thyme oil, Tangerine oil and Tangerine oil.
7. Albania: Abies alba oil, Origanum oil and Sage oil.	**33. Mexico:** Lime oil
8. Bulgaria: Abies alba oil, Anise seed oil, Blue chamomile oil, Clary sage oil, Dill weed oil and Rose oil.	**34. Canada:** Cedar leaf oil, Fir balsam oil and Fir needle oil.
9. Cyprus: Lemon oil.	**35. Cuba:** Bitter orange oil, Cascarilla oil and Lime oil.
10. Hungary: Angelica root oil, Artemisia oil, Basil oil, Caraway oil, Carrot seed oil, Roman chamomile oil, Dill weed oil, Hyssop oil, Marjoram oil, Parsley oil, Spearmint oil, Tarragon oil, and Valerian oil.	**36. Argentina:** Bergamot oil, Citronella oil, Grapefruit oil, Lemon oil and Mandarin oil.
11. Italy: Bergamot oil, Carrot seed oil, Clary sage oil, Roman chamomile oil, Garlic oil, Lemon oil, Mandarin oil, Neroli oil, Orange oil, Orris oil, Petitgrain oil, Orange flower oil, Mimosa absolute, Peppermint oil, Tarragon oil, Jasmin concrete and absolute.	**37. Brazil:** Bergamot oil, Bitter orange oil, Bois de rose oil, Cabore oil, Cabreuva oil, Clove oil, Copaiba balsam oil, Cornmint oil, Cypress oil, Eucalyptus oil, Grapefruit oil, Lemon oil, Lemongrass oil, Lime oil, Mandarin oil, Orange oil, Peru balsam oil, Petitgrain oil, Sassafras oil, Spearmint oil, Tangerine oil, Tolu balsam, Vetiver oil and Ylang ylang oil.
12. Poland: Abies alba oil, caraway oil and Coriander oil.	**38. El Salvador:** Peru balsam

13. Portugal: Eucalyptus, Lavender oil, Rosemary oil, Thyme oil and Laurel leaf oil.	**39. Guatemala:** Cardamom oil, Lemongrass oil, Palmarosa oil and Vetiver oil
14. Romania: Abies alba oil, Coriander oil and Spearmint oil.	**40. Haiti:** Amyris oil, Bitter orange oil, Lime oil and Vetiver oil.
15. Former USSR: Bergamot oil, Birch Tar oil, Calamus oil, Caraway oil, Clary sage oil, Coriander oil, Dill seed oil, Sweet fennel oil, Laurel leaf oil, Lavender oil, Lemongrass oil, Rose oil, Rosemary oil, Spearmint oil, Petitgrain oil, Star anise oil, Tangerine oil and Siberian fir oil.	**41. Honduras:** Styrax oil.
16: Turkey: Galbanum oil, Laurel leaf oil, Styrax oil, Jasmine concrete and absolute and Rose oil.	**42. Jamaica:** Allspice oil, Lime oil, Pimento berry oil, Pimento leaf oil and Vanilla resinoid

Map Key (Continued)

17. Former Yugoslavia: Abies alba oil and Coriander oil.	**43. India:** Ajowan oil, Ambrette seed oil, Angelica root oil, Anise seed oil, Artemisia oil, Calamus oil, Caraway oil, Cardamom oil, Cedarwood oil, Celery seed oil, Cinnamon Bark oil, Citronella oil, Clary sage oil, Coriander oil, Cornmint oil, Cumin oil, Davana oil, Eucalyptus oil, Frangipanni absolute, Geranium oil, Ginger oil, Lemongrass oil, Nutmeg oil, Palmarosa oil, Patchouli oil, Pepper oil, Rose oil, Sandalwood, Vetiver oil and Tuberose absolute.
18. Israel: Basil oil, Grapefruit oil, Orange oil, Tarragon oil and Thyme oil.	**44. Sri Lanka:** Cardamom oil, Cinnamon bark oil, Cinnamon leaf oil, Citronella oil, Clove bud oil and Clove leaf oil.
19: Egypt: Anise seed oil, Basil oil, Caraway oil, Celery seed oil, Blue chamomile oil, Coriander oil, Cumin oil, Dill seed oil, Bitter fennel oil, Geranium oil, Marjoram oil, Neroli oil, Tagetes oil, Rose oil, Tuberose absolute, Jasmin concrete and absolute.	**45. Indonesia**: Basil oil, Cajuput oil, Cananga oil, Cassia oil, Citronella oil, Clove bud oil, Clove leaf oil, Gurjun balsam, Nutmeg oil, Palmarosa oil, Patchouli oil, Sandalwood oil, Vetivert oil and Vanilla resinoid.
20: Ethiopia: Myrrh oil.	**46. Thailand:** Cornmint oil, Gurjun balsam
21. Iran: Caraway oil, Galbanum oil.	**47. Vietnam:** Cassia oil, Citronella oil, Star anise oil
22. Morocco: Anise seed oil, Armoise oil, Artemisia oil, Basil oil, Caraway oil, Carrot seed oil, Cederwood oil, Chamomile oil, Clary sage oil, Coriander oil, Bitter fennel oil, Geranium oil, Hyssop oil, Lavandin oil, Marjoram oil, Neroli oil, Pennyroyal oil, Petitgrain oil, Rosemary oil, Tarragon oil, Thyme oil, Broom absolute, Orange flower absolute, Tuberose absolute, Rose oil and Jasmin concrete and	**48. China:** Ambrette seed oil, Artemisia oil, Camphor oil, Cassia oil, Cedarwood oil, Celery seed oil, Chempaka concrete, Cornmint oil, Eucalyptus oil, Bitter fennel oil, Geranium oil, Ginger oil, Ho leaf oil, Lavender oil, Lemongrass oil, Lime oil, Lisea cubeba oil, Mandarin oil, Patchouli oil, Sassafras oil, Siberian pine needle oil, spearmint oil, Star Anise oil, Valerian oil, Vetiver oil and Jasmin concrete and absolute.

absolute.	
23: Tunisia: Anise seed oil, Armoise oil and Rosemary oil	**49. Taiwan:** Camphor oil, Cassia oil, Cornmint oil and Citronella oil.
24: Somalia: Myrrh oil.	**50. North Korea:** Calamus oil
25: Tanzania: Clove stem oil, and Clove leaf oil.	**51. Australia:** Eucalyptus oil, Sweet fennel oil, Boronia absolute, Lavender oil, Lemon oil, Peppermint oil, Tea tree oil and Blackcurrant Absolute.
26: Reunion: Cananga oil, Geranium oil and Ylang Ylang oil.	

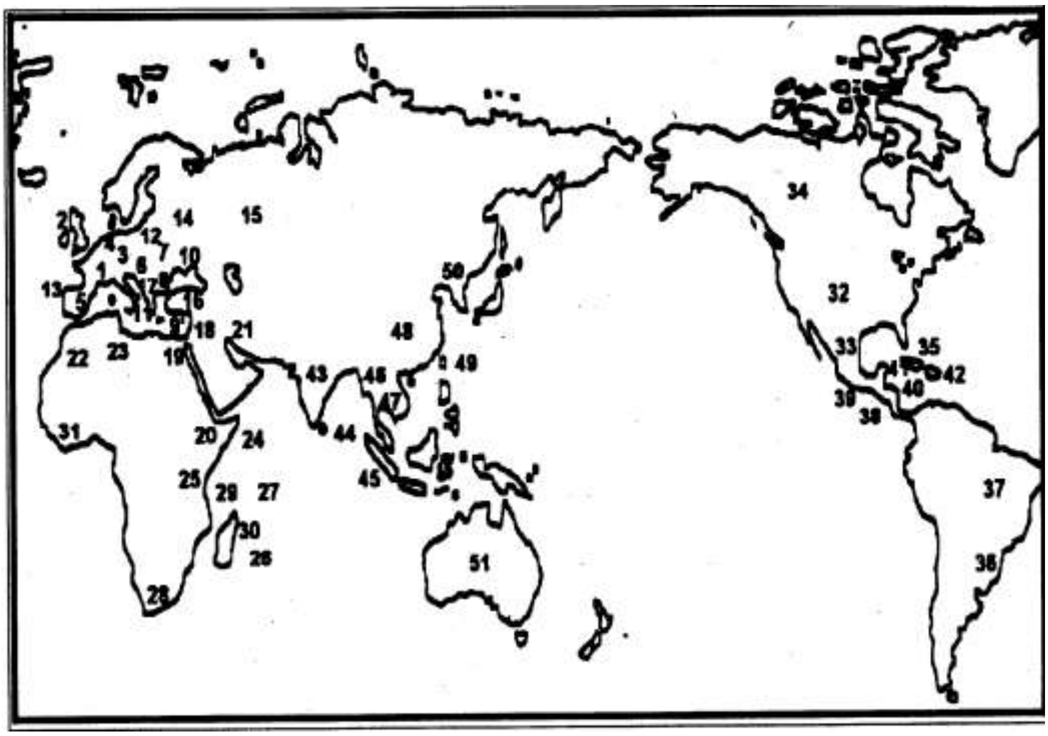

Figure 2.4. The World Geographic Distribution of Essential Oil Production.

The small holder sector has survived because; a) the cultivation of many essential oils is not profitable in industrialised countries, b) full mechanisation is not possible and c) cultivation of some plant species is only possible for a few months each year [13]. This sub-sector operates mainly at a subsistence level, where multi-cropping is usually practised. Barriers to entry and exit are usually low, so small holders select those crops providing maximum income, thus price and income expectations are the prime determinant of what they will grow. One consequence of small holder ease of entry and exit of production is vast fluctuation in supply from year to year.

Local Collectors

Essential oils produced from wild collection and small holder production often occurs in remote locations, where individuals produce small quantities, too small to sell on the open market. Local collectors travel the countryside, purchasing oil from small holders for cash. This assists the small holder convert the oil to cash quickly. The collector bulks various purchases to commercial consignment size and sells the consignment onto an exporter who purchases oil from a number of collectors based in different regions in the country. Plantation producers also purchase from collectors to supplement production to meet forward contracts or demand expectations. Sometimes there may be a chain of collectors. Essential oils produced and traded via this method include patchouli, vetiver and citronella [14].

PLANTATION PRODUCTION OF ESSENTIAL OILS

Plantation cultivation of essential oils is widespread throughout the World. Many plantations traditionally developed through family ownership and have been in existence for generations, while others have been established by Governments and public estate companies. Two types of essential oil plantations exist, a) those which have employed extensive mechanised practices and b) those that rely on low cost labour. Mechanised plantations are suitable for wide acreage, high demand and low to medium value essential oil crops with high barriers to entry and exit. Labour intensive plantations are suitable where it is difficult to develop automated systems to harvest, such as the vanilla industry in Indonesia, and the rose oil industry in Turkey and Bulgaria, and labour supply is plentiful and relatively inexpensive.

Extensive and highly mechanised plantations still dominate the production of major essential oils in industrialised countries. These industries originated from pioneers within the community, who saw favourable climatic conditions in the areas they lived. The established industry has over the years been able to remain competitive through high mechanisation and the development of improved varieties, eg., the US mint and French lavandin industries. Over time, some of these industries have come under threat from producers in other regions of the World. New emerging producers have been able to develop competitive advantage through crop mechanisation and production system development. Low cost labour as a source of competitive advantage is questionable today as many developing countries are experiencing high rates of rural/urban migration. Many alternative demands for land and labour exist, like the construction industry [15]. Many medium and large plantation companies have found economic viability very difficult over the last few decades and have been forced to diversify their businesses through a number of strategies, which will be discussed in more detail later in this book.

The production of other natural extracts like concretes and absolutes is restricted to companies with large capital and technical capabilities, and supported with a research framework, such as a university committed with R&D. Production is usually undertaken via the plantation system or through contract farming to small holders. An organisation model of Essential Oils of Tasmania's production system for boronia absolute is shown in Figure 2.5.

BY-PRODUCT PRODUCTION OF ESSENTIAL OILS

A number of essential oils are produced as by-products of other industries. These include citrus oils from the citrus industries in Brazil, Florida and Italy, eucalyptus oils from Paraguay, Spain and China, and pine and cedar oils from the US and China. The production of many natural products is only economically viable when produced as a by-product. The majority of production in this sector is thus left to companies outside the flavour and fragrance industry with other core business interests. Figure 2.6. illustrates the processes and products produced by the citrus industry.

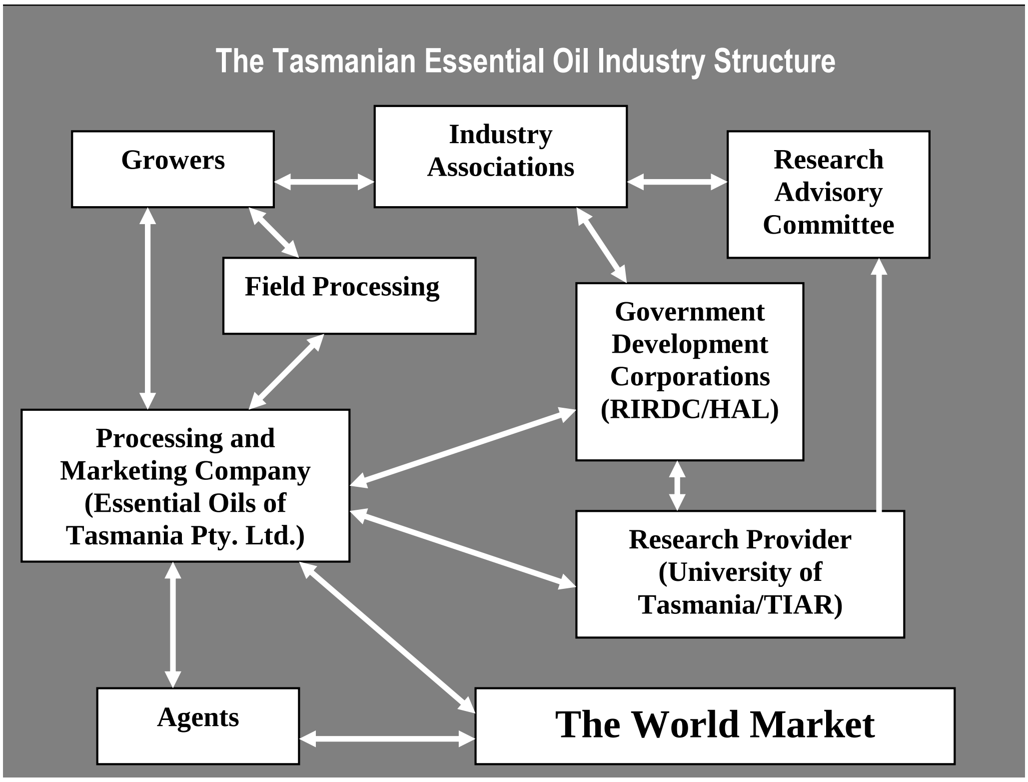

Figure 2.5. Tasmania's Essential Oil Industry Structure.

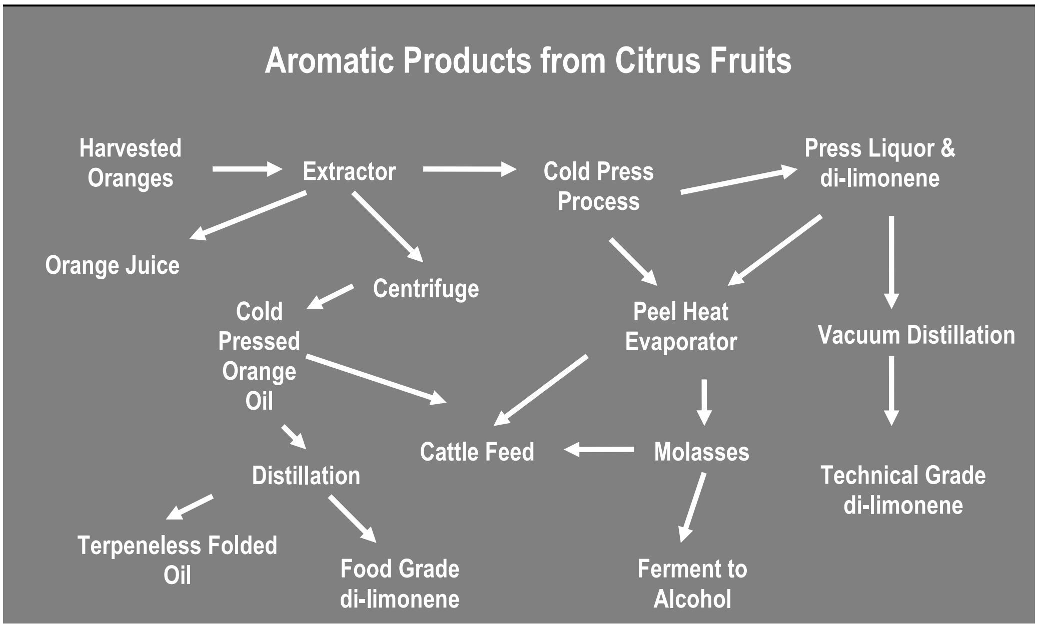

Figure 2.6. Aromatic Products Produced from Citrus (Orange).

To some extent the geographical pattern of essential oil production is reflected through the historical evolution of the industry since the beginning of the 20th Century. Many traditional regions of production are in industrialised countries where pressure from rising labour costs has made production uncompetitive. Essential oil production is slowly being relocated from traditional areas of cultivation to new geographic regions, primarily in developing countries. However hindering this is the lack of research infrastructure [16], political instability [17], the capacity to invest [18], and other structural problems [19]. Countries with large domestic markets *i.e., China and India,* and a long term commitment to research are the ones in the best position to develop new essential oil industries. Government support in other developing countries to facilitate this transformation will be important. Table 2.2. shows countries undertaking essential oil production between the 1980 and 2000.

The development of more efficient technology has been the focus of essential oil research in industrial countries. The development of higher yielding cultivars, improvements in field mechanisation, and new applications for the product and/or its derivatives is seen as a way for industries to maintain competitive advantage [20]. However this has not guaranteed industry survival. For example, the Australian tea tree industry invested very heavily in the two above areas, only for the industry to collapse and China become the major producer of tea tree oil [21]. Figure 2.7. shows tea tree oil production in both Australia and China over the last 5 years.

Essential oil production is emerging as a modern farming enterprise where production costs are minimised by developing specific and efficient propagation, planting, maintenance, harvesting and extraction technologies. Harvest yields are being increased through cloning, index selection trials, somaclonal variation and mutagenesis, specific nutrient delivery regimes in the field and improved extraction systems based on years of observation and trial and error. Growing concern about toxic chemical residues in natural materials, undesirable in both flavour and fragrance materials is increasing the pressure to reduce residual solvent traces through use of alternative solvents like CO_2 and fluorocarbon extraction. Plantations are looking toward organic and integrated farm management and developing zero waste sustainable farming techniques. Plantations are also looking to diversify their activities in the areas of by-product production from waste materials [22], vertical integration into specialized end products [23], agro-tourism [24] and even becoming traders.

Table 2.2. Countries undertaking new essential oil production between 1980 and 2000

Country	**1980s**	**2000**
Tea Tree Oil	Australia	China, South Africa, Kenya, Cambodia, Vietnam, Malaysia, Haiti
Coriander Oil	Former USSR, Egypt, India	Bulgaria, Canada, Morocco, Netherlands, Poland, Romania, South Africa, UK and US.
Spearmint Oil	US, China and India	Argentina, Australia, Brazil, Bulgaria, Egypt, France, Hungary, Japan, Korea, Morocco, New Zealand, Paraguay, Romania, Russia, Taiwan, UK.
Peppermint Oil	US, China and India	Australia, New Zealand, Italy

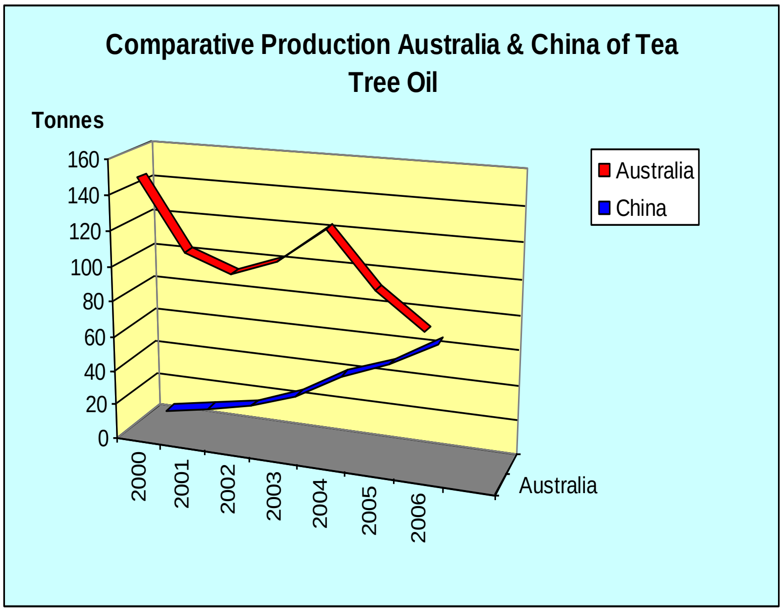

Figure 2.7. Tea Tree Oil Production in Australia and China between 2000 and 2006.

World essential oil supply could come under pressure as subsistence and small holders switch to the more lucrative production of food crops, as world population continues to increase [25] and more plants are declared endangered species. Increasing European Union regulation through bodies like REACH and the SCCP may further restrict essential oil use in the European market. It is difficult for subsistence and small holder farmers who produce a number of widely used essential oils to group together, organize and fund the dossiers required by the European authorities. Barriers to entry and exit for large producers in this sub-sector will remain high due to capital and technology requirements.

The major threat to the essential oil and natural product growth is the continued development of synthetic aroma chemicals. Since the advent of very sophisticated and sensitive analytical techniques, aroma chemical and specialty product manufacturers have been able to isolate molecules from essential oils and synthesize these compounds. The discovery of new aroma compounds is more likely to lead to synthesis rather than cultivation.

The use of essential oils in fragrance compounds no longer has its place of dominance, especially in the lower cost functional compound market. As technical requirements for these products increase, the use of natural materials in fragrances will become even more limited. Synthetic compounds now make up about 86-95% of fragrance compounds [26]. The poor supply record of many high priced floral oils in the past has encouraged essential oil users to rely more heavily upon reconstitutions of essential oils. As better and more cost effective reconstitutions are developed in the future, the use of many individual essential oils may decline.

Nevertheless it is expected that demand for essential oils will continue to increase over the long-term. Natural World economic growth will lead to increasing demand, particularly in the flavour area. On the supply side, more producers will be attracted into this sub-sector, with strategies framed around taking advantage of changing channels of distribution. More producer-end user collaboration and trade will be expected. This may improve price stability to some degree, through the greater use of long term supply contracts. However the overall bargaining power of producers in this sub-sector will remain low.

PRODUCE BROKERS AND AGENTS

Produce brokers and agents act for producers. A broker or agent may have several non-competing principals (producers) for whom they act, either on an exclusive or non-exclusive basis. A producer may have one or more brokers or agents acting on their behalf selling to different regions or industries. The function of a broker or agent is to find buyers for the products offered by the principals. The broker or agent usually acts on a commission basis and does not handle the goods or keep stocks. Goods are usually sold on a contractual basis, to be shipped after harvest. Brokers and agents are particularly important in the higher volume essential oils like mint and citrus oils to the confectionary industry. The brokerage method is also used by some Chinese producers, as this method seems to be compatible with the Chinese business culture, where manufacturers' representatives have been traditionally employed for sales.

RESEARCH INSTITUTIONS AND UNIVERSITIES

Most essential oil producing countries are supported with essential oil and natural product research through universities and other agricultural based research institutions. The types of research being undertaken include the analysis of chemical constituents of essential oils from plants not previously investigated, the analysis of plants indigenous to a region, chemo type identification, field trials and experiments to increase yields of essential oil bearing plants, the development of new isolation and extraction techniques, standardisation, the improvement of propagation and agronomic methods and practices and bio-transformation research.

The relationship between essential oil producers and research institutions in each country is varied. For example in Tasmania, Australia, the University of Tasmania played a catalytic role in developing the essential oil industry in the state. In South-East Asia, some countries have dedicated Institutes like the Indonesian Medicinal and Aromatic Crop Research Institute in Bogor [27], Indonesia and the National Institute of Medicinal Materials, in Hanoi [28], Vietnam, to carry out essential oil research. In countries like Malaysia, Thailand and the Philippines, research is decentralised around a number of universities and agricultural research institutes. Generally, research institutions in South-East Asia rarely collaborate directly with producers.

Over the last few decades funding for essential oil research for aromatic application has dwindled in favour of research into phyto-biotechnology for medicinal applications. Aroma application research has been left to flavour and fragrance companies themselves which have tended to invest into research on synthetic compounds and developing specialties. Advances have been made in extraction methods of natural materials to create finer olfactory and flavour profiles. The Asian region is also hampered by lack of up to date equipment, expertise and method knowledge to operate them effectively. There is also a World Wide shortage of botanists [29], which has increased the difficulty of identifying new plant species. Generally, agriculture as a profession in many countries has lost popularity [30]. Experienced people are retiring and current farmers lack skills, particularly in the fast growing South-East Asian countries.

GOVERNMENTS

Government involvement in the flavour and fragrance industry is diverse and wide ranging. Governments set national development priorities, regulate trade and set tariffs. These activities directly influence trade and production. Governments regulate chemical substances in the production of end products through their respective regulatory authorities. Governments determine policy for the environment, and assign costs to resource, as is the case with water levies in Australia [31]. Government interventions directly influence the viability of primary industries within national boundaries. Governments fund or partly fund research institutes and universities engaged in essential oil and natural product research, which act as incentive or disincentive to the field. Governments through their respective departments of agriculture act as a facilitator and advisor to growers through extension activities.

PRODUCERS OF ANIMAL EXTRACTS

Four animal secretions have been used in perfumery, castoreum from the Siberian and Canadian beavers, civet from civet cats, ambergris from the throat of the sperm whale, and musk from the musk deer.

The beaver has for many years received legal protection in Canada and Russia. Production is restricted to farms where the oil glands of the animals are removed and dried to form castoreum. Most fragrances now use synthetic equivalents [32]. Civet is available from cats held in captivity in Africa, China, Vietnam and India [33]. However most are on the IUCN red list of critically endangered civet species. Ambergris is formed in the throat of the sperm whale and with very limited legal whaling allowed; it has become almost totally replaced with synthetic substitutes. The availability of natural ambergris is limited to finds washed up on beaches amongst tidal debris. However there are documented reports that as much as 96% of the continuing ambergris trade is sourced from slaughtered sperm whales [34]. The sperm whale is protected under CITES appendix I, but this does not prevent trade in products from it. Musk is one of the perfumery materials produced in Afghanistan, Bhutan, China, India, Myanmar, Nepal and Pakistan and Tibet [35], with the majority of production originating from China for Traditional Chinese Medicine (TCM) usage [36]. Most of the trade is illegal, where pods are exported through Hong Kong, the centre of the musk trade. Most perfumery compositions over the last twenty years have been reformulated with synthetic equivalents. The use of animal ingredients in perfumery has over recent times come under much scrutiny and criticism by consumer groups [37].

ESSENTIAL OIL PRODUCER ASSOCIATIONS

Most essential oil producing countries have producer associations. Generally the aim of a producer association includes the promotion and encouragement of the advancement of natural product science, promotion of opportunities to exchange information and knowledge and to impart training to improve the present state of production techniques with a view to product standardization within international requirements [38]. Producer associations usually take a strong stand on product standards and act as a vehicle for dialogue with Governments and other bodies on an industry to industry basis. Some associations conduct education, training, hold conferences and publish journals. Following a few scandals involving the trade of essential oils in the 1970s, a number of national associations formed with the aim of improving the reputation of the industries in their own respective countries. There is no official World peak body, but the International Federation of Essential Oils and Aroma Trades (IFEAT) was set up in 1977 to represent all aspects of the essential oil industry [39]. IFEAT has not been without criticism seen by some to represent the traders' interests above other groups, especially small holder farmers.

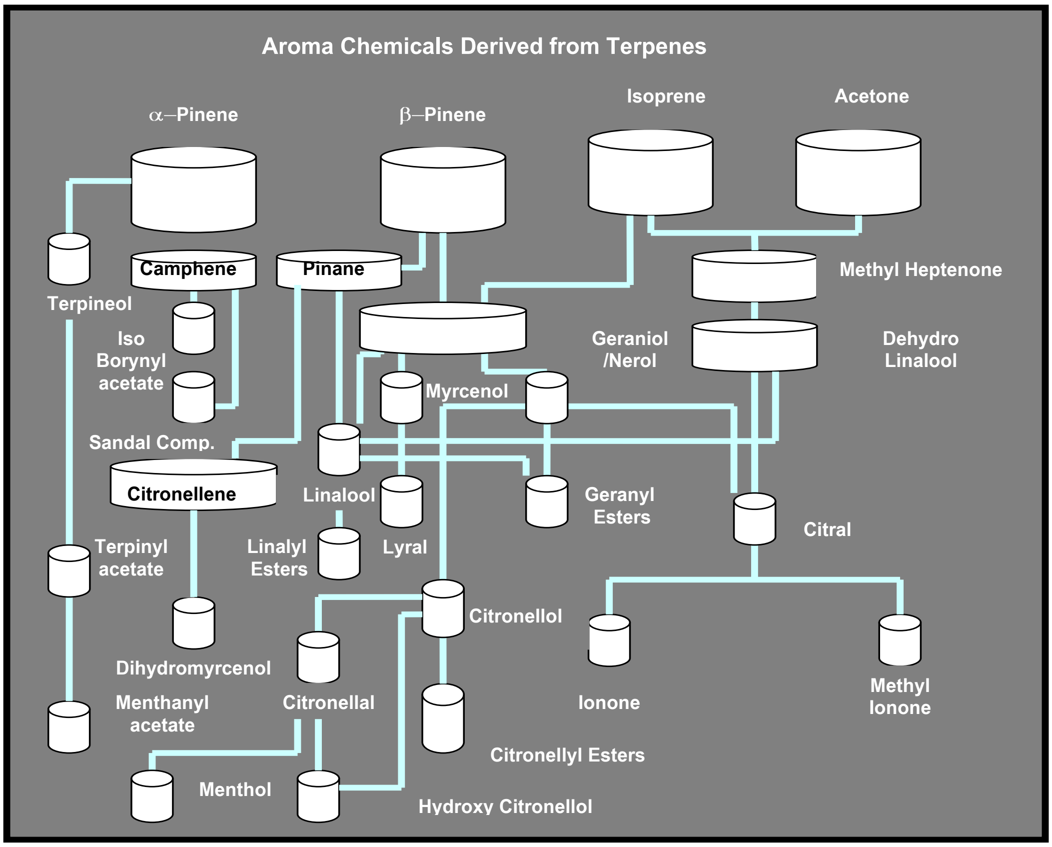

Figure 2.8. Aroma Chemicals Derived from Terpenes.

CHEMICAL FEED-STOCK MANUFACTURERS

As aroma chemicals comprise the major ingredients of flavours and fragrances, the following section will give a brief outline of this industry sub-sector.

Chemical feed-stocks used by the flavour and fragrance industry are mostly sourced from the petroleum industry and used as starting materials for synthesis into aroma chemicals. The major basic feed-stocks required for aroma chemical manufacturing include *alpha* and *beta* pinene, isoprene, isobutene, acetylene, toluene, naphthalene, benzene, cresols, cyclopentene and phenol. These materials are produced by companies that are themselves not part of the flavour and fragrance industry. The manufacture of these materials was once concentrated in the US and Europe, but now China and India have become major producers. Figures 2.8. to 2.14. illustrates the hierarchy of aroma chemical production from the major source materials.

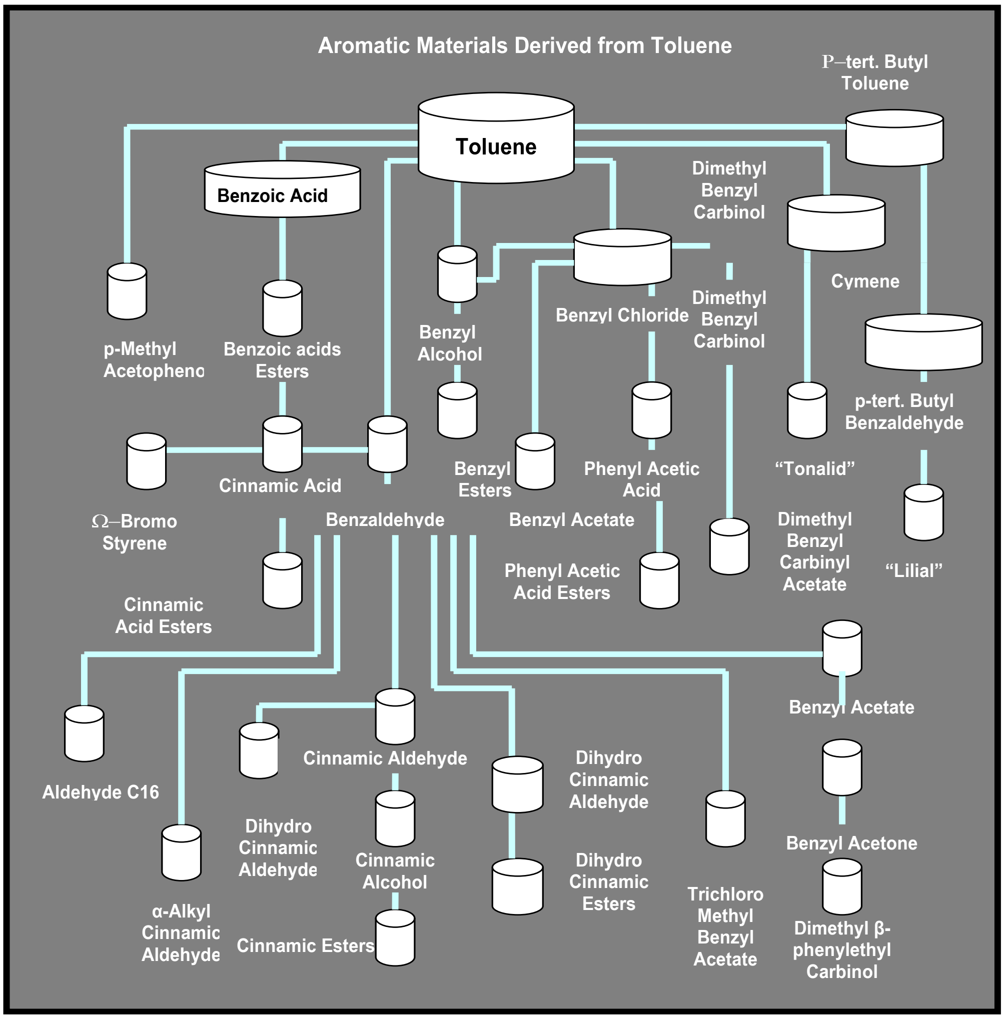

Figure 2.9. Aroma Chemicals Derived from Toluenes.

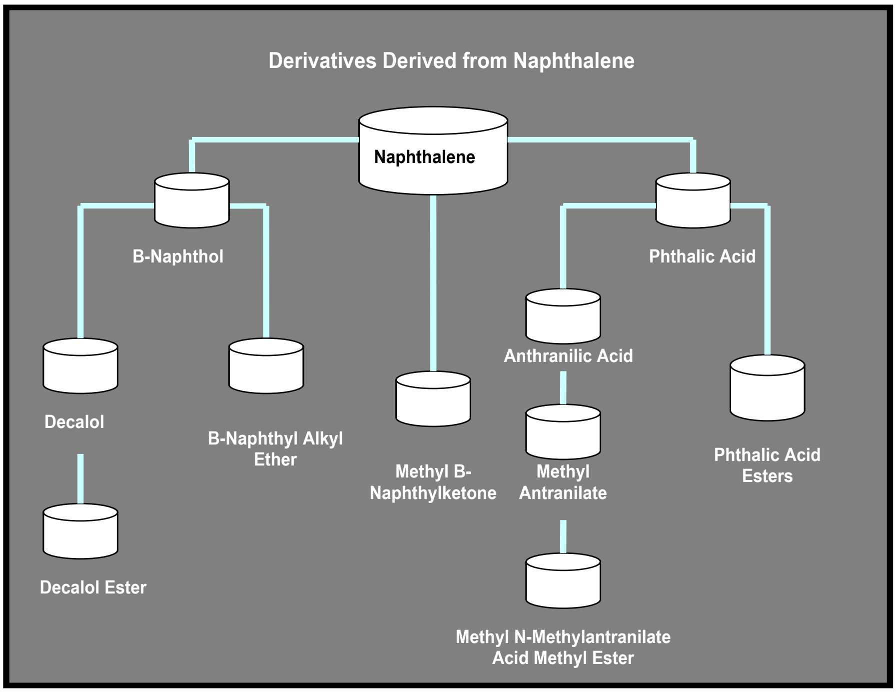

Figure 2.10. Aroma Chemicals Derived from Naphthalene.

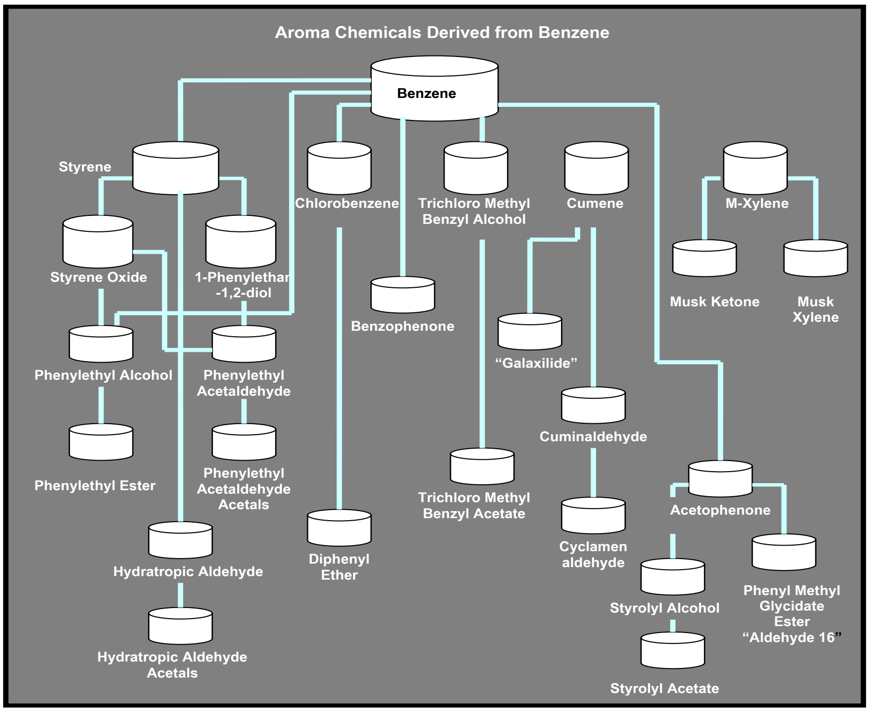

Figure 2.11. Aroma Chemicals Derived from Benzene.

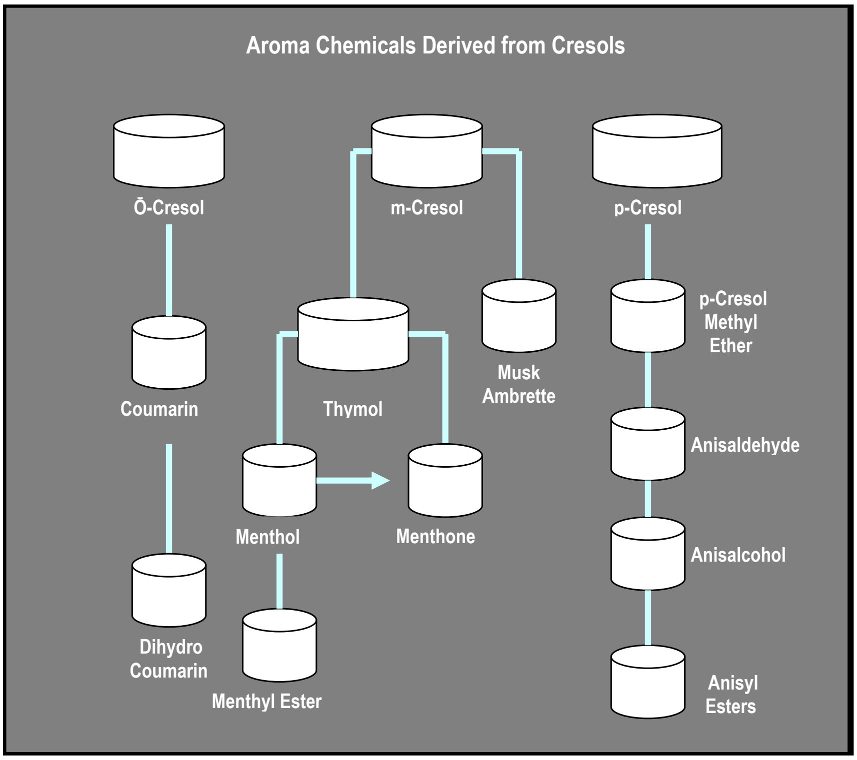

Figure 2.12. Aroma Chemicals Derived from Cresol.

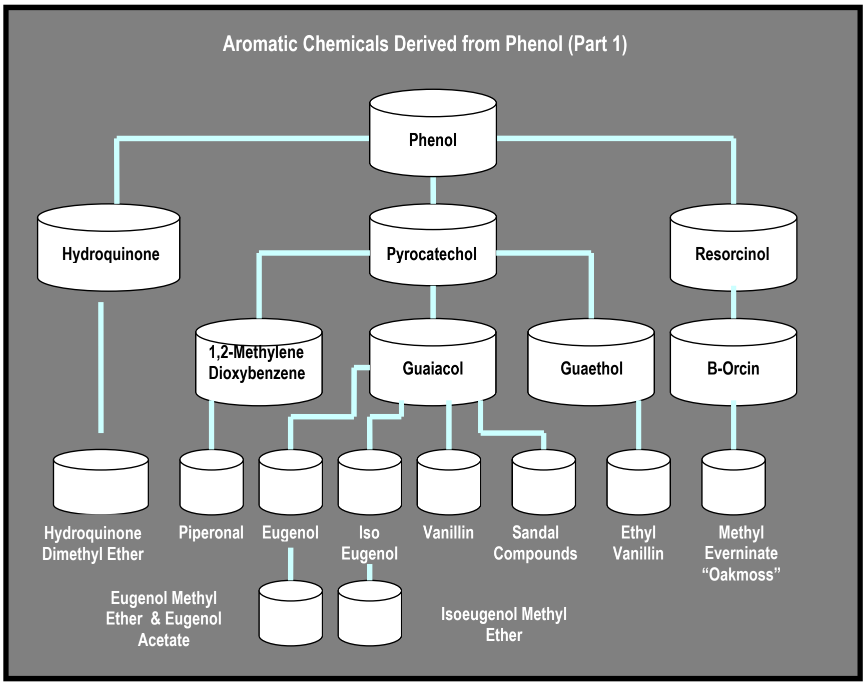

Figure 2.13. Aroma Chemicals Derived from Phenol (Part1).

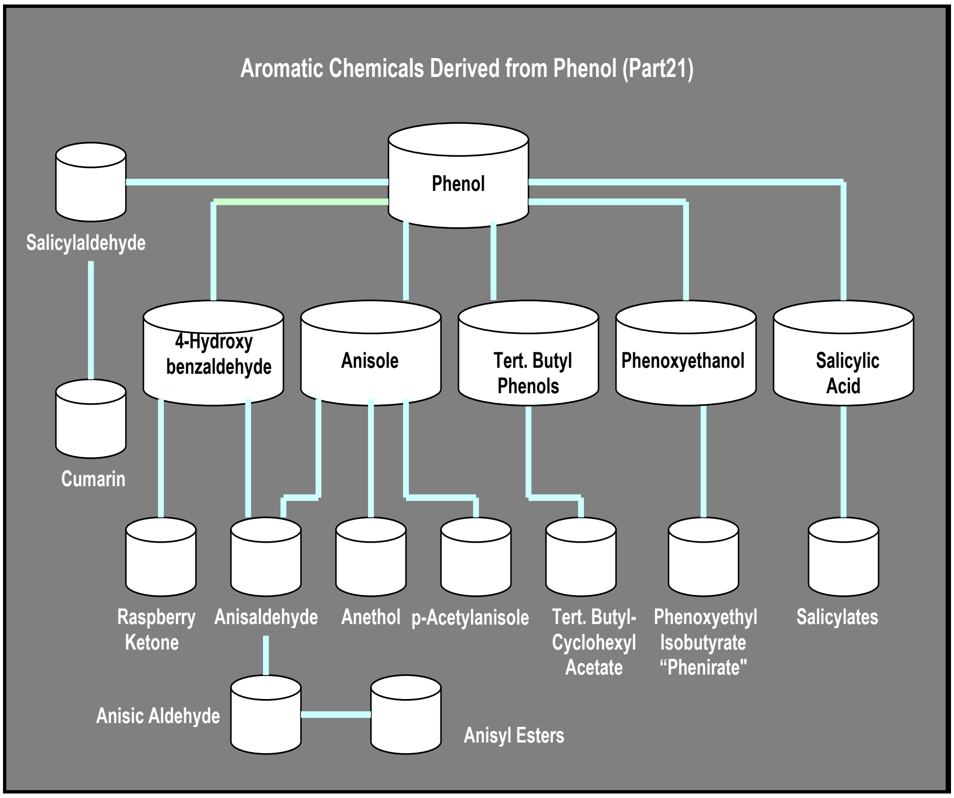

Figure 2.14. Aroma Chemicals Derived from Phenol (Part2).

AROMA CHEMICAL MANUFACTURERS

Aroma chemicals are a group of chemically defined substances that are used as raw materials in the compounding of flavour and fragrance compositions. They may be based on either synthetic or natural materials.

A long list of alcohols, aldehydes, esters, ketones, lactones and phenols, etc., can be synthesized from the basic materials produced by the chemical feed-stock industry, as can be

seen in figures 2.8. to 2.14. previously. Aroma chemical manufacturers usually produce a range of different materials. In some cases over ten materials can be manufactured through the chain of intermediate processes. Synthetic aroma chemicals can be duplicates of chemical structures found in nature, although the isomers may be different. Alternatively they are substances that have no relationship with naturally found materials. Natural isolates are removed by physical processes, *i.e., distillation, fractionation, or by salt formation*. Those isolates can be further modified through the use of biotechnological processes like fermentation, etc.

Many large companies are involved in the manufacture of aroma chemicals, but tend to concentrate their interest on a small number of materials that have some synergy with group operations. Flavour and fragrance houses also undertake the manufacture of these materials but over recent years have focused more on higher value specialty chemicals, due to the commoditisation of aroma chemicals. The flavour and fragrance industry has benefited from parallel research in other industries, such as in the case of the development of polycyclic musks [40].

SPECIALTY FINE/AROMA CHEMICAL MANUFACTURERS

A fragrance compound is made up of essential oils, modified and/or rectified essential oils, isolates, resins, concretes and absolutes, aroma chemicals, and specialty fine chemicals. The concept of a specialty can also include patented aroma chemicals, which provide alternatives and/or replacements for scarce and rare materials like musk. Other specialties include concentrate bases or accords developed by a perfumer, and raw materials that have been synthesized in some way. Some essential oils produced by methods providing high quality olfactory characteristics *(i.e., CO_2 extraction)*, can also be classified as specialties.

In the early 1980s, companies producing specialties tend to be small to medium sized manufacturers specializing in a particular niche market, too small to be of interest to larger companies. However, many of these over the last decade have been taken over by the larger flavour and fragrance houses. Most concentrates and accords originate from flavour and fragrance houses. Patented aroma chemicals may originate from any of the above, including aroma chemical manufacturers. Specialties are usually only available from a single company under a trade name. Some specialties remain captive *(i.e., kept for exclusive use)* by flavour and fragrance houses for a number of years before they are released to the rest of the industry.

Inspiration for specialties can come either from nature or as the result of a designer made molecule with some sort of intensive olfactory characteristic. Compounds based on the modeling of molecules of natural origin are usually the result in the identification of a compound within a natural aromatic material that in traces, and has a significant influence on the total odour profile of a fragrance. However where isolation of these materials from the natural material is not economically feasible, because it only exists in trace amounts, synthesis is the only viable method of production. An example of this is Ambrettolide (cyclohexadecen-7-olide), a constituent of ambrette seed oil in only trace amounts. This material has exalting properties when used in fragrances, and as a synthetic material is extremely economic to use. Figure 2.15. shows the compound form. Designer molecules maybe inspired by nature and modified for stability and ease of synthesis or enhancement of performance. An example of this is hedione (Methyl dihydrojasmonate) patented and produced by Firmenich, which has powerful lifting characteristics within floral fragrance types (see Figure 2.15.). Because of their tenacity and novelty, these specialty materials have become one of the cornerstones of modern perfumery and have become used in larger doses in fragrance compositions, taking perfumery away from traditional concepts of balance towards compositions where these specialties gave them a leading individual character, with dramatic effects [41].

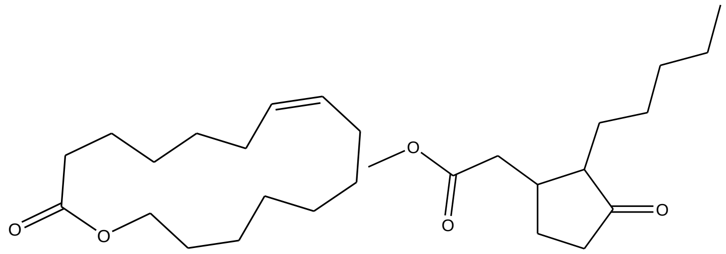

Figure 2.15. Ambrettolide Molecule (Nature identical) and Hedione (A "designer" molecule) *Registered Trademark of Firmenich.*

Effluent disposal regulations have increased the cost of production of many aroma chemicals and to some degree have pushed production to developing countries like China and India. Increasing environmental regulation has forced aroma chemical manufacturers to seek more cost effective and environmentally responsible routes in the synthesis and manufacture of aroma chemicals. Increasing stringency and surveillance of toxicity levels in aroma chemicals has placed the future of some in question [42]. The number of new aroma chemicals developed in recent years has declined, due to the high costs of toxicity screening and safety validation.

Trader/Exporter

The trader/exporter is usually domiciled in essential oil producing countries. The trader/exporter purchases essential oils from domestic producers usually through a chain of collectors. The trader/exporter undertakes quality assurance and bulks essential oil consignments before they are sent for final shipment to overseas customers. Trader/exporters may also engage in some value added activities like the isolation of aroma chemicals from crude essential oils, as is with the fractionation of eugenol from clove oil in Indonesia.

International Trader

International traders are commercial houses that generally trade in aromatic materials. They are mainly located in the major consuming markets. Most traders are importers from overseas shippers. They are either an agent for an essential oil producer or purchase on the open market. International traders carry large inventories, sell to domestic and overseas customers, re-export to overseas customers and also trade with other traders. International traders break consignments down into smaller packs for domestic sales. Some traders also import certain unprocessed plant material and distil essential oils on their own site (eg., patchouli). The bulk of the World international trade in essential oils is handled by international traders, rather than through direct purchases by users from producers. This is because producers and end users are remote from each other and lack information that enables direct connections, and most often purchase quantities are too small to warrant direct trade with end users.

The primary function of international traders is to smooth out the peaks and troughs in the markets for the materials in which they deal. This helps to minimize the drastic price swings and maintain price stability by keeping supply and demand in balance. International traders carry out quality assurance and standardization of products, through filtering and blending consignments when required to assure minimum quality specifications.

Some commentators argue that traders distort the market to their advantage by using their power over the market [43]. The relative bargaining power of producers is weak, as there are too many growers for any one to have significant bargaining power over international traders [44]. It is also argued that international traders must take responsibility for price fluctuation in the market because their position provides them with unique information about supply and demand trends [45]. Moreover international traders have been further criticized for their reluctance to divulge substantial information to producers about essential oils markets [46]. More recently traders have been attacked on their inaction to assist producers make representations to REACH on new directives concerning some essential oils [48] (see chapter seven).

The future role of traders will depend upon individual company abilities to adapt to the changing geographical balance of the flavour and fragrance industry. A greater proportion of essential oil and aroma chemical markets will be in Asia with new producers and new users. Survival will depend upon how well they service these clientele and compete against new competitors originating from the Asian region itself. The concentration of traders should slightly diminish, as new traders service developing markets. Many traders are vertically diversifying into value added specialist production of essential oil isolates and aroma chemicals. Some are even developing their own flavour and fragrance houses aiming at small to medium manufacturers that large flavour and fragrance houses do not focus upon.

FLAVOUR AND FRAGRANCE HOUSES

Flavour and fragrance houses early last century were family owned artisan based enterprises and served customers in national markets. Today most large and medium flavour and fragrance houses serve the entire globe with product development, manufacturing and sales organizations in multiple locations. This rapid growth from nationalism to internationalism was encouraged by the expansion and concentration of end product manufacturers through merger and acquisition.

The prime profit making activity of a flavour and fragrance house is the development and compounding of flavours and fragrances for manufacturers of end products. Flavour and fragrance compounds are specific formulations composed of both natural and synthetic aroma materials developed for the specific needs of an individual customer. Custom flavour and fragrance compounds are a key factor in the success of any product and not easily interchangeable with other fragrances or flavours, once the product has been launched and consumers associate the product with the flavour or fragrance.

Demand for flavours and fragrances are dependent upon the production and sale of consumer, industrial and institutional products manufactured by end-product manufacturers. Flavour and fragrance houses have relatively few but large customers. In many cases the international turnover of individual customers is larger than the whole flavour and fragrance industry. Figure 2.16. shows the relative sizes of markets flavour and fragrance houses serve.

There are three basic types of flavour and fragrance houses, transnational, large independent houses, and small to medium size independent houses. Transnational flavour and fragrance houses are usually owned by another entity in the chemical industry, however many have become listed companies in their own right. Large independent houses usually operate across a region and small to medium houses usually serve a single market or region. The majority of flavour and fragrance houses have branches or agents in a number of countries, often with regional based production facilities. The smaller independent houses have generally been passed down from generation to generation or established by former employees of the larger houses.

Flavour and fragrance houses carry inventories of up to 3,000 raw materials, purchased from all parts of the World. Raw materials are either purchased directly from manufacturers and producers or through traders, agents and brokers, depending upon the strategic importance of the material and volume required. Large inventories are required due to the necessity to hold many grades of each material and the need to purchase some materials (essential oils) on a seasonal basis. The production of flavour and fragrance compounds are usually made to customer order and manufactured on a batch basis because of the high value, low volume and exclusive nature of each product to an individual customer. Production schedules are usually short term and must be flexible enough to respond to customer demand.

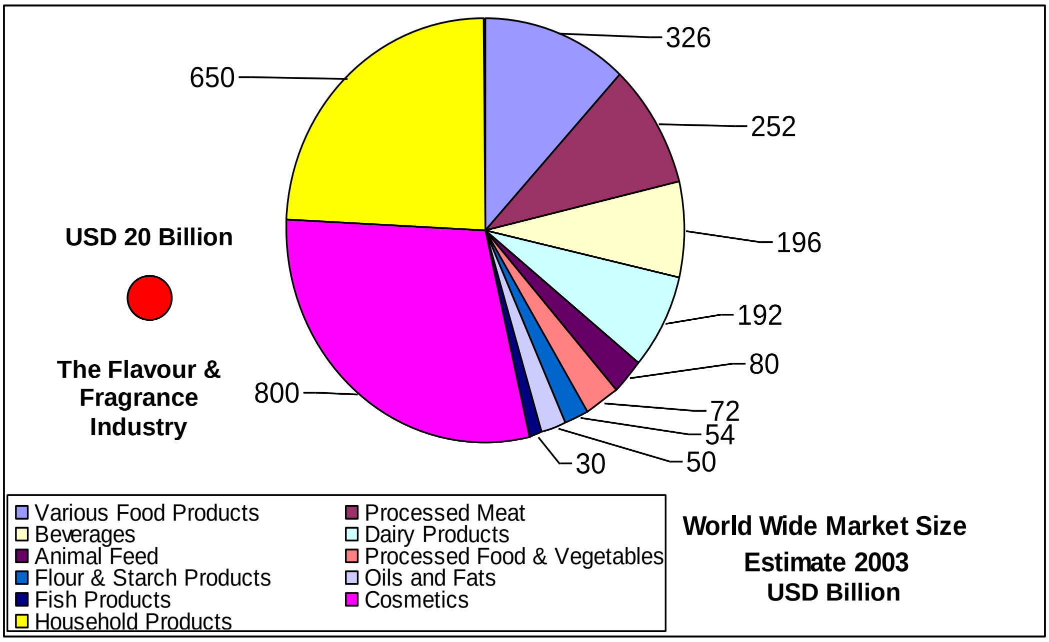

Figure 2.16. The Relative Size of the Flavour & Fragrance Industry with Industries its Serves.

All large and medium sized flavour and fragrance houses are active in both flavour and fragrance compound markets. However flavour and fragrances are completely different markets and businesses. Production facilities for flavours and fragrances require separate storage, compounding and filling facilities. Also flavour production has more stringent regulatory requirements.

The larger fragrance and flavour houses invest between 5.0-8.5% of net sales into research and development. The maintenance of effective product development capabilities is essential to long term success. Developing flavour and fragrance compounds requires both an artistic and technical approach to product development. Applications development by perfumers, flavourists, cosmetic chemists, surfactant chemists and food technologists is important in creating flavour and fragrance compounds in response to customer requests. Flavours and fragrances are manufactured according to end user product manufacturers' specific requirements. These requirements will take into consideration consumer tastes and trends when creating a theme. The flavours and fragrances must also be produced within the constraints of end-product technical requirements and regulatory considerations. Flavour and fragrance houses build application capabilities in specific customer product areas and conduct market research into consumer markets through panel and product testing. In most cases they become partners with end-product manufacturers in the new product development process.

Raw material research undertaken by flavour and fragrance houses includes, the analysis of natural materials to identify new aroma chemicals with novel organoleptic qualities and greater tenacity, searching for more cost effective ways to synthesize existing aroma chemicals, the evaluation of health, safety and toxicity issues in relation to raw materials and manufacturing processes, the improvement of product applications ability and the building of corporate image by presenting papers at conferences and in journal articles. Achieving breakthroughs in technology is a key strategy for a flavour and fragrance house to maintain competitive advantage and a creative edge in the industry.

Over the last couple of decades flavour and fragrance houses have expanded their product ranges to include dyes, natural botanical extracts, odour agents, preservatives, cosmetic and food ingredients and UV absorbers. Some flavour and fragrance houses are vertically diversified into aroma and specialty chemical and fruit juice and pulp production. Very few flavour and fragrance houses are currently directly involved in essential oil production, although there are a number of strategic alliances and close working relationships.

The aggregate Worldwide sales of flavour and fragrance compounds is difficult to determine because of the non-reporting of sales turnover by many private companies, the questionable accuracy of data in markets like India and China, the captive production of flavour and fragrance compounds by some end-product manufacturers and currency distortions. A reasonable estimate would be USD 20 Billion. Sales can be broken up into approximately 60% flavour compound and 40% fragrance compounds. The industry is growing around 8-10% per year.

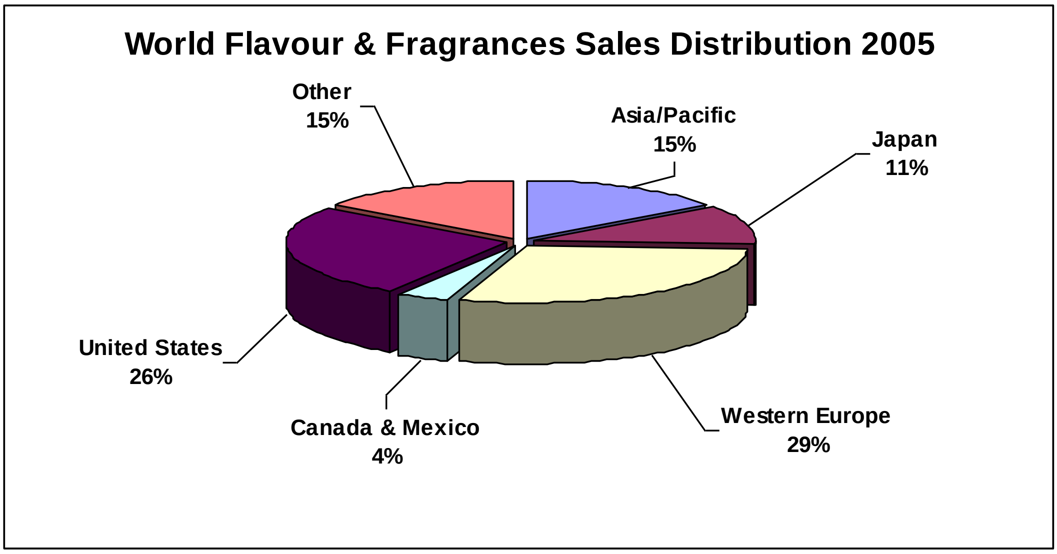

Figure 2.17. World Flavour and Fragrances Sales Distribution 2005.

The flavour and fragrance house sub-sector was once considered fragmented, where no single flavour and fragrance house held over 10% market-share in the early 1990s [48]. However major mergers and acquisitions over the last 15 years have changed the sub-sector landscape, where it is now much more concentrated. The World geographic distribution of sales [49],[50] is shown in Figure 2.17.

One of the casualties of international trends is the smaller flavour and fragrance house that is finding it difficult to survive. A single national market is too restrictive today due to acquisitions and mergers of end product manufacturers who tie up global supply contracts with a single flavour and fragrance house that can serve them globally. Thus smaller flavour and fragrance houses in a single market will not have the sales to support research and development and make large investments in manufacturing facilities.

FLAVOUR AND FRAGRANCE HOUSE SUBSIDIARIES

Most flavour and fragrance houses operate across national boundaries in all continents through subsidiaries. A subsidiary operation may only consist of a sales office in very small markets. Extensive regional compounding facilities will usually exist in the larger markets. Subsidiary operations are usually responsible for their own flavour and fragrance development as local knowledge is required in understanding domestic market tastes and preferences. Subsidiaries are technically well coordinated with head offices through regular transfer of employees, particularly perfumers and flavourists. Subsidiaries source materials both independently and through the parent company.

FLAVOUR AND FRAGRANCE HOUSE AGENT

In a country where a flavour and fragrance house does not have a subsidiary, it may employ a sales agent (which could be a freelance person) to look after sales in a particular geographic territory. The agent may report to a subsidiary that has regional responsibilities.

NATIONAL REGULATORY SYSTEMS

National Governments through their respective national regulatory bodies have the responsibility for regulating domestic drug, food and cosmetic products. In the United States, flavours and fragrances are regulated under the US Food, Drug and Cosmetics Act. US food laws are complex and come under several categories. The US FDA does not subject cosmetics to a pre-market approval process, and operates a voluntary scheme for ingredient disclosure at present, although all manufacturing facilities must be registered [52] and have obtained GMP status. The US FDA allows the flavour and fragrance industry to exercise self regulation through industry established bodies [53]. There is no pre-market registration of flavours and fragrances but all flavour and fragrance houses adhere to the FDA GRAS list (Generally Required as Safe) [54], a positive list of flavour raw materials and food additives known to be safe for human consumption, and will not use a material in a flavour or fragrance unless it is listed.

The Flavor and Extract Manufacturers' Association (FEMA) [55] was formed in 1909 in the United States to protect the interests of the flavour and fragrance industry in the regulatory area. The major goals of the organization are to promote the creation of better flavours for the benefit of the consumer, to assess and evaluate regulatory changes affecting the flavour and fragrance industry, to assist members with a broad variety of support services. The success of FEMA is partly the reason why the flavour and fragrance industry has a large degree of self regulation within the United States. FEMA is the body that actually maintains the GRAS list, on behalf of the US FDA.

The Research Institute for Fragrance Materials (RIFM) is a research body set up voluntary by members of the flavour and fragrance industry to evaluate the safety and toxicity of aroma chemicals [56]. RIFM operates as a non-profit organization with members from all over the World. Raw materials are the only items evaluated by RIFM and are selected on the following criteria for testing: the material must be representative of the material in actual use by the industry, it must conform to the specifications and standards of the Fragrance Materials Association of the United States (FMA) [57] or the International Fragrance Association (IFRA), it must be supplied to RIFM without any indication of supplier and it must be accompanied with an analysis. RIFM regularly publishes monographs relating to the safety and toxicity of aroma chemicals.

The International Fragrance Association (IFRA) was established in 1973 with its headquarters in Belgium [58]. Member organizations include fragrance manufacturers' associations around the World. The basic purpose of IFRA is to formulate and maintain a Worldwide code of practice for the fragrance industry. The aim of the code of practice is to arrive at a uniform approach towards ingredients used in fragrance formulations and their testing.

All members of IFRA have adopted a good operating practice for firms in the fragrance industry. The principal areas covered are standards of good manufacturing practice, adequate training of personnel, maintenance of premises and sanitation, quality control and storage of fragrance ingredients, labeling and packaging, adequate laboratory facilities and maintenance of safety. The International Organisation of Flavour Industries (IOFI) was established in Geneva in 1969 to look after the interests of the flavour industry. IOFI issues a code of good practice and undertakes research into the toxicity and safety of aroma materials [59].

Until 1st June 2007, European flavour and fragrance materials were governed by a positive list and voluntary compliance by manufacturers', similar to the United States [60]. A new legal framework called the registration, evaluation, authorization and registration processes for chemical substances (REACH) has come into force under the European Chemicals Agency based in Helsinki [61]. The objective of REACH is to standardize all European processes regarding chemical substances, ensure their safe use, look after the environment, and promote non-animal testing. REACH requires any substance over one tonne that is manufactured or imported into the EU to be registered, under a pre-registration process. The legislation has taken seven years to get through the European Parliament [62] and has not been without its criticisms [63] from numerous parties, and is considered the strictest law to date regarding toxicity and will impact industries all over the World [64]. Unlike other countries where new regulation only concerns new chemicals, REACH is applied to all chemicals, existing and new, as there are no grandfathering provisions.

STANDARDS ASSOCIATIONS

The major objective of standards is to assist in the creation of a consistent material across the industry to gain consumer confidence and credibility. Standards also define what is an acceptable product and what is not, *i.e., to define particular chemical constituents and their levels in an essential oil, which may have a number of chemotypes.* Standards Associations exist in most countries to develop minimum specifications for products. The international Organisation for Standardization (ISO) is the peak body that has representatives on various technical committees from member countries to set down internationally recognized standards. The relevant technical committee for essential oils is ISO technical committee 54 [65], which have representatives from approximately 30 countries.

Standards specifications for essential oils contain physical and chemical constraints (specific gravity, refractive index, optical rotation, non-volatile residue, and solubility in alcohol in certain specified conditions, chemical specifications and ranges such as the level and range of a particular constituent in an essential oil based on a nominated method, acid values, ester values after acetylation, carboxyl and phenol contents may also be nominated depending upon relevance to the specific essential oil). Most specifications are issued with GLC analysis. Specifications also indicate colour, appearance, and provide an olfactory profile with the material.

Standards are important to the essential oil industry where major producing and consuming countries have established them for most major oils of trade. Generally speaking, essential oils that meet minimum standards are tradable items, although olfactory criteria are most important. Many users establish their own internal standards that may differ from standards issued by various standards associations. Until recent years, standards were purely voluntary, but now they have been put down as regulatory standards in some food and cosmetic instances as mandatory minimum levels.

END PRODUCT MANUFACTURERS

The range of formulated products incorporating flavours and fragrances is enormous. These include cosmetics, personal care products, household products, food, beverages, snack foods, biscuits and baked goods, wine, alcoholic beverages and spirits, institutional products like paints, motor oils, paper, textiles and plastics.

The use of flavours in food is of the utmost importance in satisfying consumers. Indulgence on the part of the consumer has become a key factor in product development and marketing [66]. Food sub-sectors comprise beverages 17%, bakery products 12%, confectionary 11%, dairy 9%, sauces and seasonings 8%, snacks 8%, meals and meal centres 7%, processed fish, meat and egg products 6%, deserts and ice creams 6%, side dishes 3% and fruits and vegetables 3% [67].

Fragrance is an important part of the brand image of a product, in synergy with product presentation (packaging, colour, advertising and corporate image), promotion, and other market strategies [68]. Fragrance helps render a product distinguishable to the consumer in the vast array of products on the shelf, helping to differentiate the product from its competitors [69]. In highly developed markets, cosmetics, toiletries and household products have reached a stage where differentiation of primary product image builders (advertising, promotion, price, packaging) have become difficult to develop as a source of competitive advantage over competing products. Secondary image builders (fragrance, colour, types of ingredients used in the product) are taking on more importance [70].

Table 2.3. Australian Top 10 Non-Food Retail Categories with Generic Brand Market Value and % Market Share (2005-2006)

Rank	Category	Market Size (AUD)	% Market Share
1	Shampoo	$60 M	25.80%
2	Dishwashing Liquids	49.4M	41.50%
3	Toothbrushes	38.9M	40.20%
4	Disposable Nappies	$32.5M	8.10%
5	Hair Conditioners	$28.5M	18.40%
6	Deodorants	$26.8M	15.0%
7	Laundry Powders	$26.7M	7.20%
8	Baby Wipes	$24.2M	41.9%
9	Wipes & Cloths	$22.8M	45.0%
10	Scourers	$22.6M	63.6%

Consumer profiles can be constructed from psychographic, demographic and/or geographic segmentation. End product manufacturers seek to develop products that will satisfy these target customer profiles. Customer profiling is one of the primary tools of marketing today which focuses on consumer lifestyles, attitudes, values, beliefs and aspirations.

Consumer product sectors have undergone massive rationalization through numerous mergers and acquisitions over recent years. Markets have become internationalised, supported by global brand marketing strategies. Multi-national firms during the 1980s and 90s practiced conglomerate strategies, buying up strong local brands. These groups operate globally with business units in almost every country, with a high linkage of cross ownership between food and non-food companies [71]. Some medium sized manufacturers still remain specialized in selected product and geographical niches. Some of these companies have also expanded internationally, along defined product groupings. Long established small and medium sized manufacturers are disappearing from the industry, leading to high market concentration. The remaining small to medium companies have tended to change their product strategy and became dedicated manufacturers of retail chain brands. Retailers' brands vary between 5-40% market segment share in countries like Australia and New Zealand. With the advent of foreign retail chains in South-East Asia, this trend is also happening in Hong Kong, Singapore and Thailand. Table 2.3. shows the chain in-house *(Generic)* brand market-share against the total market in Australia [72]. The increase of concentration in this sub-sector has strengthened the bargaining power of end-product manufacturers in relation to flavour and fragrance houses.

WHOLESALERS AND RETAILERS

The retail sub-sector has rapidly transformed from service orientated independent stores to high volume sales orientated international chains. Like the consumer manufacturing sector, concentration in the retail sector has increased through mergers and acquisitions. The entry of foreign retailers into the Asian region has very quickly concentrated consumer retail spending into hypermarket, supermarkets and convenience store sub-sectors. Through the introduction of category management, less self space is now available for individual brands, while new product entry costs have become very high. Through retail chain competition, markets have become very competitively priced. Category management and larger margins demanded by retailers is forcing manufacturers to provide both innovation and competitive pricing [73]. Chain market concentration has resulted in lower margins for manufacturers. Chains have segmented the retail business into hypermarkets, supermarkets, and convenience stores, where different consumer buying habits and patterns exist. This segmentation creates manufacturer opportunities to develop specific products for each retail segment. Table 2.4. shows the relative retail market concentration in Malaysia, Thailand, Hong Kong and Australian markets [74].

Table 2.4. The relative retail market concentration in Malaysia, Thailand, Hong Kong and Australia

Outlet Type	Malaysia	Thailand	Hong Kong	Australia
Hyper & Supermarkets (Chain Owned)	20%	68%	91%	85%
Independent Hyper & Supermarkets	20%	2%	2%	10%
Wholesale Trade – Sundry & convenience Stores	57%	10%	2%	3%
Other	3%	20% Convenience Chains	5%	2%

CONSUMERS AND DERIVED INDUSTRY DEMAND

Consumers ultimately have incredible influence over the flavour and fragrance industry through what they purchase. Consumer purchasing patterns ultimately decide market trends. Consumer behaviour is complex and influenced by many factors. These include complex dynamics between demographics, disposable income, economic environment, culture, social values, habit, tastes and preferences, government regulation and future expectations. End product manufacturers try to influence consumer behaviour through advertising and building loyalty towards their brand images. Aggregate demand patterns also change through new technology and product innovations, modifications to existing brand ranges through entry and promotion in new developing consumer markets, *i.e., organic cosmetics*. Consumers also exert pressure on industry through organized pressure groups concerned about consumer health, safety and environmental issues.

Production in the flavour and fragrance industry fluctuates according to changes in demand for flavoured and fragranced end products. The consumption of essential oils, aroma and specialty chemicals by flavour and fragrance houses is determined by the demand for flavour and fragrance compounds from end product manufacturers, where demand for the end product is determined finally by the consumer. Consequently, demand for flavour and fragrance compounds and the raw materials that they consist of *i.e., essential oils, aroma chemicals and specialties, etc*, is of a derived nature, passing through all the industry sub-sectors.

Demand patterns and production are also influenced by raw material availability. In the short term, demand is inelastic as flavour and fragrance houses are reluctant to change existing flavour and fragrance compound formulations. A shortage of raw materials will however effect the development of new flavour and fragrance compounds immediately, as perfumers and flavourists will avoid materials with questionable supply. In the longer term, new technological advances will influence raw material demand patterns as new aroma chemicals, specialties and essential oil reconstitutions are developed.

ESSENTIAL OILS IN THE COSMETIC INDUSTRY

One of the most influential trends upon the cosmetic industry over the last 20 years has been the trend to natural materials. Most cosmetics and personal care products on the shelves of supermarkets and pharmacies display some influence of this trend to 'naturals. The issue of natural products has become somewhat confused with concerns for ecology, the environment, health and lifestyle. The natural trend is partly based on misconceptions on the part of consumers that natural products are more gentle, safer to use and more ecologically and environmentally responsible than synthetic derived materials [70].

Manufacturers in the cosmetic, personal care and associated industries have not been slow to respond to consumers concerns of the environment by developing new concepts in packaging and incorporating a greater amount of renewable resource based materials into their products. Many long established cosmetic and personal care product manufacturers perceive a great threat to their jealously defended market shares from the 'natural' trend as many new and small companies are appearing in the market capturing market share through non-traditional channels of distribution, exploiting the 'natural' theme. However to a great degree essential oil and herbal extracts in cosmetics and personal care products remain as ascetic ingredients rather than functional ingredients.

Notwithstanding the above, the last twenty years or so has seen the dramatic rise of companies like Aveda and the Body Shop, utilizing essential oils as active ingredients in their products. These companies have utilized non traditional means to market their products and greatly expanded the industry. The internet has allowed new ways for companies to get their message across to the consumer with themes and stories consumers aspire to. Some essential oil producers have vertically integrated their business from producer to direct marketer to the consumer through the internet very successfully, as Thursday Plantations in NSW, Australia has been able to achieve [75].

The impact of consumer aspirations on the cosmetic industry has certainly changed the marketing paradigm and brought a lot more plant extracts and essential oils into products as both ascetic and functional ingredients. However this has not necessarily been matched by thriving essential oil industries. The cost of trials and registration of new materials is a major barrier to innovation of new materials. Regulation in the cosmetic industry has tightened up almost everywhere around the World.

In Europe, the SCCP (Standing Committee on Consumer Products – previously called the SCCNFP: Scientific Committee on Cosmetic & Non Food Products) is an expert committee set up under the EC Health and Consumer Protection DG. The SCCP reports to the EC H&CP Scientific Steering Committee on matters relevant to the EC countries in their defined area. The committee is comprised of a diverse range of experts in toxicology from industry, the medical fields and tertiary institutions. The SCCP/SCCNFP has provided scientific opinions on a wide range of ingredients used in personal care products including actives & excipients for oral care, hair care and skincare products. Partly due to overzealous industry claims about the efficacy of certain products [76] and general concerns about toxicity, the EU issued directive 76/768/EEC [77], which effectively governs the cosmetic industry in the EU. The effect of this directive is that many essential oils that have been in use for long period of time cannot be used in cosmetic products or must be used with a warning on the label. In Australia, the Therapeutic Goods Administration [78] now stringently regulates the industry. Cosmetics need to be pre-registered before sale in Malaysia [79], Thailand [80] and Vietnam [81].

Within the cosmetic and personal care industry, new market segments related to natural products are being created and developed. In very recent years products have been appearing on the market claiming to be organic. Organic cosmetics are the fastest growing consumer segment with sales in the US of USD 218 million in 2006 [82]. Some large transnational brands have also jumped into the market. In this emerging market many issues remain to be resolved. No mandatory rules exist on what is organic in the cosmetic market and there is no regulatory authority. Some certification bodies have emerged in the UK, France, Germany and the United States, but don't agree on uniform criteria.

ESSENTIAL OILS IN THE PHARMACEUTICAL INDUSTRY

At one time, the use of plant material for medicinal purposes was the only source of therapeutics [83]. The use of plant materials in medicine has been well documented in Traditional Chinese, Ayurvedic, European, Amerindian and African systems of medicine. These early branches of herbal medicine had their own pharmacopeias recording the uses of herbs for therapeutic purposes. Essential oils were once an important part of pharmaceutical preparations, but have largely declined in use, as more potent active ingredients have been found.

Many products containing essential oils as active ingredients have survived in the topical area.

A long surviving example of this is Bosisto's Eucalyptus Oil, which has been on the market for more than 150 years and used to ease cold and flu symptoms, relieve arthritic pain and as an anti-bacterial and ant-fungal agent [84]. Before the advent of antibiotics, tea tree oil was used to treat skin infections, rashes, and fungal growth, especially during World War II. Within the South-East Asian region there are numerous traditional products in the forms of balms and ointments for external application containing essential oils, Tiger Balm [85] from Singapore being the most well known. With the advent of stringent licensing, these firms have developed into small to medium sized specialist pharmaceutical companies throughout the Asia-Pacific region.

Essential oil constituents are used as feed-stock or precursors utilized in the production of modern prescription drugs. Some of the most important modern drugs were discovered from plant sources. These include reserpine, isolated from the *Rauwolfia* species in 1952, vinblastine, developed from the *Catharanthus* species in 1958, vincristine, also derived from the *Catharanthus* species in 1962 and silybin from the *Silybium* species in 1968 [86]. These successes led to more intense screening programs for anti-tumor activity undertaken by the National cancer Institute (NCI) between 1960 and 1980. Due to the narrow screening protocols utilized, it is felt that many broader spectrum activities and applications were missed by this study [87].

Pharmaceutical companies are still very interested in finding new plant derived compounds for therapeutic applications and development is continuing. One case is oseltamivir, produced by Roche under the tradename Tamiflu. Shikimic acid, a constituent in Chinese Star Anise, produced in Vietnam and China is the starting material to produce oseltamivir. As in this case, problems exist in utilizing essential oils as active ingredients because of supply shortages [88]. This forces pharmaceutical companies to seek other ways to synthesise required active ingredients in their products. So plant derived compounds serve as molecular templates, rather than the plant becoming a source of the natural material. Other essential oils used in pharmaceuticals include anise oil, citronella oil, clove oil, fennel seed oil, fenugreek oil, ginger oil, lavender oil, lemon oil, mint oil, oregano oil, orris oil, rosehip oil, rosemary oil, tarragon oil, thyme oil, wintergreen oil and yarrow oil.

However still today, approximately 35% of pharmaceutical products active compounds originated from plant derived compounds [89]. Pharmaceutical companies are becoming much more active in producing naturally derived products as *nutra* and *cosmo-ceuticals* to cater for growing consumer preferences for these products [90].

ESSENTIALS OILS AND THE AROMATHERAPY INDUSTRY

Extrait perfumes and fine fragrances were once the undisputed glamorous showpiece and pinnacle of the essential oil industry [90]. However this mantle has been challenged by the rapid growth and consumer acceptance of aromatherapy over the last 30 years. Once considered a fringe movement by the established traders in the essential oil industry, aromatherapy has become a large and growing market, which has facilitated the development of many new companies, as producers, traders, and end-product manufacturers in the market. In fact aromatherapy was probably responsible for a renaissance in essential oils during the 1990s.

Aromatherapy has been blended in with Ayurveda, Traditional Chinese Medicine, Herbalism, Phytho-Medicine, homeopathy, new-age, mainstream cosmetics and personal care products, as well as traditional medicine industries in many countries, to create an extremely large market. There are now enterprises specializing in the production of organic aromatherapy essential oils, aromatherapy essential oil trading, aromatherapy products, client consultations in practice and exclusive spas all over the World. The market is large enough to have segmented into distinct high end, middle and low end markets.

The growth of the internet during the 1990s has probably been part of the catalyst in putting essential oils in front of consumers. One could also argue, that because of the World's rapid economic development and the relative affluence of World consumers to consumers of past decades, today's consumers are now looking for something spiritual and self actualizing to achieve some sense of self satisfaction. This could be partly true for modern consumers, particularly with growing concerns for health, wellbeing, the environment, sustainability and alternative lifestyles, within their existing hectic corporate/urban routines. This trend is also penetrating South-East Asian markets, where consumer motivations to purchase may be similarly based, or have something to do with the concepts of prestige. The popularity of aromatherapy is certainly reflected by the number of books published on the subject, websites and courses available around the World.

Determining the actual size of the aromatherapy market is extremely difficult. A precise definition is important to decide what should and what should not be included in any estimate. Should services such as spas be included? Should products include cosmetics that are claimed to have aromatherapy applications? Should the turnover of companies that have both aromatherapy and 'standard' ranges be included? Much small scale recent essential oil production is not counted in any statistical databases. The market is extremely fragmented to make any accurate estimates. In the UK alone, estimates of the market range between USD 52 million [92] and USD 340 million [93], where obviously both reports are not measuring the same "defined market". Another report projects the value of the US market at USD 800 million in 2003 [94]. This would equate to a several Billion US dollar World market. However actual farm-gate essential oil value would be only approximately 5% of this value [95].

New aromatherapy product launches tend to be dominated by large companies in the cosmetic and pharmaceutical sectors. The concept of aromatherapy as an alternative medicine is being mixed with personal care, health and beauty concepts, seen in the number of ‘hybrid’ personal care, cosmetics and beauty products now in the market. Aromatherapy is seen as a growth opportunity by these companies. While aromatherapy products are now in the shelves of major hypermarkets and pharmacies, small specialized niche market specialists that pioneered the industry are being pushed out of the market.

Yet, with all the hype and growth, aromatherapy faces many challenges. Aromatherapy in Europe is now subject to REACH and SCCP recommendations that have been put into regulation, a reaction to the overzealous claims that have been made about essential oil healing and health properties. Aromatherapy has also been associated with a number of toxicity issues, where some hydrosols (distillate water of floral waters) were found to contain bacteria and a number of users suffered poisoning as a result [96]. However the aromatherapy industry was able to open up new opportunities for boutique essential oil producers and allowed the development of some novel new oils in the 1980s and 90s, and this is still continuing at a slower rate today.

Essential Oils as Intermediates in the Production of other Compounds

Essential oils are natural sources of alcohols, phenols and aldehydes, etc. Thus many essential oils are used as starting materials for other products through fractionation, separation, transformation and synthesis, utilizing both chemical reactions and biotechnology methods. A number of essential oils that consist of a single primary component can be utilised for the isolation of useful aroma chemicals. Examples of this are Bois De Rose oil for linalool, cedrol from cedarwood oil, geraniol and citronellal from citronella oil, eugenol from clove oil, rhodinol from geranium oil, citral from litsea cubeba oil and safrol from sassafras oil. For a time, synthetic versions of these materials were popular and production of these natural isolates waned. However natural isolates have become popular again because their olfactory profiles exhibit a depth and quality that cannot be duplicated by their synthetic counterparts. The difference between a natural and synthetic aroma chemical lies in the proportions of impurities they contain. Natural isolates from essential oils carry over traces of their parent material while impurities in synthetic aroma chemicals most likely detract from the olfactory quality of the material.

Table 2.5. Fragrance Materials Obtained Through Microorganisms

Microorganism	Odour Type	Chemical Constituents
Bacillus subtillis	Soybean	Tetramethylpyrazine
Ceratocystis moniliformis	Fruity, Banana, Peach, Pear, Rose	3-Methylbutyl acetate, ó- and Ў-decalactone, geraniol, citronellol, nerol, linalool, α-terpineol
Ceratocystis variopora	Fragrant Geranium	Citronellol, citronellyl acetate, geranial, neral, geraniol, linalool, geranyl acetate
Ceratocystis virescens	Rose, Fruity	6-Methyl-5-hepten-2-ol acetate, citronellol, linalool, gernaiol, geranyl acetate

Corynebacterium glutamicum	Soybean	Tetramethylpyrazine
Daedalea quercina	Apples	
Inocybe corydalina	Fruity, Jasmine	Cinnamic acid methyl ester
Kluyveromyces lactis	Fruity, Rose	Citronellol, Linalool, Geraniol
Lentinus cochleatus	Anisaldehyde	
Lenzites sepiaria	Slightly spicy	
Mycoacia uda	Fruity, Grassy, Almond	P-Methylacetophenone, p-tolyl-1-ethanol, p-tolylaldehyde
Penicillium decumbens	Pine, Rose, Apple, Mushroom	Thujopsene, 3-Octanone, 1-octen-3-ol, nerolidol, β-Phenylethyl alcohol
Pholiota adipose	Earthy	
Polyporus croceus	Narcissus	
Polyporus obtusus	Jasmine	
Poria xantha	Lemon	
Pseudomonas perolens	Musty, Potato	2-Methoxy-3-isopropylpyrazine
Pseudomonas odorifer	Musty, Potato	2-Methoxy-3-isopropylpyrazine
Stereum murrayi	Vanilla	
Stereum rugosum	Fruit, Banana	
Streptomyces odorifer	Earthy, Camphor	Trans-1,10-Dimethyl-trans-9-decalol, 2-exo-hydroxy-2-methylbornane
Trametes odorata	Honey, Rose, Fruity, Anise	Methyl Phenylacetate, geraniol, nerol, citronellol
Trametes suaveolens	Anisaldehyde	
Trichoderma viride	Coconut	6-Pentyl-2-pyrone

Some essential oils have the terpenes removed to provide them with more strength, particularly in flavours. The terpene residuals are very good extenders in fragrances. Another advantage of di-terpenation is that the diterpenised oil is free of insoluble hydrocarbons, so becoming much more soluble in ethanol. *d*-Limonene is removed from orange oil, usually through vacuum distillation. *d*-Limonene is also a major industrial cleaning solvent. Sassafras oil as a source of safrole is a starting material for the material heliotropine. Safrol can also be transformed into piperonal butoxide (PBO), a vital ingredient of pyrethroid insecticides. Piperonal butoxide is a synergist with natural pyrethrum, which makes natural pyrethrum a much powerful insecticide. The oil is on the restricted list in most countries as it is also the starting material for hallucinogenic drugs like MDA (3,4-methylenedioxyamphetamine) and MDMA, known as ecstasy. Peppermint and spearmint oils are often sources of menthol used in a number of food and pharmaceutical applications. Eugenol, isolated from clove oil is often transformed into iso-eugenol used in the dental industry as a local antiseptic and analgesic, as a route in the production of vanillin and as stabilizers and anti-oxidants for plastics and rubber.

The paradigm change to natural over the last three decades has led the essential oil industry to seek 'milder' methods of chemical modification that can still qualify as a natural material. This has been driven by resurrecting certain technologies that are now called biotechnology, *i.e., fermentation, ultra-filtration, column chromatography, reverse osmosis, cold pressing and other processing technologies.* Micro-organisms are capable of producing interesting volatile metabolites, exhibiting food flavours, floral type and woody odours. Table 2.5. shows a number of materials that can be derived from micro-organisms.

Essential Oils in the Organic Agro-chemical Industry

There are over 120 countries that are involved in organic farming with a total area of 31 million hectares currently under cultivation. The organic food market is growing at 20% per annum [97] and was valued Worldwide at USD 31.2 billion (EU USD 13.7 Billion, North America USD 13 Billion) in 2005 [98]. Organic foods have flowed into all categories now including cosmetics and sold in mainstream supermarkets and retail outlets throughout the World [99]. Lagging behind the exponential growth of organic farming are organically certifiable chemicals to assist in production.

The World market for agro-chemical products is in excess of USD 35 Billion [100], which excludes fertilizers. Many have argued that genetically similar crops under monoculture systems [101] utilizing conventional agro-chemicals has great costs to the environment [102], health [103] and is not sustainable [104]. Consequently, agriculture itself is currently undergoing a revolution with major changes in practices taking place. Agriculture is being redefined. Those involved in agriculture once held the view that the environment can be totally controlled through fertilisers, pesticides, herbicides, hormones and trace elements. However accepted practices began to show their shortcomings and basic assumptions about agriculture re-questioned. Evidence showed conventional practices led to phosphates, heavy metals and herbicides seeping into water tables, crops absorbing unsafe levels of chemicals and land just failing to provide satisfactory yields, due to unsustainable practices. In some cases, agricultural communities have just been wiped out and ceased to exist or continued to operate with negative capital returns.

Agriculture was once a so precise *science* that farmers believed they knew what remedy to use for what problem and even knew how to prevent these problems through establishing precise and disciplined preventative regimes and methods. Modern science provided this sense of confidence with *hi-tech* solutions such as using geo-stationary satellites to predict crop yields and insect plagues. Also through land sensing, farmers could obtain advice on what fertiliser, how much, and when to apply it, to obtain the planned yield. A massive agro-chemical business evolved, providing all the technical answers needed, dominated by strong trans-national companies, where almost total *oligopoly* competition exists. As a result, farmers re-evaluated the ways, practices and methods of the past. New paradigms have been developed with the catch phrases of *'sustainable', 'integrated', 'organic'* and *'balanced eco-system'.* As a consequence a much wider information base is utilised to make decisions, with a *holistic* orientation, *i.e., understanding in great detail relationships between 'inputs' and 'outputs', focusing on balance.*

These approaches to agriculture require new practices based on inputs and methods that are non-threatening to the eco-system *(i.e., prevent further contamination and pollution of the water tables)*, add value, promote sustainability and assist in providing long term profitability. Only certified fertilisers, pesticides and other chemicals are allowed in organic farming, including those derived from micro-organisms and materials derived from plants, animals, or mineral bearing rocks. Soaps are also allowed under many certifying authorities. Generally, pesticides and soaps allowed for organic farming are those that will break down quickly and non obtrusive to the eco-system. This has created a push in research and development for the application of essential oils in agriculture [105].

A new generation of crop protection products is emerging in the market, based on soap and essential oil emulsions. These products take advantage of the anti-microbial properties of essential oils to function as a fungicide. Biomor of the United States manufactures these products under the trademarks of *Timor* and *Timorex* [106]. These products are certified as fully organic and are sold as fungicides and insecticides. The company claims that these products can be tailor made to selectively attack insects, leaving those beneficial alone. It is further claimed that these products leave no residual and can fully negate the need to use copper or sulphur in field application. The company solved the problem of essential oil volatility through patented encapsulation processes [107], and sales have rapidly grown to a turnover of USD 50 million per annum, within the first three years of operation [108], through sales in South America, South Africa, Philippines, Greece, Australia and the United States. According to the company sales growth is severely hampered by the unavailability of enough tea tree oil to expand production. A search through the US patent databases shows that a number of new patents are emerging in this area [109].

Other research has been carried out to solve a number of agricultural problems, utilising essential oils. Degrading soil fertility, salinity, heavy metal residuals in the soil, and the effects of global warming, are subjecting crops in many temperate countries to stress. This has created a market for anti-stress products, which is slowly growing in importance to agriculture. The essential oil of some trees, *Meleleuca bractea* for example, have been found to substantially reduce the stress of crops [110]. Plant stress levels can be lowered by applying *betaines* produced from *methylated prolines, N-methyl proline, trans-4-hydroxy-N-methyl proline and trans-4-hydroxy-N-dimethyl proline,* extracted from various specifies of *Meleleuca* [111]. A compound *platyphyllol* [112], found in *Melaleuca cajuputi*, a native of Malaysia, Thailand, Indonesia, Vietnam and New Guinea has *'UV blocking'* attributes [113], This could be used in treatment of plant stress, as one of the major stressors of plants is *UV radiation*. None of these natural products have been patented for this application or commercially produced at this point of time, although it was patented for cosmetic applications [114].

On the shelves of supermarkets, hardware stores and garden centres in developed countries, a wide range of agricultural products utilising essential oils as active ingredients can be found. These include soap based insecticides, organic dusts, white oils, fungicides [115]. This is perhaps the fastest growing area of essential oil application today, currently growing at exponential rates [116], however growth will be restricted by the available supply and economical costs of essential oils for these applications. A number of new companies have entered into this field, rather than traditional agro-chemical manufacturers.

Natural or synthetic agro-chemicals need to be pre-registered before sale in most countries. In the United States this falls under the jurisdiction of the Food and Drug Administration and US Environment Protection Authority. In Australia the product must be pre-registered with the Australian Pesticides and Veterinary Medicines Authority (APVMA) and also with the National Industrial Chemical Notification and Assessment Scheme (NICNAS) [117], if the essential oil is new. An in depth discussion on agricultural chemical registration can be found in chapter 7.

THE VALUE-CHAIN FOR ESSENTIAL OILS

Finally to put the whole industry and its sub-sectors into perspective requires looking at the value chain. Each industry sub-sector requires inputs (or products) from the sub-sector preceding it to pass on outputs (or products) to the next sub-sector. Each sub-sector takes an input or group of inputs to transform them into an output which adds value to that organization. In the case of the flavour and fragrance industry, the consumer can only make use of the product after it has passed through all entities in the value chain. Within the aromatherapy industry, essential oils in their own right can be either input materials for transformation into other products or end products in their own right (packaged down to consumer items from bulk). Each organization or entity within the value chain must have infrastructure, systems and operations to carry out their functions which act as costs. The revenue they earn from transferring their outputs to the next sub-sector minus the sum of all costs equals the value added to the inputs while passing through their sub-sector.

Figure 2.18. depicts an adaptation of Porter's value chain [118]. It can be observed that essential oil production as a sole activity has extremely low value in the chain. Most value is added through the other sectors. This highlights the challenge for primary producers of essential oils, to develop strategies through innovation, technology and entrepreneurship to enable them to gain a larger share of the total value chain. The next chapter will review essential oil production in the South-East Asia-Pacific region.

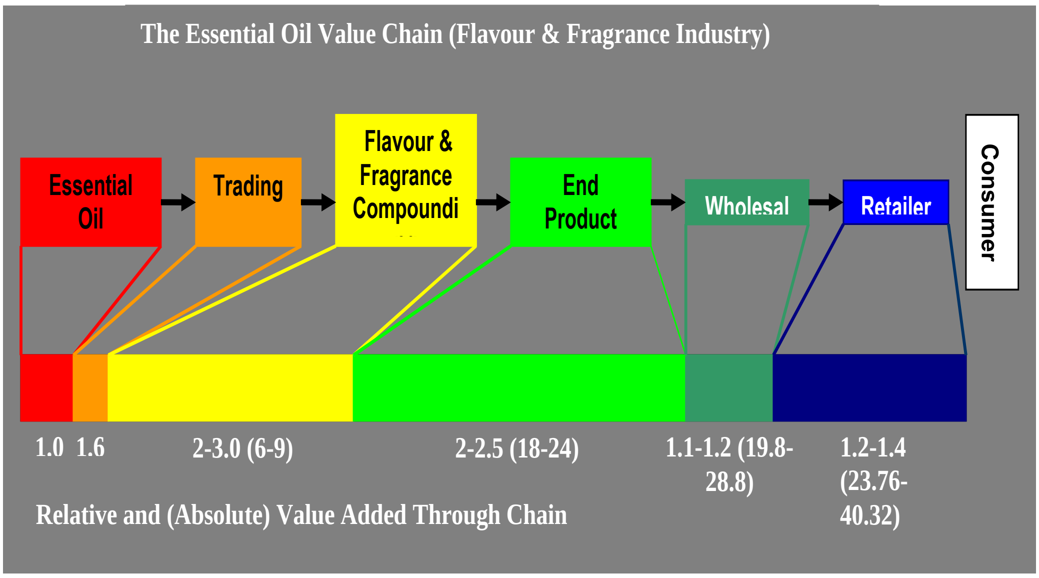

Figure 2.18. The Essential Oil Value Chain for the Flavour and Fragrance Industry.

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Chapter Three: Current Essential Oil Production in the South-East Asia Pacific Region

The production of essential oils in the various countries of the South-East Asia Pacific region is varied in regards to the types of essential oil crops, the methods of cultivation and the stages of development. Different production areas are at different stages of development and have adopted different strategies because of varying historical backgrounds, sizes of domestic markets, awareness about the industry and bases of competitive advantage. This chapter briefly reviews the production of essential oils within Australia, New Zealand, Papua New Guinea and the Pacific Islands, Indonesia, Malaysia, Thailand, Laos, Cambodia, the Philippines and Vietnam. The state of research in each country is also discussed as a guide to potential support and future development. The chapter concludes with a few comments about common issues facing production in the region.

The production of essential oils in the South-East Asia Pacific region is varied because of different climates, histories, size of domestic markets, and bases of competitive advantage. Therefore each country is at a different stage of development according to the influencing factors above. Different production models exist throughout the region where some

countries have a long history of cultivating essential oils like Indonesia, some countries are re-establishing their industries after years of war and catastrophe, and others have developed their industry based on research and development support.

Australia

The traditional essential oil industry in Australia has been slowly declining for many years. Mid last century, the eucalyptus industry moved to Spain, South America and China. In addition, the peppermint industry failed to grow with any momentum in North-East Victoria and Central Tasmania. All the major plantations in the tea tree industry have ceased production, leaving only small and medium family concerns surviving. The general reputation of investing in essential oil production is under a cloud with a number disputes within the industry [1]. This is part of wide investor disillusionment with agriculture, as new crop development in Australia has also been smeared through too many *tax minimization schemes* and mismanagement, which has made potential investors shy away from alternative agricultural investments.

Developing an essential oil plantation in Australia is a massively expensive undertaking, due to high capital set up, maintenance and processing costs. Droughts and water regulations enforced by local authorities have put undue burdens on those entrepreneurial enough to *'have a go'* in this industry. The development of new essential oil and other natural product plantations, unless they are based on an existing family farm would appear to be daunting due to the costs involved. Australia's potential competitive advantage in boutique type agriculture relies on product differentiation through developing innovative products for niche markets, rather than the development of cost competitiveness. Developing niche natural products also runs into the gambit of European regulation which puts prohibitive costs in the way of gaining registration for potential new products

The estimated production of essential oils in Australia is shown in Table 3.1 below.

Table 3.1: Estimated Current Production of Essential Oils in Australia

Essential Oil	Annual Production (tonnes)	Major Production Centres
Tea Tree	160	New South Wales, Queensland
Eucalyptus Cineole type Citronellal type	120 0.7	Victoria, Western Australia, New South Wales, Queensland
Citrus Orange Lemon Mandarin Grapefruit	35-45 4-8 3-4 4-8	Victoria (Mildura), South Australia (Berri) Victoria (Mildura), South Australia (Berri) Victoria (Mildura), South Australia (Berri) Victoria (Mildura), South Australia (Berri)
Mints Peppermint Spearmint	16 2	Victoria, Tasmania Victoria, Tasmania
Sandalwood	6	Western Australia
Fennel	12	Tasmania
Parsley	8	Tasmania
Dill	2	Tasmania
Lavender Type Lavender Lavandin	1.2 0.5	Tasmania, Victoria, New South Wales Victoria
Lemon Myrtle	8.4	New South Wales, Queensland
Leptospermum petersonni	4.3	New South Wales, Queensland
Boronia	0.1	Tasmania
Other Oils	2.4	

In monetary terms, Australian essential oil production (farm gate) is approximately a USD 11.0 million per annum. This is about 1.2% of total world production [2].

Australia's position in production and market for each essential oil are summarized below.

Eucalyptus oil production is primarily derived from *Eucalyptus polybractea* or Blue Mallee, which is a cineole rich oil. There is also some production of other cineole types, including *E. smithii* and *E. radiata.* This oil competes with the lower yielding *E. globules* which is cultivated commercially for oil in China, Spain, Portugal and Brazil. Small quantities of *Corymbia citriodora* are cultivated, but the oil cannot compete internationally with production from China. Other varieties are also produced for aromatherapy and tourist products, including *E. viridis, E. cneorifolia* and *E. dives.*

The eucalyptus industry is over 100 years old and enjoyed its peak production period during the 1940's when over 1000 tonnes was produced annually. Production has declined to present levels due to the development of antibiotics after World War II and competition from foreign producers. Today only two main producers remain. These producers *(GR Davis in West Wyalong, NSW & Felton Grimwade & Brickford in Inglewood, Victoria)* have switched from wild harvesting of eucalyptus to plantation centred production. High yielding planting material was developed in conjunction with local universities and harvest/distillation systems mechanised to minimise labour requirements to improve competitiveness. Both companies also import, refine and trade in oil and other value added products [3]. Another major production area is along the Western Australian wheat belt.

Current Australian production is less than 5% of total world production and is marginally profitable. The industry has been subject to a number of booms and crashes over the years [4]. Whether Australia can become a major influence again will depend upon the success of developing a cost advantage over other producers, the ability and success of Australian companies in developing markets for high grade and other value added products and the prevailing market price levels in the future.

Tea Tree Oil *(Melaleuca alternifolia)* was one of the success stories in Australian essential oil industry during the mid 1980's with prices topping USD 55/kg. This attracted large numbers of new growers to enter the industry (in excess of 350), until production exceeded demand and prices tumbled to less than USD 6/kg. This has shaken out the industry and the largest producers have all ceased production, leaving only a number of small and medium sized producers to supply the market. Prices have been creeping up again and are reaching the USD 50/kg mark, at the time of writing. However many large customers including some of the major European and US retail chains who carried the product have discontinued it, due to lack of confidence in future supply. Likewise many major personal care companies have also switched to other natural additives in their product ranges, leaving the task ahead for producers to convince the cosmetic and retail industries to support the product again [5]. This unstable period has opened the door for producers in countries like China to step up production and compete with Australian producers.

Figure 3.1. The tea tree harvester and bio-mass collection bin towed by a tractor at the former "Maincamp" plantation (Photo courtesy of Mr. John Bax) [6]

Citrus oils are produced as a by-product of the large citrus industry centred around the Riverland in South Australia, Murray Valley in Victoria and Riverina in New South Wales. Approximately 50-60 tonnes of citrus oils are produced annually and most of this oil is consumed domestically, which is less than 10% of domestic demand. The main oils produced include orange, lemon, grapefruit and mandarin. Citrus oil production is not internationally competitive with the

US, Brazilian, Italian and Argentinean industries because of the much larger scale processing facilities in those countries, leading to better economies of scale [2].

Peppermint oil *(Mentha piperita)* production was established in the Derwent and Huon Valleys in Tasmania during the 1970's and in the Ovens Valley, Victoria during the 1980's. Approximately 20 tonnes of oil are produced annually and sold to customers in Australia and internationally. Peppermint oil is purchased on its olfactory and taste profile by confectionary manufacturers. Producers in this industry have been able to develop *niche* customers, through their specific blends of the oil. Farmers involved in the production of this oil have decreased over the years leaving only a small core of committed farmers to this crop. It doesn't appear that this crop will be dramatically expanded over the next few years. Spearmint oil *(Mentha spicata)* which attracts lower prices than peppermint oil is also grown in very small quantities.

Figure 3.2. Peppermint Harvesting in Myrtleford, Victoria (Photo Courtesy of Mr. Fred Bienvenu) [7]

Sandalwood oil *(Santalum spicatum)* production was redeveloped during the 1990's from scattered wild collection over the wheat belt area of Western Australia, to a planned industry, partly in response to salinity problems [8]. Sandalwood tree stock is both wild and plantation based. The industry has been able to redevelop because of over-utilised wild stocks of *Santulum aibum* in India, the existence of similar species in Western Australia over sparse areas, the long length of growth times (50 years) of the tree, preventing other entrants, and efficient processing and extraction methods employed by the producers. Thus Western Australia controls a scarce genetic resource, which enables industry viability. Sandalwood oil is used in fine fragrance, attars and incense and is exported to Europe, Middle East, Asia and USA.

Lavender oil *(cultivar of Lavandula angustifolia)* was first produced in Australia by C. K. Denny at the Bridestowe Estate in 1921. The plantation currently produces approximately 1.5 tonnes of oil per annum which is valued by particular customers around the world for its specific olfactory profile. The remainder of the oil is sold locally and used in products sold at the estate which is a major tourist attraction in the region. A number of small scale farmers in other parts of Australia are also producing small quantities of lavender oil.

Lemon Myrtle oil *(Backhousia citriadora)* is increasingly popular for its sharp citrus profile oil and the leaves are highly valued for the production of boutique lemon teas. The tree is difficult to propagate and develop into large scale plantations, so expansion of this industry is slow. There is not enough oil or leaf stock to satisfy the requirements of potential major users, i.e., tea manufacturers at this point of time.

Lemon tea tree *(Leptospermum petersonii)* is produced by a number of growers in New South Wales and Queensland for use in cosmetics and insect repellents. The essential oil is more limited for use as a flavouring material than lemon myrtle because of its *citronellal* content, modifying the sharpness and sweetness of the *citral* constituent. There is currently excess supply of this oil as demand is not increasing at the same rate of production.

The Tasmanian oils. In the 1980's a unique partnership was formed between the Government of Tasmania, University of Tasmania, Essential Oils of Tasmania (EOT) and farmers cooperatives to develop selected herb oils in current use by the flavour and fragrance industry and new local bush herbs for the international market. This initiative attracted substantial funding from the Rural Industries Research and Development Corporation (RIRDC) to develop this industry. The project commercialized a number of oils in existing international trade including chamomile (German), fennel, parsley, peppermint and dill weed oils. An investment in a solvent extraction plant made the production boronia absolute *(Boronia megastigma)* and blackcurrant bud concrete possible. Local plants have also been developed as sources of essential oils and absolutes, including kunzea oil *(Kunzea ambigua)* and Tasmanian black pepper concrete *(Tasmannia lanceolata)* [9]. The project had successfully developed and commercialized a number of natural products suited for particular market niches and maximized the value of their products through application of solvent extraction technology. It will be interesting to see the future growth of this project given the specialty approach taken and the number of times the company has changed ownership in the last few years.

A number of **other oils** for specialty markets are also produced in Australia. A native mint *(Prastanthera spp.)* is cultivated for dried herbs and oil (around 500 kg per annum). Small amounts (100-200kgs per annum.) of white cypress oil *(Callitris glaucophylla)*, extracted from a hardy timber tree native to the North Coast of Queensland is produced for use as an insect repellent. About 30-600 kgs per annum of blue cypress oil*(Callitris intratropica)* is produced. It was heavily promoted as a therapeutic oil for cosmetic applications but failed to gain wide acceptance due to formulation difficulties [10]. Other essential oils produced include emerald cypress *(Callitris columellris)*, around 10-30 kg per annum, Australian nerolina *(Melaleuca quinquenervia)*, Australian Rosalina *(Melaleuca ericifolia)* and *Melaleuca linarifolia* and *dissitifolia*.

In most cases, the Australian essential oil industry was developed by passionate, entrepreneurial pioneers who were single minded and determined to develop their industries. These people are legends on the Australian scene and played a paramount role in making the industry what it is today. However, some producers had to adapt to the realities of the international environment and develop strategies to minimize production costs through, 1) mechanizing maintenance, harvesting and extraction systems, 2) value add production through developing specialty products, 3) seek and develop niche markets, 4) add value to their business through activities like tourism and/or 5) enter into the general trading of the oils, sourced from other producers, both locally and overseas to survive. The original businesses that exist today earn their revenue from a wider range of sources of revenue than they did when they focused solely on essential oil production. Over the last 60 years, the Australian essential oil industry has become a specialty producer for selected niche markets, rather than a volume supplier.

The apparent rise in international interest in indigenous Australian products is enhancing potential for producers to develop niche product.markets. However, the establishment costs are high with restrictive regulation in the EU through REACH, the SCCP and BPD. GMP, HACCP, and other necessary certifications make small boutique production difficult due to the investment required. New essential oils almost have to be completely financed by the individuals or companies concerned due to the reluctance of financial institutions to lend on what they see as *speculative* ventures due to a poor history of new crop development. Also hindering future new oil development is the continuos cut back in government funded research in this sector.

Australian essential oil research is focused around a number of small research groups at University of New South Wales, Southern Cross University, University of Tasmania, University of Western Australia and the Wollongbar Agricultural Station. Based on an examination of three major international journals, some groups are still focusing on bio-prospecting. Other groups are exploring the applications of essential oils. Table 3.2. shows internationally reported research between 2003-2008 [12]. There is a lot more research undertaken in the agronomy aspects of crops, including breeding that are not published in the international journals. There appears to be a decline in the number of chemists who are active in the area of essential oil research in Australia [13].

Table 3.2. Internationally Reported Essential Oil Research between 2003-2008 - Australia

Species Investigated	Type of Investigation	When/Reported
Backhousia citriodora	Essential oil application	January 2003
Zingiber officinale	New chromatography methods	Jan/Feb 2003
Eucalyptus species	Taxonomic methodology	March/April 2003
Basil	Use of anti-microbial properties in packaging	May 2003
Santalum spicalum (work done in Germany)	New compounds and isomers	May/June and Nov/Dec. 2003
Essential oils of Tasmanian conifers	Screening for Chemical compounds	July/August 2003
Ozothamnus diosmifolius	Essential oil analysis of	July/August

	flower	2003
Leaf oils of *genera Barongia, Mitrantia, Sphaerantia and Ristantia*	Screening for chemical compounds	July/August 2003
Melaleuca teretifolia chemovars	Analysis of previously un-investigated essential oil	Sept/Oct. 2003
Ochrosperma lineare	Analysis of previously un-investigated essential oil	Sept/Oct. 2003
Eryngium L. species	Chemical analysis	Nov/Dec. 2003
Homoranthus species	Chemical analysis	Jan/Feb 2004
Cinnamomum camphora and C. eberm	Chemical variation	Jan/Feb. 2004
Melaleuca ericifolia	Genetic variation	Jan/Feb. 2004
Artabotrys spp.	Essential oil analysis	March/April 2004
Eucalyptus miniata, E. chartaboma, E. gigantangion	Chemotype analysis	March/April 2004
Milusa Genus	Essential oil analysis	May/June 2004
Medicosma Species	Essential oil analysis	May/June 2004
Palmeria Species	Essential oil analysis	July/August 2004
Pseuduvaria Species	Essential oil analysis	July/August 2004
Podocarpus species	Chemistry analysis	July/August 2004
Euodia and Melicope species	Essential oil analysis	July/August 2004
Endemic melicope	Leaf oil analysis	Sept/Oct. 2004
Brombya Genus	Leaf oils analysis	Sept/Oct. 2004
Melodorum species	Leaf oils analysis	Sept/Oct. 2004
Acronychia species	Leaf oil analysis	Nov/Dec. 2004
Lycopus australia	Leaf oil analysis	March/April 2005
Coatesia and Geijera species	Essential oil analysis	March/April 2005
Chemical defenses of *Trifolium glanuliferum* against earth mites	Essential oil application	July 2005
Flinersia species	Essential oil analysis	July/August 2005
Hedycarya species	Essential oil analysis	July/August 2005
Galbulimima baccata	Essential oil analysis	Sept/Oct. 2005
Decaspermum species	Essential oil analysis	Nov./Dec. 2005
Haplostichanthus Species	Essential oil analysis	Jan/Feb. 2006
Zingiber officinale	Analysis of essential oils	February 2006

	from clones	
Xanthostemon species	Essential oil analysis	March/Aprl 2006
Leionema ambiens	Essential oil analysis	March/April 2006
Phebalium species	Essential oil analysis	July/August 2006
Drummondita calida	Essential oil analysis	Nov./Dec. 2006
Melaleuca uncinata	Essential oil analysis	Nov./Dec. 2006
Backhousia enata	Essential oil analysis	Jan/Feb. 2007
Callitris species	Essential oil analysis	Jan/Feb 2007
Bosistoa Species	Essential oil analysis	May/June 2007
Philotheca species	Essential oil analysis	July/August 2007
Acacia howittii	Essential oil analysis	Sept/Oct. 2007
Plasmodium falciparum growth arrested by monterpenes from Eucalyptus oils	Essential oil application	Sept/Oct 2008

The Australian Government, through the Rural Industries Research and Development Corporation (RIRDC) in conjunction with a number of essential oil associations including the Essential Oil Producers Association of Australia (EOPAA), the Australian Lavender Growers Association (TALGA), The Mallee Oil Association, Natural Plant Extracts (NPE), a Tasmania essential oil farmers cooperative and the Tasmanian Boronia Growers Association, developed a five year research plan (2008-2013). The plan recognizes that for the industry to survive, a number of actions must be taken. These are, 1) increasing productivity through further value-adding of production, 2) responding to changing consumer requirements and supply chains both domestically and internationally, 3) improve natural resources management, 4) cope with climate change, and 5) improve bio-security. Consequently, the five year plan was developed to focus on 1) enhancing productivity through improved production systems, 2) building a capacity to cope with the changing regulatory environment, 3) support product development and 4) generally improve research and development capabilities within a sustainable framework. Some of the industry has established a levy system to raise funds for Research, which is supplemented by RIRDC funds to a total of around AUD 500,000 per annum.

New Zealand

The production of essential oils in New Zealand is a relatively recent activity dating back to the 1970s. The New Zealand industry is somewhat modeled on the Tasmanian industry in Australia. It is small, diverse and innovative as to what oils it selected for production. Production included peppermint oil, averaging about 4-5 tonnes, exported mainly to the United States, dill oil around 6 tonnes, also exported to the United States, fennel oil, around 6-8 tonnes, exported mainly to France and small amounts of Boronia Concrete, which is fed onto the Tasmanian industry. At this time, most of this industry was centered around

Canterbury where expertise was gained from the US peppermint industry in Oregon. However, many new ventures were short lived and closed down operations [13]. Plant rust, fluctuating prices and management issues all contributed to the demise of the industry in the 1990s.

Production of Dill, Coriander and Parsley proved themselves viable crops with good yields and returns which became the focus of further research to improve oil qualities. Similar to Tasmania, Universities and Research institutes (Crop & Food Research Ltd.) focused on plant physiology to develop the best means to produce acceptable industry standards of oil. Effort was also focused on producing maintenance, harvesting and transport systems that would allow for a number of small geographically diverse farms to produce dill oil. However although successful and efficient, relative returns for alternative crops rose faster than for the returns for dill oil and production died out. Boronia concrete was produced by Bay Boronias Ltd in Nelson where the concrete was passed onto Essential Oils of Tasmania to refine it into an absolute and market the product together with Tasmanian production. However due to over supply and price fluctuations, this industry died out and ceased to operate.

New Zealand remains a producer of a few essential oils, including Turpentine oil, Manuka oil, Lavender oil and Hop oil.

Turpentine Oil is produced from *Pinus radiate,* which was introduced from America and is now New Zealand's major forest species. Crude sulphate turpentine and crude Tall oil are processed at Mount Maunganui by a subsidiary of the Akzo Nobel Group. Production is a by-product of the timber industry. Crude tall oil is produced by acidulating the crude tall oil soap that separates from the liquor during the chemical recovery process in paper production. The crude sulphate turpentine is recovered from pulp digesters during steaming and cooking of wood chips. Approximately 18,000 tonnes of crude tall oil and 4,000 tonnes of crude sulphate turpentine are produced annually.

Crude Sulphate turpentine oils are rich sources of both alpha and beta pinenes. The pinenes are recovered through distillation where it is used to make pine oil (primarily terpineol and dipentene) Terpineol is recovered from pine oil by distillation and terpinolene from the dipentene. Beta pinene is used to make myrcene. Vacuum fractional distillation is used to process crude tall oil into distilled tall oil, tall oil rosin, tall oil pitch and tall oil heads. One of the early fractions, tall oil fatty acids consists of oleic acid, linoleic acid, and small amounts of linolenic acid and rosin. These materials are used in a number of industrial areas, including adhesives, ink resins, coatings and metal lubricants, emulsifiers for SB, ABS, various rubber products and fuels.

Manuka Oil has been promoted by New Zealand as a version of Australian tea tree oil and is steam distilled from the scrub *Leptospermum scoparium.* This scrub grows naturally around various habitats in New Zealand and is steam distilled from the wild or grown in small holdings. This oil has antimicrobial efficacy against yeasts, fungi and gram positive bacteria because of the β-triketones (23-32%) found in the oil [14]. Approximately 3-10 tonnes is produced each year and the oil used in personal care and an aromatherapy oil. The small industry is about 15-16 years oil and usually collectors undertake this activity in conjunction with honey collection.

Lavender and Lavandin Oils are produced in New Zealand based on some local varieties of *L. angustifolia* . Approximately 6 tonnes are produced annually based on small plantings, where the oil is sold to local markets or used in the manufacture of toiletries by growers.

Other Essential Oils. Hops have been cultivated in New Zealand for over one Hundred years and in 2002, a company ESL Extract Solutions Ltd. Was set up to extract hop oil through supercritical CO_2 extraction in the Nelson area. Using the same techniques, the company also extracts a number of non-volatile oils [15]. New Zealand also produces about a tonne of kanuka oil *(Kunzea ericoides)* used for personal care and aromatherapy applications. Some small amounts of organic tea tree (*Melaleuca alternifolia),* rose, rosemary and blue chamomile oils are also produced for the local market.

An examination of international research publications shows very little research between 2003-2008. However much research is either undertaken without publication or has been published locally. Some research has been patented with commercialization in mind, particularly in the area of isolation of 6-(1-oxo-2-methylprop-2-enyl)-cyclohexa-2,2,4,4-tetramethyl-1,3,5-trione from the *Kunzea* species, utilizing CO_2, rather than the traditional steam distillation [16].

Table 3.3. Internationally Reported Essential Oil Research between 2003-2008 – New Zealand

Species Investigated	Type of Investigation	When/Reported
Podocarpus halli	Analysis of the levels and variances of sesquiterpenoids and diterpenoids in the essential oil	July/August and Sept/Oct. 2003
Pittosporum species	Essential oil analysis	Sept/Oct. 2004
Kiwi fruit	Analysis of aroma compound release	July 2007

Papua New Guinea and the Pacific Islands

New Guinea is one of the richest areas in the World for biodiversity, hosting between 5-10% of the Worlds plant species which are largely unexplored. The essential oil industry is extremely small in Papua New Guinea and limited to wild collection of Agarwood in the jungles [17] and some wild harvesting of cajuput trees for local oil consumption. In Western Province, *Asteromyrtus symphyocarpa* and *Melaleuca quinquenervia* are harvested by community groups and sold as a medicinal oil and balm in the local markets [18]. Within the Pacific Islands, Fiji, Samoa, Tonga, Vanuatu, and French Polynesia, very small quantities of vanilla [19], pepper, nutmeg, cinnamon, ginger and clove oils are produced and exported to niche customers [20]. Other essential oils produced in the Pacific region include, sandalwood oil *Santalum austrocaledonium)* produced in Vanuatu [21] and on the Isle de Pines, New Caledonia, where many natural stands are greatly depleted [22].

Over the years there has been great interest in essential oils by botanists and natural product chemists from outside the region. Currently a small team from the University of the South Pacific, in Fiji is investigating indigenous plants for their essential oil constituents [23]. Another group based at the University of Auckland has studied a number of essential oils around the Pacific basin [24]. Most published research to date was undertaken by foreign universities in Europe (see Table 3.4.).

Table 3.4. Internationally Reported Essential Oil Research between 2003-2008 – Pacific Islands

Species Investigated	Type of Investigation	When/Reported
Myoprum crassifolium	New constituent identification	Nov/Dec. 2005
Dysoxylum richii and Synedrella nodiflora	Essential oil analysis	June 2006
Melaleuca quinquenervia	Essential oil analysis	July/August 2006

Indonesia

Indonesia is considered one of the world's major producers of tropical essential oils, with over USD $65 million exports per annum. Most essential oils produced compete with other producers based on comparative cost advantage, benefiting from the low labour and capital cost base that subsistence farming provides to the industry. This base also provides the industry with a very elastic supply, increasing or decreasing according to prevailing world prices. Indonesia has been involved in the production of essential oils since early colonial times and has strong links with the international market. Indonesia also has a large domestic market which is often turned to, in times of low prices.

Indonesia produces cajuput, cananga, cassia, citronella, clove leaf, ginger, gurjun balsam, nutmeg, palmarosa, patchouli, sandalwood, vetiver oils and vanilla resinoid [25]. Some Massoia bark oil is also produced and eugenol is refined from clove leaf oil and sold as a natural aromatic chemical.

Cajuput oil is produced in the Moluccan Islands, East Java and parts of Sumatra from natural stands. Production varies according to demand, ranging from 70-150 tonnes per annum [26]. Vary small amounts of *Asteromyrtus* symphyocarpa are wild harvested by communities around Marauke, in Papua and bottled as cajuput oil for domestic sale in Java under a community development program [27]. There are over 160,000 Ha. of Cananga trees cultivated around East Java, producing around 120 tonnes of oil of cananga oil [28]. Indonesia is the major world producer of cassia oil *(Cinnamomum burmanii)*, producing over

40,000 tonnes in 2000 [29]. Indonesia also ranks as the largest producer of patchouli oil from both small holder and plantation production in Sumatra and Java. About 1,100 tonnes are produced annually. Nutmeg production in Indonesia dominates world supply with 300-500 tonnes produced annually in Sulawasi, Moloccu Islands (Ambon) and Aceh in Northern Sumatra. Most production is small holder enterprise.

Citronella production has fallen over the last 10 years in Indonesia due to poor viability, even for small holders. Annual production is around 200 tonnes with the main production areas in Sumatra and West Java. Cultivation of clove trees is extensive to supply buds for the kretek (Indonesian cigarette) industry. However clove leaf oil is still produced as a by-product of the bud production, averaging over 1000 tonnes per annum. Approximately 15 tonnes of sandalwood oil are produced in West Timor and Sumba Islands. Vetiver production is declining in West Java from competition from vegetable farming and production has slipped over the last 10 years from 1000 tonnes to 40 tonnes.

Indonesia is the second largest producer of vanilla to Madagascar with the industry based in Bali. It is a very labour intensive crop and takes over 3 years for the vines to grow to fruit bearing age. Once harvested the vanilla pods must be stored for long periods of time to develop their fragrance. About 150 tonnes of resinoid is produced annually. Finally, massoia bark oil production over the last decade has resurrected in Papua from the tree *Cryptocarya massoy* [30]. The oil is valued for its sweet, coconut aroma and is steam distilled from the bark. The oil is rich in lactones and is used both in flavours for butter and milk and some fine fragrances. Table 3.5. shows Indonesian exports of essential oils over the last few decades.

Table 3.5. Export Statistics for Indonesian Essential Oils 1997-2002 [31]

Essential Oil	1997	1998	1999	2000	2001	2002
Patchouli Oil	**766**	**1,355**	**1,592**	**1,052**	**1,188**	**1,295**
Nutmeg Oil	**209**	**382**	**384**	**350**	**495**	**295**
Citronella Oil	**85**	**204**	**231**	**244**	**199**	**173**
Vetiver Oil	**38**	**24**	**1,045**	**413**	**1,583**	**75**
Cassia Oil	**37,334**	**38,080**	**39,232**	**39,833**	**40,673**	**41,038**
Other Essential Oils	**1,617**	**1.118**	**1.180**	**2,913**	**2,168**	**1,999**

A small amount of collaborative research is internationally published (see Table 3.6.). Indonesia faces funding, equipment, language and expertise difficulties. Most research on essential oil analysis, screening, agronomics and application are published domestically in Bahasa Indonesia. The Research Institute for Veterinary Science in Bogor has long been active in essential oil research, both at a field and laboratory level. There does not appear to be close ties between the commercial and research communities in Indonesia.

Table 3.6. Internationally Reported Research between 2003-2008 - Indonesia

Species Investigated	Type of Investigation	When/Reported
Melaleuca cajuputi (joint Australian project)	Use of infrared spectroscopy for foliar oil screening characteristics	April 2003
Kaempferia rotunda, K. angustifolia	Essential oil analysis	Feb/March 2004
Salacca zalacca (Snake fruit)	Identification of potential odourants	February 2005
Piper cubeba	Essential oil analysis	Jan/Feb 2007

Malaysia

Malaysia's agriculture sector is primarily based on palm oil and rubber. The country has developed a strong competitive advantage in these crops and established a well managed estate sector. However one of the disadvantages with this success is the lack of interest in other potential new crops. Essential oil production has been a curiosity and is not attracting serious mainstream interest. One of the major hindrances of essential oil development in Malaysia is lack of international market knowledge and the small domestic consumer market, thus making it unfeasible to develop any sizeable production for the domestic market.

Figure 3.3. Tea Tree cultivated in Perlis, Malaysia

With renewed national interest in agriculture and the biotechnology sector, essential oils are being viewed seriously again. There is currently around 200 hectares of tea tree plantation in Malaysia, producing small commercial quantities, which is consumed in the local market.

This may expand over the next few years. There is also some very minor production of patchouli, citronella and lemongrass for the local herb and aromatherapy industries.

Malaysian research has been focused on bio-prospecting forest trees for new compounds by the Universiti Kebangsaan Malaysia (UKM) and Forest Research Institute of Malaysia (FRIM) groups. Another group has been focused on identifying aromatic compounds from flowers and fruits at Universiti Sains Malaysia (USM), (see Table 3.7). These small groups have been very active and a number of other groups have restricted their publications to local journals, which have been concerned about oil analysis and crop trials. Other groups like the Malaysian Agricultural Research and Development Institute (MARDI) is involved in agronomic trials of essential oil crops, the Institute of Medical Research (IMR) in essential oil and constituent efficacy studies and the Malaysian Institute of Nuclear Technology(MINT) is involved in mutagenesis work.

Table 3.7. Internationally Reported Research between 2003-2008 - Malaysia

Species Investigated	Type of Investigation	When/Reported
Cinnamomum species	Comparative chemical analysis	Nov/Dec. 2003
Boesenbergia stenophylla	Essential oil analysis	Nov/Dec. 2003
Cinnamomum rhyncophyllum	Essential oil analysis	May/June 2004
Alpinia galanga	Chemical analysis	May/June 2004
Hedychium cylindricum	Chemical analysis	July/August 2004
Goniothalamus macrophyllus	Bark oil analysis	March/April 2005
Clerodendron fragrans	Essential oil analysis	July/August 2005
Alpinia conchigera, A. latilabris	Essential oil analysis	July/August 2005
Cinnamomum sintoc	Essential oil analysis	Nov/Dec. 2005
Elettariopsis slahmong	Essential oil analysis	March/April 2006
Elettariopsis elan	Essential oil analysis	May/June 2006
Curcuma indora	Essential oil analysis	May/June 2006
Elettariopsis smithiae, E. rugosa	Comparative oil analysis	Sept./Oct. 2006
Plumeria species	Comparative oil analysis	Nov./Dec 2006
Homalomena sagittifolia	Essential oil analysis	Oct/Nov. 2006

Thailand

Unlike Indonesia and Vietnam, interest in Thailand is mainly in producing herbs and traditional remedies. Essential oils are cultivated in a number of projects in small quantities for aromatherapy products and sold at retail level, thus maximizing their value and integrating cultivation and production with agro-tourism. These activities are strongly supported by the

Royal family as with the Non-Commissioned Royal Project on essential oils [32]. Oils produced include Lime *(Citrus aurantifolia)*, Lemongrass, Tangerine *(Citrus reticulate)*, Ginger, Tuberose *(Polianthes tuberose Linn.)*, Tumeric, Vetiver, Grapefruit *(Citrus maxima var. racemosa)*, sweet basil, clove, citronella, Galanga *(alpinia galangal)*, Jasmine, Kaffir Lime *(Citrus hystrix)*, and Champaka. Some novel essential oils like *Plai oil (Zingiber cassumunar)* have been developed for use in herbal therapies and small quantities of oil are marketed internationally to the aromatherapy market.

Figure 3.4. Domestic sales of essential oil based cosmetics is a growth market in Thailand

A company (Phurua Natural Oils) is operating in the highlands of Loei Province utilizing a solvent extraction technology developed by Dr. Peter Wilde of the UK. The benign solvent employed (HFC 134a or 1,1,1,2 - tetrafluoroethane) is a liquefied gas. It was originally developed as the "green" replacement for CFC refrigerants (the use of which was curtailed under the Montreal Convention). Because the process operates entirely at ambient temperature, the products are of unsurpassed quality. The process does not damage by heat (cooked) nor vacuum stripping (as is the case when attempting to remove less volatile solvents such as gasoline and alcohol) nor through exposure to acids (as with SCFE CO2 products) [33]. A modern plant is operating producing high value flower and plant extracts for the US and European markets. Products produced include Arabia Coffee Bean extract *(Coffea arabica L.),* Champaka Absolute *(Michellia champaca),* Ginger Extract *(Zingiber officinalis L),* Rose Absolute *(Rosa damascena Miller),* Jasmine Absolute *(Jasminum sambac L)* and Tuberose absolute *(Polianthes tuberosa L.).*

Figure 3.5. A small distillery in Trang for the extraction of oil from wild collected *Cinnamonum* species.

Essential oil research in Thailand is tended towards medical application. Most research is published locally due to language difficulties. Some internationally published research is shown in Table 3.8. Universities leading essential oil research in Thailand include groups at Maejo and Chiang Mai Universities in Chiang Mai in the North, Mahidol University and the National Cancer Institute.

Table 3.8. Internationally Reported Research between 2003-2008 - Thailand

Species Investigated	Type of Investigation	When/Reported
Vallaris glabra	Headspace analysis of volatile compounds	January 2003
Pandanus amaryllifolius	Experimental extraction techniques	May/June 2004
Streblus asper	Essential oil application	Sept/Oct. 2004
Citrus hystrix	Essential oil application	Sept/Oct. 2007
Chili Paste	Identification of aroma compounds	January 2008

Laos

Loas is a landlocked country between Thailand, Cambodia and Vietnam. The country produces around 100 tonnes of *benzoin resin*, integrated with shifting agricultural practices of which about 40 tonnes are exported to France. A variant of sassafras oil from *Cinnamomum camphor* is produced and exported to Vietnam and China. *Agarwood* is produced by some of the tribal communities in the country. This has been undertaken through wild collection. Currently plantations are being developed to step up production of *agarwood*.

Cambodia

Cambodia is a relatively new producer of essential oils with the economy rapidly developing after many years of war. Most land is idle and rural populations are looking for activities to earn a stable income. Currently three essential oils are being produced. *Cajuput oil* is produced from the wild in Southeast Svay Rieng province. Production of around 100 tonnes per annum is estimated, which is sold to neighbouring Vietnam. It is also estimated that between 100-200 tonnes of *sassafras oil* is also produced and being sold into Vietnam. Pilot production of *tea tree* and *lemongrass oils* is also being undertaken in the country [34].

The Philippines

Although the Philippines has a large domestic market and there is a large subsistence farming sector, essential oil production failed to develop in the same way as the Indonesian industry.

Elemi gum *(Canarium luzonicum)* is produced around the Bicol Region and is processed into resinoid and oil from the pathological gum, where it is exported primarily for aromatherapy and perfumery applications. There is some concern about poor regeneration of the forests as this oil is wild collected. This has caused the inclusion of *Canarium luzonicum* on the IUCN red list of threatened species. Elemi gum is exported to Europe for CO_2 extraction. Small quantities of Champaka absolute are extracted from the tree *Michelia longifolia and alba.* Clausena oil (*Clausena anisata*, Hook) is produced in small amounts as a medicinal flavour for the local brandy *Anisdos*, as a replacement for synthetic anethole [35].

Research appears to be locally orientated with international publication low because of budgetary constraints. The Ecosystems Research and Development Bureau (ERDB) is currently promoting essential oil production as a viable industry within the Philippines [36].

Table 3.8. Internationally Reported Research between 2003-2008 – The Philippines

Species Investigated	Type of Investigation	When/Reported
Citrus madurensis	Peel and juice oils	Jan/Feb. 2005

Vietnam

The cultivation of essential oils dates back to colonial times. However this industry was destroyed during the long Vietnam War. Under Government support the industry recommenced in the early 1980's, initially focused on exporting to the then Soviet Union and China. Oils developed through this era included *basil*, cornmint *(Mentha arvensis)* and *citronella oils*. When the Government gave farmers the freedom to decide what to grow, the production volumes of essential oils followed price trends. Production of cassia oil has increased steadily over the last 30 years to reach almost 5,000 tonnes per annum [37]. Citronella production varies between 200-500 tonnes per annum and has taken up much of the market that Indonesian production has lost. *Sassafras oil* was produced from wild growing plants in Lam Dong Province, but banned in 2000 because of depletion of the forest. Now *sassafras oil* is purchased from neighbouring Laos and Cambodia to supply the international market. Between 20-40 tonnes of basil oil *(methyl chavicol type)* is produced annually and exported to France. Around 150 tonnes of *cajuput oil* is produced for the local medicinal market each year. Vietnam is reported to also produce *star anise*, *Litsea cubeba*, *patchouli*, *palmarosa*, *tea tree*, *Eucalyptus citriadora*, *ginger* and *agarwood oils* [34].

Some collaborative research is coming out from various universities and institutes in Vietnam, including the Vietnam Pharmaceutical Corporation. Research has been most concerned with plant chemical analysis (see Table 3.10.). The Institute of Natural Products Chemistry in Hanoi and Ho Chi Minh City carries out both basic and applied natural product research, including essential oils and conducts training at the national level. Another body, the National Institute of Medicinal Materials (MIMM) undertakes bio-prospecting of the national bio-diversity, identifies and isolates compounds, develops products and extraction technologies, transfers technology and conducts training [38].

Table 3.10. Internationally Reported Research between 2003-2008 - Vietnam

Species Investigated	Type of Investigation	When/Reported
Crinum latifolium L.	Chemical composition analysis	May/June 2003
Artemisia vulgaris	Chemical analysis during lifecycle	July/August 2004
Illicium griffithi	Essential oil analysis	Jan/Feb. 2005
Litsea cubeba	Essential oil analysis	Jan/Feb. 2005
Citrus bergamia	Essential oil analysis	May/June 2006
Chloranthus spicatus	Essential Oil analysis	May/June 2006
Cupressus funebris	Essential oil analysis	May/June 2006
Citrus bergamia	Odour components	July/August 2006

The brief summary of essential oil production within the South-East Asian Pacific region shows great variance in growth and development. As mentioned at the beginning of this section, the established essential oil industry in Indonesia developed through a long history of trade links with colonial trading companies. After independence this continued as a sustainable industry because of natural competitive cost advantage and large domestic market. However not many new essential oils are being developed and commercialized. The case is similar in Cambodia, Laos and Vietnam. Although these industries died out during political instability and war, they have been re-established under trade promoted through the now defunct communist block in the 1980s. Both indigenous and foreign entrepreneurs are primarily responsible for the development of new essential oils in Cambodia and Laos. Malaysia's agriculture is heavily influenced by focus on palm oil and rubber and thus has been very slow to develop essential oils and development has relied upon entrepreneurs with the passion and interest in this industry. Essential oil development in Thailand was like Malaysia slow, but Thailand has recently focused on value adding agro-products and proactively developing market channels, seeking to develop domestic demand rather than focus on the international market. Other development in Thailand is focused on high value and specialty products.

Producers of essential oils in the South-East Asia and Pacific region generally face the problem of identifying viable oils to produce for commercial trade. This requires searching for potential opportunities. For example, blackcurrant buds were once imported by processors who found the supply of buds was seasonal and the export of buds for the production of an absolute was a secondary market. This was assessed as a market opportunity by the School of Agricultural Science at the University of Tasmania, where the industry was developed successfully, through developing mechanical harvesting as a source of competitive advantage [39].

However when new opportunities are exploited other producers will follow pioneers and create large over supply situations, which cause fluctuating price cycles. Essential oils are very specialised products where some markets are as small as 100 kg per annum in the case of some flower oils, while others could be as high as 30-40,000 tonnes in the case of citrus oils. Normally the higher the prices, the more stringent will be quality demands. Competition on the supply side for the major essential oils is always very competitive and price based. Customer servicing is another factor that acts against smaller producers.

As the major of essential oils in South-East Asia are produced through subsistence farming, it is expected that there will continue to be deficiencies of capital, expertise, technology and understanding of global markets. These markets will always be subject to erratic supply changes in response to increasing and decreasing demand. Lower cost producing countries will threaten established industries and the rising cost of food and increasing urban development will divert available land and attention away from essential oil crops. In the wild harvest sector, continued depletion of material will lead to declines in production and scarcity of oils.

The essential oil industry in the South-East Asia Pacific region has developed because of two main factors. Firstly, the presence of genetic material, for example, eucalyptus and tea tree in Australia, Cassia and citronella in Indonesia allowed an industry to develop as a crop. Long term sustainability depended on the country's relative comparative advantage to grow and survive. Secondly, many new essential oil crops have been developed by Governments, institutes and individuals assessing global opportunities and focusing research and development to assist in the commercialisation of the crop, thus developing a new source of competitive advantage through investment in research and development. It would appear that successful development of new essential oil industries in the region will be more dependent upon research and development and entrepreneurial opportunity assessment, rather than the basis of competitive advantage through low cost base environments.

Future essential oil development in the South-East Asia Pacific region will depend on Governments, enterprises and individuals developing a well thought out strategy to commercialise production. Failure to do so would only lead to an unsustainable and short term industry. Sustainability is linked more to strategy and differentiation, than cost advantage. Essential oil production cannot be looked at in macro terms, it is made up of individual producers and production clusters that have established a specific strategy which either succeeds or fails in the long term. As a non-vertically integrated primary industry, not only does essential oil production provide a low return to the producer, production is based on a turbulent market and immense potential competition from other producers.

Before going further into the business development aspects of the industry, the next few chapters will cover important technical issues of chemistry, extraction and the selection of an essential oil crop to develop.

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Chapter 4

THE PHYTO-CHEMISTRY OF ESSENTIAL OILS

Plants contain a number of chemicals based on simple sugars and carbohydrates. These include fatty acids, lipids, amino acids, nucleotides, nucleic acids and proteins, etc. Some chemicals act as primary metabolites which are vital to a plant's life and survival or act as precursors for secondary metabolites are concerned with the plant's interactions with the surrounding eco-system, principally acting as deterrents and attractants to pathogens. Some of these chemicals make up essential oils which comprise of materials from a number of chemical groups. It is important to understand the basic chemistry of plants and essential oils for the purposes of cultivation, extraction and trade. This chapter will introduce a basic outline of essential oil chemistry and highlight some of the relevant issues involved in this specialised field of natural product chemistry, relevant to essential oil development.

INTRODUCTION

Only as recently as fifty years ago the isolation of natural materials had to be undertaken physically, by chemical reactions to identify compounds. This limited the ability to identify more than just a few compounds in essential oils. The advent of spectroscopic methods created a revolution in natural product chemistry which enabled the identification of trace constituents and understand in more detail the chemistry of plants.

The spectrum of odorous substances is very narrow where only materials with a molecular weight below 300-400 and an appreciable vapour pressure at room temperature have noticeable odours to humans. Relatively few organic materials have pleasant odours, with the majority of materials diffusing acetic, propionic, butyric and lactic odours.

Essential oils are not the only chemical substances found in plants, metabolites like fats, fatty acids, waxes, oils, coumarins, anthraquinones and alkaloids are also soluble in ethanol and other solvents and can be extracted by distillation. Thus materials extracted from plants contain both volatile aromatic and odourless substances.

Generally, essential oils can be physically distinguished from other compounds because a drop of a volatile oil on paper will completely evaporate, unlike fatty oils. Essential oils are generally a pale to clear or slightly yellowish liquids, mostly insoluble in water, with specific gravities between 0.80 to 1.20. The odour of an essential oil will resemble the source flora, made up of a large number of constituents, sometimes into the hundreds. Some essential oil odours are dominated by a single constituent, like citral in lemongrass oil, but most oils rely on a complex mixture of constituents to provide the overall odour profile. Constituents in essential oils can be put into three classes, those greater than 1.0%, which are main constituents, those present in parts per thousand, which are minor constituents and those less than one part per thousand, which are trace constituents.

The odour contribution of each constituent to the overall profile depends upon individual volatility (boiling point and vapour pressure at room temperature), the perception threshold, synergism with other materials and masking by other constituents. Thus the role of trace and minor constituents in overall profile is often important and has implications in the extraction techniques required.

Due to different constituent volatility, changes to an essential oil odour profile can be noticed during evaporation. Thus an essential oil odour profile can be divided into top notes, which evaporate quickly, middle notes, which last for a longer period and residual base notes. Various studies have shown that straight chain aliphatic aldehydes and aldehydes with phenyl or cycloalkyl substituents at eight carbon atoms exhibit the highest threshold values and straight alkyl chains the lowest threshold values in natural aromatic materials [1]. Our olfactory receptors often confuse similar odour profiles in the sensory centres of our brain, where dissimilar chemical structures appear much more dominant as is sometimes the case with double bonded alcohols and aldehydes. This can mask other odour notes.

Given the vast number of different odours and chemical structures in essential oils, most compounds are biosynthesized by a small number of metabolic pathways. Although these pathways are common to all plants, small genetic differences introduce important differences in these pathways, thereby producing variances in biosynthesis [2]. These numerous reactions and transformations create exotic fragrance blends, which we call essential oils.

THE PLANT METABOLISM

Plants are metaphorically like a *'chemical factory'*, producing a wide range of complex compounds to promote growth and health (primary metabolites), some for defence and co-existence with the surrounding eco-system (secondary metabolites) and some chemicals for reasons that are still unknown to science. Plants are complex open systems with both positive and negative entropy. Plants through processes not fully understood, are a dynamic system under continual change, utilising sunlight, carbon dioxide, oxygen, moisture and soil nutrients in the synthesis of various chemical compounds (see Figure 4.1.).

A plant metabolism is the set of metabolites which can be categorised as primary and secondary. The primary metabolites are concerned with the basic life functions of the plant and provide precursors for the production of secondary metabolites. Secondary metabolites are concerned with the plants interactions with the surrounding eco-system and principally act as deterrents and attractants to insects.

The two most important primary metabolite processes are glycolysis process and the Krebs or TCA (tricarboxylic acid) cycles. Through the break up of glucose into other compounds, energy is also produced. The glycolysis process oxidizes glucose produced in the plant by photosynthesis, releasing both energy and a series of chemicals, of which pyruvate (pyruvic acid) is of prime importance as an intermediate for the Krebs cycle. This process can be carried out both aerobically and anaerobically.

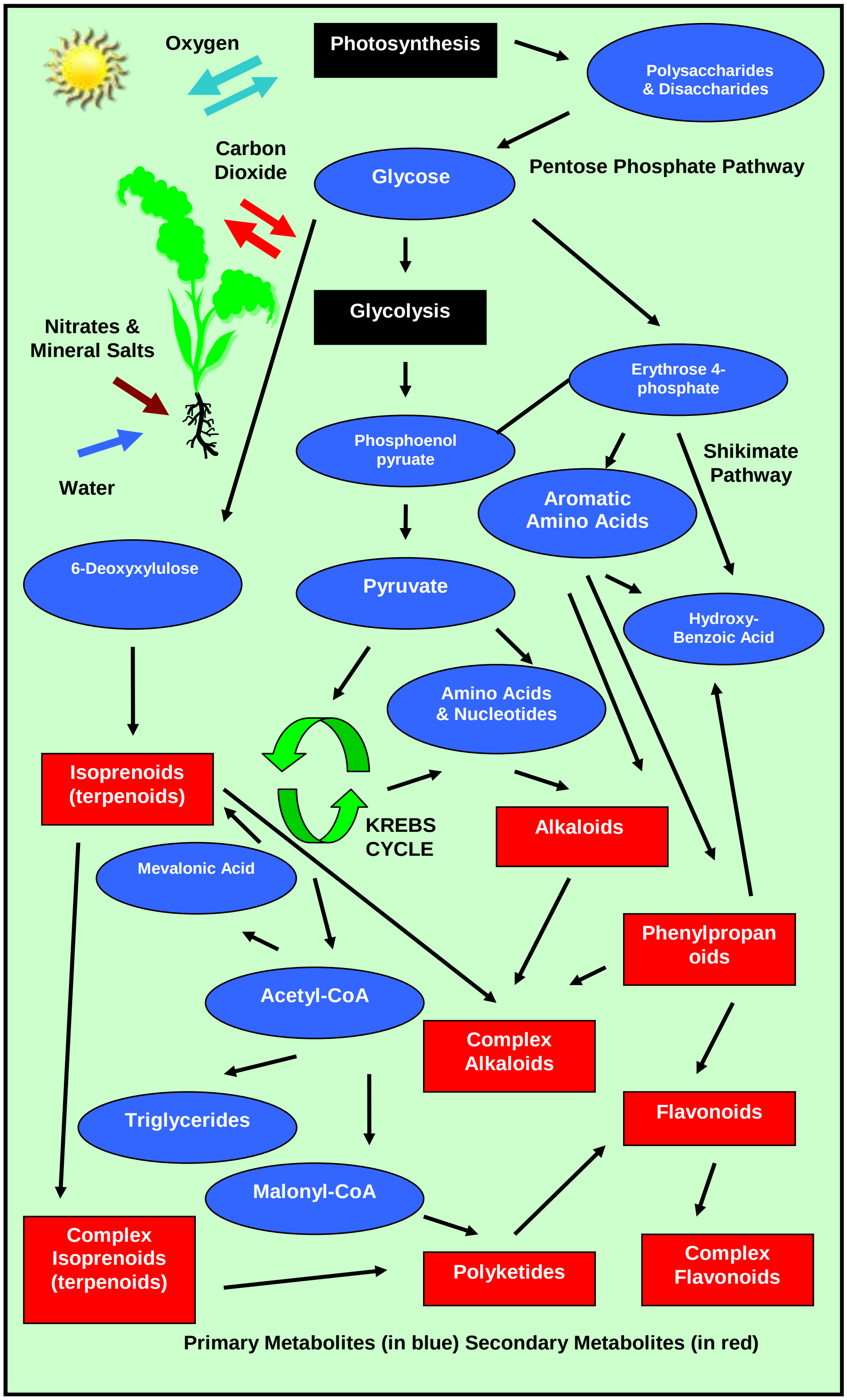


Figure 4.1. The Plant as a *"Chemical Factory"*.

Pyruvate is carried through to the Krebs cycle which is a series of enzyme catalysed chemical reactions, not exclusive to plants, but all living cells. Pryuvate is combined with coenzyme A, to form acetyl CoA, carbon dioxide and nucleic acids, through the route of nicotinamide adenine dinucleotide (NAD), a coenzyme and FADH2, an energy carrying molecule to form macromolecules comprising deoxyribonucleic acid (DNA) and ribonucleic acids (RNA), known as ATPs. ATPS play a role in signalling and carrier molecules for amino acids in protein synthesis. Mevalonic acid is also formed from acetyl CoA through the route of 3-hydroxy-3-methylglutaryl CoA (HMG-CoA), which goes to form terpenoid and steroid compounds. Coenzyme A breaks down to form malonyl CoA which plays a role in fatty acid and polyketide synthesis.

Another pathway, the pentose phosphate pathway also processes sugars through oxidation and synthesis. This is an alternative pathway to glycolysis, although it also involves the oxidation of glucose. Through different processes of dehydrogenation, hydrolysis, oxidative decarboxylation and isomerisation assisted by enzymes a number of precursors are produced for fatty acid and amino acid synthesis and the production of hydroxy-benzoic acid through the shikimate pathway, discussed later in this section. Finally a pathway, polyamine biosynthesis through 6-deoxyxylulose is known to produce a number of precursors for the synthesis of terpenoids [3].

The factors that influence these complex reactions very briefly summarized above are still the subject to research and thorough understanding [4]. Primary metabolites provide the precursors for aromatic chemical production in plants. They are also the precursors of a number of other compounds that are present in plants. A brief summary of these classes of compounds is as follows;

Carbohydrates

Carbohydrates are sugars, starches, saccharides and polysaccharides. They are formed in plants through the process of photosynthesis carried out in the leaves to convert carbon dioxide molecules in the air with water molecules from the root system with energy from the sun to produce glucose with oxygen as a by-product. The purpose of carbohydrates in plants is primarily to store energy in the form of starches, supply carbon atoms for synthesis into other compounds and form the structural components of the plant through cellulose production for cell walls and tissue. Carbohydrates make up most of a plant’s dry weight.

All carbohydrate compounds have polar heads and consequently carry simple glucose based sugars which are soluble in water. Sugars are moved around the plant in the form of sucrose, where glucose and fructose have been joined through a glycosidic bond made by removing water from the two sugars. The sugars are reconverted back to their original forms through hydrolysis, when they are needed for energy supply. These processes are governed by enzymes.

Two important carbohydrates in plants are polysaccharides and disaccharides. Polysaccharides are polymers made up of monosaccharides joined together by glycosidic bonds. They carry out the function of storing and moving energy for the plant in an insoluble form and forming celluloses, pectin and chitin for plant structures mentioned above. Disaccharides are carbohydrate sugars and involved in storage and transport of energy.

Lipids

Lipids are fatty substances with long hydrocarbon chains which are fat-soluble or hydrophobic. Lipids naturally occur in all flora as fats or non-volatile oils. There are three classes of lipids in plants;

1. Triglycerides or fats that attach themselves to glycerol to form energy reserves, usually in seeds. These also encompass the main unsaturated and saturated acids in plants (caprylic, oleic, linoleic, palmitic and stearic),
2. Membrane lipids which carry a polar group such as a sugar in a glycolipid or phosphate form (phosphate lipid), which act through enzyme catalyzed hydrolysis to create secondary messengers concerned with signal transduction, and
3. Cuticular lipids which are a complex mixture of hydrocarbons and esters of long chain aliphatic acids and alcohols that create a waxy type barrier between the plant tissue and cells and the immediate environment. This lipid layer is called a liposome where the polar heads of the lipids orientate towards an aqueous cell environment and tails minimize contact with any water, thus building a lipid bi-layer.

Most lipids are formed through biosynthesis involving acetyl-CoA with coenzyme A during the Krebs cycle. Most lipids are stored in the seed tissue, embryo or endosperm. The amount of lipids a plant can store varies greatly from 0.1% to up to 70%. The amount of lipids contained in plants varies with the stage of growth where in early growth energy is stored as a carbohydrate and during maturity transform to mainly triglycerides. Triglycerides convert back into carbohydrates during seed germination. Lipids in plants are the source of edible vegetable and other oils used in industry for lubricants, cosmetics, paints and pharmaceuticals, etc.

Amino Acids

Plants require nitrogen compounds for life in the form of proteins. Amino acids are the building blocks or precursors of proteins and are thus a basic component of all living cells. The starting point of most amino acid production originates from the Krebs cycle. Carbon and oxygen from the air are combined through photosynthesis with hydrogen in the form of carbon hydrate and nitrogen taken up from the soil as nitrate, reduced to nitrite and ammonium ions. Amino acid molecules contain both amine and carboxyl groups, attached to the same carbon molecule, which can make them either a weak acid, a weak base which does not easily ionize in water, a hydrophile soluble in water if they are polar and hydrophobe not soluble in water, if non-polar.

Amino acids act in the physiological development of plants and different amino acids are produced at different stages and times as required. Amino acids primarily form into proteins, although there are a number of pathways through condensation of amino acids into chains which are linked through peptide bonds, which also produce a molecule of water from the process. Proteins are defined by the particular sequence of amino acid residues within the structure of the protein.

Most proteins in plants are enzymes, which act as catalysts to control and carry out all the chemical changes required in the plant metabolism. Enzymes control photosynthesis, gene replication, information processing, stress reduction processes and building cell structures in growth. The specific purpose of each protein is set by the particular sequence of amino acid residues in the structure.

Nucleotides

A nucleotide is a compound that consists of a heterocyclic base (a basic aromatic ring), a sugar and one or more phosphate groups. Nucleotides are the structural units of DNA, RNA and several cofactors which play an important role in the plant metabolism and signaling.

Nucleotides are formed from phosphates attaching to nucleosides (an amine of a carbohydrate), which are basically glycosylamines attached to a sugar ring called the nucleobase. Nucleosides get their name from the sugar. These processes are controlled by coenzymes, NAD which is biosynthesized from asparatame to form nicotinate nucleotide reacting with ATP to form di-phosphates and deamido-NAD, then onto a cycle to produce a number of various nucleotides through various reactions.

Nucleic acids are comprised of nucleotide chains which carry the basic genetic information to form the structure of the plant cells. The role of nucleotides and nucleic acids in plants is still not fully understood [5] and cannot yet be broadly compared to the role they play in humans and animals [6], although they are understood to play a role in germination of seeds, seedling growth, flowering, fruit ripening, responses to stress and pathogens, the regulation of proteins and nutrient entry into cells [7]. Deoxyribonucleic acid (DNA) contains the genetic blueprints and instructions to develop a plant and its functions and ribonucleic acid (RNA) plays an important role in the process of transferring genetic information from DNA to proteins.

There are numerous other primary metabolites in plants.

Plants produce hormones which work with enzymes to control chemical production within the plant to achieve cell division, enlargement, flowering, fruit ripening and seed germination, etc. Examples of plant hormones include auxins (example indole acetic acid) that assist in promoting stem elongation, inhibit growth of lateral buds and promoting growth on the darker side of plants away from sunlight, so plants bend towards the light. Auxins also promote the starting of growth where buds or stems have been broken off from the plant. Other plant hormones include gibberellic acid to promote stem elongation and abscisic acid, to promote seed dormancy by inhibiting cell growth. Not all compounds can be strictly classified as hormones, but as plant regulators which include polyamines, jasmonates, salicylic acid, brassinosteroids and florigens.

Chlorophyll is a large molecule made up primarily of carbon and hydrogen atoms with a single atom of magnesium surrounded by a nitro aromatic ring. The purpose of chlorophyll is to carry out photosynthesis by trapping photons to stimulate electron activity to induce the production of adenosine triphosphate and ATP for storage in the chloroplast as starch. Chlorophyll is present in both the leaves and stems and can vary in its concentrations during the year. Chlorophyll is also the pigment that gives plants their green colour.

Vitamins are molecules in plants that function as cofactors for enzymatic reactions and perform a number of other functions in plants. There is still little knowledge about the pathways, application, regulation, storage and degradation of vitamins produced in plants [8]. Vitamin C as ascorbate is produced by GDP-L-galactose phosphorglase as an anti-oxidant to deal with plant stress issues caused by drought and UV radiation [9]. Thiamin, known as vitamin B1, as thiamin pyrophosphate is a cofactor for pyruvate and alpha-ketoglutarate dehydrogenase reactions and transketolase catalysed reactions through the pentose phosphate pathway. TPP acts as an energy synergist in these reactions. Riboflavin, known as vitamin B2, is a precursor for the coenzymes flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD) in the Krebs cycle. Riboflavins are produced through hydrolysis in the cycle [10] and is reported to assist in the induction of disease resistance in plants through signaling the expression pathogenesis genes [11]. There are a number of other vitamins produced by plants for various purposes including niacin (nicotinic acid and nicotinamide), known as vitamin B3, which required for the synthesis of NAD+ and NADP+, and pantothenic acid, known as vitamin B3, formed from beta-alanine and pantoic acid, required for the synthesis of coenzyme A and as a component of the acyl carrier protein (ACP), required to metabolise carbohydrate through the Krebs cycle.

Some other important primary metabolites include the compounds listed in Table 4.1. [12]

Table 4.1. Some Other Important Primary Metabolites

Class	**Function**
Lectins	Assists in absorbing nutrients and absorbs toxic substances.
Chitinases	Damages insects midgut
Alpha-amylase inhibitors	Digestive enzyme inhibitor
Proteinase inhibitors	Digestive enzyme inhibitor
Indole-3-glycerol phosphate lyase (IGL)	Formation of free indol
Vegetative storage protein (VSP)	Part of the systemic response
Glutathione S-transferase (GST)	Detoxify or inactivate toxic compounds
Beta-glucosidase	Unknown
Calcium binding elongation factor (caEF)	Signalling pathway
Hevein like protein (HEL)	Unknown
Phospholipase A2	Generation of second messenger
MAPkinase	Phosphorilation of transcription factors
Polyphenol oxidate (PPO)	Reduction of the nutritive value of protein
1-aminocyclopropane-1-carboxylic acid oxidase (APO)	Ethylene biosynthesis
Allene oxide synthase (AOS)	JA biosynthesis
Phenylalanine ammonia-lyase (PAL)	Phenylpropanoid pathway
Peroxidase	Lignin synthesis, hypersensitive response
Lipoxygenase (LOX)	JA biosynthesis

Many primary metabolite activities such as enzyme activation, carbon depletion and sugar addition are diurnally regulated according to light/dark cycles. What triggers the actual movements and their interrelationships is not totally clear [13], although it has something to do with low sugar levels at night, which appears to be controlled with as many as fifteen different proteins [14]. These processes also differ in various plants. Our understanding of primary metabolites is still growing through research and a number of functions of chemical compounds in the areas of plant metabolism regulation are still being discovered, especially in biosynthesis and plant signaling [15].

THE METABOLIC PATHWAYS

One of the functions of primary metabolites is to provide feed-stocks for secondary metabolite production. This is undertaken through three primary pathways.

The mevalonic acid pathway, sometimes called the terpenoid pathway is responsible for the synthesis of a wide range of metabolites and terpenoids. The metabolites produced through this pathway include the phytol chain found in chlorophyll and plant growth regulators or pseudo hormones, gibberellins and abscisic acid, discussed above. The mevalonic acid pathway is an enzymically controlled route to the formation of mevanolic acid, which through a number of steps synthesizes into isopentenyl pyrophosphate (IPP) and dimethylallyl pyrophosphate (DMAPP) where they are oxidized, reduced or hydrated into a wide range of terpenoids and steroids. Recently, a mevalonic acid independent pathway to IPP and DMAPP has been found utilizing deoxyxylulose phosphate and methylerythritol phosphate as precursors [16]. The following groups of terpenoids are produced by these methods;

- Hemiterpenoids: consist of a single isoprene unit, examples phenol,
- Monoterpenoids: consist of two isoprene units, examples geraniol, limonene and terpineol,
- Sesquiterpenoids: consist of three isoprene units, example farnesol,
- Diterpenoids: composed of four isoprene units, example cafestol,
- Sesterterpenoids: comprise of five isoprene units, example cericerane,
- Triterpenoids: comprise of six isoprene units: example squalene,
- Tetraterpenoids: comprise of eight isoprene units, example, *gamma*-carotone, *alpha* and *beta*-carotenes, and
- Polyterpenoids: long chains of many isoprene untis: example polyisoprene in rubber.

Chemically terpenes which are very important in flavour and fragrances are very similar to terpenoids, where methyl groups are adjusted or removed or oxygen atoms added.

The shikimic acid pathway produces precursors for a number of metabolites, amino acids, plant regulators, alkaloides and phenolic compounds. This pathway is unique to plants and continues on from the pentose phosphate pathway, where carbohydrate precursors derived from glycolysis as erythrose-4-phosphate react with phosphoenol pyruvate to form shikimic acid [17]. The shikimic acid pathway breaks into a number of branches as shown in Figure 4.2.

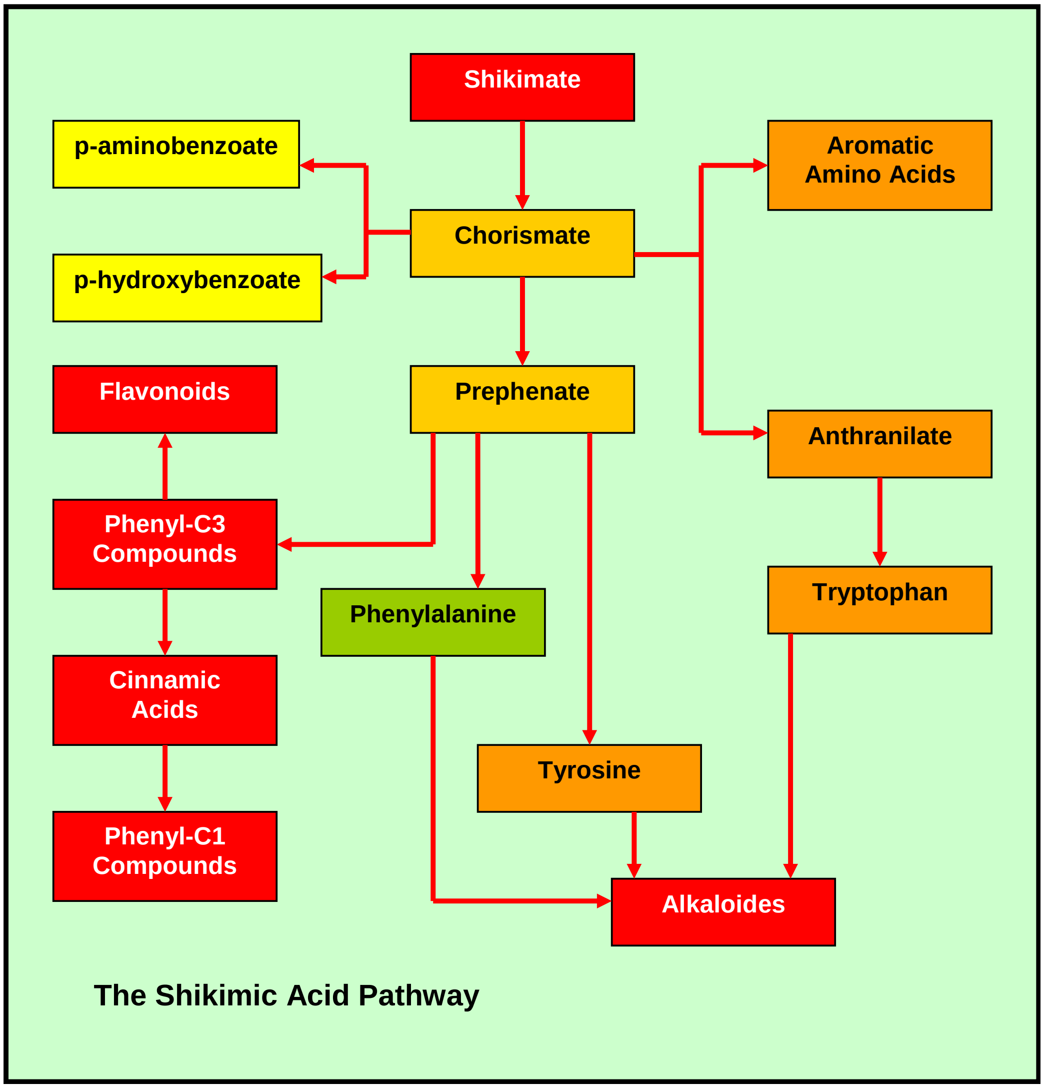


Figure 4.2. The Shikimic Acid Pathway.

Approximately 20% of all carbon fixed in a plant's leaves is processed through this pathway, which makes up around 30% of a plants dry weight [18]. Shikimic acid undergoes hydrolysis to break off pyruvic acid and through a number of other steps converts to chorismic acid, a precursor for a number of compounds. Chorismic acid is a precursor of salicyclic acid, a plant hormone. Chorismic acid also undergoes a Claisen type rearrangement to form prephenic acid, which converts into tyrosine and phenylalanine. Tyrosine, an amino acid is believed to be involved in the photosynthesis process, acting as an electron donor in the chloroplasts to reduce oxidised chlorophyll, the signal transduction process in proteins, and to assist in producing insect deterring glucosinolates. Tyrosine is also a precursor to the pigment melanin. Phenylalanine, also an amino acid derives a number of flavonoids, lignin and coumarins, and also assists in producing insect deterring glucosinolates, similar to tyrosine.

Through another path anthranilate and its derivatives are produced. Little is known about the purpose of anthranilates in plants, although they occur as both methyl and acid forms in many plants. Anthranilates are precursors for alkaloids and tryptophan. Tryptophan is another amino acid and is a building block for proteins and a precursor for niacin, a number of alkaloids and indole. Finally through the shikimic acid pathway a number of phenyl propanoid compounds are formed through cinnamic acid by elimination of ammonia phenylalanine. Common phenyl propanoids include methyl chavicol, methyl eugenol, eugenol, methyl cinnamate and vanillin. Phenyl propanoid accumulation in the plant metabolism is still an area where little is known.

Flavonoids and anthocyanins are pigments and phenolic compounds responsible for the colours of flowers in higher plants. Flavones provide the yellow and orange colours and the anthocyanins are the source of red, violet and blues. Flavonoids play some role in attracting insects to feed and pollinate, while other have bitter tastes and repel insects like caterpillars. Flavonoids are also considered antioxidants. Another important small group of polyphenols are the tannins that bind and precipitate proteins and may assist in the repair of damaged plant tissue, in conjunction with phytoalexins, which are reported to have antimicrobial properties [19]. Tannins are very important flavonoids in teas, wines and some fruits. Tannins are used in the preparation of leather, the manufacture of colours and as dietary supplements.

Saponins are glycosides of steroids, steroid alkaloids or triterpenes found primarily in the outer tissue of plants as a waxy protective layer, although they are also found in other parts including the roots [20]. Many saponins are toxic and thought to be part of the metabolism to deter insect predators. Saponins are not found in all plants. Within the last few years a number of medical and industrial uses have been found for saponins. Some of the existing uses include foaming agents in soft drinks and beer, fire extinguishers, photographic emulsions, and food sweeteners. In the medical field saponins are used for cough medicines and cholesterol. Research is ongoing utilizing saponins to fight cancer [21].

Remnants and artefacts from the pathways and degradation of fatty acids, amino acids, nitrogen and sulphur compounds and also from storage of foliage after harvesting lead to the formation of a number of compounds. These trace compounds, some desirable while others undesirable will contribute to the odour profiles of a number of essential oils. Unsaturated C6 aldehydes can arise in green tissue wherever they are cut, damaged or attacked by insects, through enzymic degradation of linolenic acid [22]. The degradation of lipids in plants leads to the formation of short chain alcohols and aldehydes, such as the *n*-hexanol and *cis*-3-hexanol, compounds that provide green notes to an essential oil. Only with much more sensitive analytical equipment over the last few last years have volatile constituents contributing to the flavour of fruits and vegetables been discovered. However their enzymic pathways are often still unknown. In some plants essential oil constituents are free within or bound with glycosides within the plant.

The pathways create the through-fare from which the primary metabolites produce a set of secondary metabolites primarily concerned with the plant's interaction with the immediate environment. The secondary metabolite compounds concern themselves with defences against predators, parasites, diseases, interspecies competition and facilitate the reproductive processes. It is from the secondary metabolites that the constituents of essential oils originate and also a number of other economic products. The secondary metabolites are unique to each plant species, unlike the primary metabolites which are common across the flora genus.

Secondary Metabolites and Plant Defence Systems

The secondary metabolites, primary terpenoids, alkaloids, phenolics and nitrogen compounds evolve within the metabolism and are utilised to improve a plant's chances of survival against herbivory, primarily insect predators. Plants utilise a number of attributes against predators which include physical characteristics, such as surface protections [23], the production of complex polymers that inhibit digestion of the plant [24], the production of insoluble terpenoids to inhibit digestion, the production of toxins through the alkaloids, and the production of volatiles to attract predators of the insect herbivores [25]. Conversely, insect herbivores utilise a number of counter measures to overcome plant defences such as detoxification of toxic compounds [26], avoidance mechanisms [27], sequestration of poisons [28] and adulteration of the gene pattern [29]. Multiple defence systems are required because of different parts of a plant [30] and different types of herbivory [31], [32]. These defences also assist the plant during times of stress due to droughts, water logging, intensive UV radiation and plant damage. In the reproductive cycle plants emit aromatic odours to either attract insects to assist in pollination. An overview of the plant defence system is depicted in Figure 4.3.

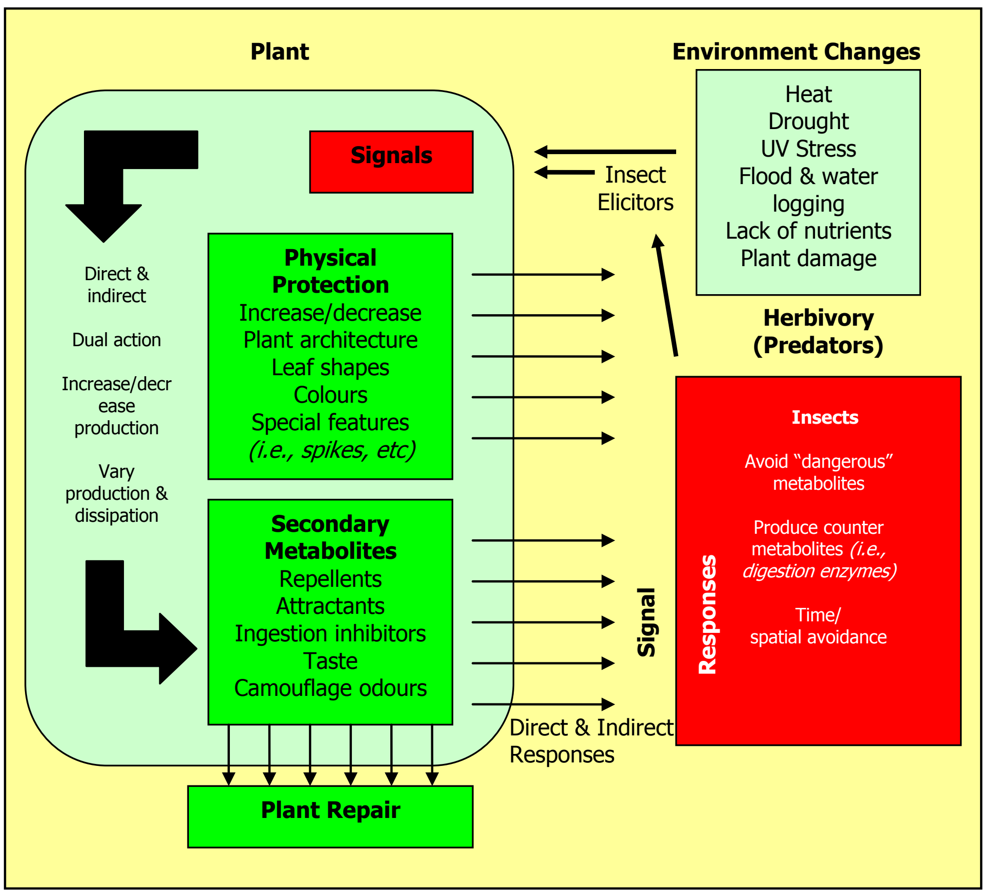


Figure 4.3. A Plant's Defence System.

Within the eco-system plants and insects interact, co-exist and compete continuously in very complex ways. This is an evolutionary process as both plants and insects modify their defences and attack strategies continually. Therefore from the plant perspective, different chemical defences will be utilised at different times to meet these evolving threats and stresses [33]. Thus as plants grow, they change in leaf, branch and other physical characteristics, including the growth of flowers and fruits which involves certain chemical changes within the plant metabolism, where certain insects can take advantage [34]. This is an important consideration in essential oil production as the desired oil constituent profile may only develop during a particular part of the plant lifecycle [35].

AROMATIC COMPOUNDS FOUND IN PLANTS

With the exception of compounds that are products of catabolic breakdowns of lipids, amino acids, fatty acids and terpenoids, the plant metabolism is directly responsible for producing aromatic compounds within a plant through a limited number of pathways discussed above. Specific and unique extensions of these pathways exist in particular plants, yielding specific aroma compounds found in certain plants. In addition there are also a number of aromatic compounds found in fruits and vegetables.

Through the plant metabolism, essential oils comprise of a large number of volatile terpenoid and non-terpenoid compounds which are based on hydrocarbons and oxygenated derivatives, although some contain nitrogen or sulphur derivatives. The hydrocarbons are connected by single, double or triple bonds to form higher molecular weight hydrocarbons, through rings or chains. Oxygen, hydrogen, nitrogen, sulphur, and other carbon atoms attach themselves to form various aromatic compounds. Methane, a colourless and odourless gas is the simplest hydrocarbon. Some hydrocarbons are non-terpenoid and exist as short chain alcohols and aldehydes formed through degradation of phospholipids and fatty acids. Saturated homologous straight chain structures are alkanes and their unsaturated forms alkenes. Alkenes can form as isomers, a molecule with the same chemical formula with the same bonds between atoms, but arranged differently. These are mostly as stereo isomers in the *cis-* and *trans-* form, where the two molecules appear as a ‘mirror’ image of each other. Molecules with three carbon atoms form straight chains, where those with four carbons or more can form either straight or branched chains. Terpenoids usually have a carbon base of 10, 15, 20 or 30 atoms, where five carbon atoms are called an isoprene unit. Various types of terpene compounds can be classified according to the number of isoprene units they contain as Table 4.2. lists below.

Table 4.2. Classification of Terpenoids according to Isoprene Units

Terpene Classification	Carbon Atoms	Isoprene Units
Hemiterpenes	5	1
Monoterpenes	10	2
Sesquiterpenes	15	3
Diterpenes	20	4
Triterpenes	30	6
Tetraterpenes	40	8

A single isoprene unit is a hemiterpene, when two isoprene units link together they form a monoterpene, three form a sesquiterpene, four form a diterpene, and so on.

The types of aromatic compounds found in plants are;

- *Terpene Hydrocarbons*

  Terpenes are a very large group of plant hydrocarbons formed by polymerization of five carbon atom units (isoprenes) that form in both chains and rings. They may be reduced and oxidized into a vast array of other compounds including alcohols, lactones, acids and aldehydes, thus the starting point of synthesis of the majority of aromatic compounds. Terpenes are present in the resinous foliage of leaves. Terpene compounds heavier than diterpene do not contribute to the odour of essential oils, although they may be present.
- *Monoterpenes*

  Monoterpene compounds are found in nearly all essential oils and have a structure of ten carbon atomes (two isoprene units) with at least a double bond. They quickly react to air and heat and consequently lack stability and long shelf life as they are quickly oxidised. Monoterpenes are present in citrus, conifers, herbaceous plants as well as vegetables and fruits. Monoterpenes are formed through the mevanolate pathway by the conversion of methylallyl pyrophosphate with isopentenylpyrophosphate (IPP) to form geranyl pyrophosphate, the precursor of monoterpenes (see Figure 4.4.). Compounds like *alpha*-pinene and *beta*-pinene are formed through cyclization from geranyl pyrophosphate through linaloyl pyrophosphate. A large number of monocyclic compounds like myrcene are also derived through this route.
- *Sesquiterpenes*

  Sesquiterpenes consist of 15 carbon atoms or three isoprene units linked to each other, head to tail. This formation can produce more than 300 different hydrocarbon sesquiterpenes. Sesquiterpenes have great diversity in construction containing up to four carbocyclic rings. Sesquiterpenes are synthesised from farnesylpyrophosphate which is condensed from geranylpyrophosphate, derived from isoprenyldiphosphate (IPP) and dimethyllallyldiphosphate (DMAPP), along the mevalonate pathway. Through further oxidative transformations, a number of other terpene compounds are formed (see Figure 4.4.).

  Ionones and damascenones are potent aroma compounds derived from degrading of high molecular weight terpenes or carotenoids through oxidation. Carotenoids are found in a variety of plants and fruits, especially berries.
- *Oxygenated Compounds*

  Oxygenated compounds contain oxygen molecules within their structures. These include alcohols, aldehydes, amides, carboxylic acids, esters, ketones, nitro compounds and oxides.
- *Phenols*

  Phenols are one of the three major chemical groups in plants along with terpenoids and alkaloids. Phenols originate from phenylalanine or tyrosine through the shikimic acid pathway. Phenylalanine ammonia-lyase removes ammonia from phenylalanine to produce *trans*-cinnamic acid. Cinnamic acid itself is not an important odourant but acts as a precursor for numerous aromatic metabolites including aldehydes, alcohols, lactones, and esters, outside the phenolic group.

Phenols are defined as any compound having molecules with one or more hydroxy group bonded to a benzene ring. As such, many compounds including flavonols, catechins, anthrocyanins, isoflavones, dihydroflavonols, chalcones, quercetin, ellagic and tannic acids, vanillin, caffeic acid, curcumin, courmarins and lignans are also defined as phenols. Phenols oxidise easily and are partly the reason why plant material darkens after cutting due to this reaction. Phenols in essential oils also darken on exposure to air and tend to oxidate. Phenols are acidic due to the –OH group in the molecule. In plants phenolic compounds usually couple themselves with glucosyl compounds.

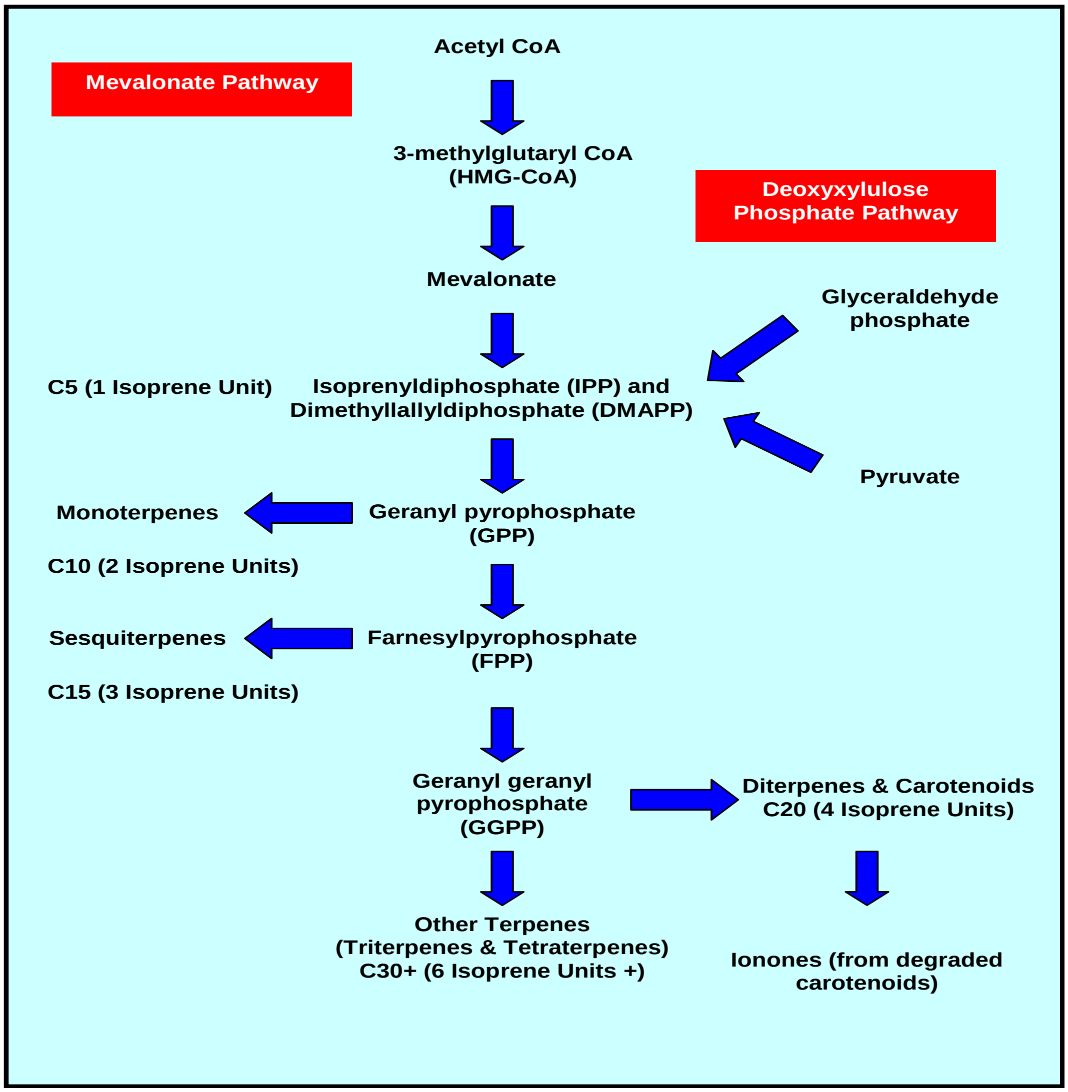


Figure 4.4. Mevalonate and Deoxyxylulose Phosphate Pathways to Terpene Formation.

- *Alcohols*

  Alcohols are very similar to phenols and aldehydes in structure. Alcohols are derived from aldehydes through dehydrogenase activation. They are also produced through amino acids through oxidative decarboxylation in ripening fruits. Coenzyme A esters may also be transformed in some way to alcohols [36]. Fatty alcohols C8 (octyl, caprylic) occur in citrus fruits with their corresponding esters and aldehydes. Alcohol C9 (nonyl, pelargonic) is found in orange and oakmoss. Alcohol C10 (decyl, capric) is found in orange and ambrette seed. Alcohol C11 (undecylenic) is found in the leaves of *litsea odorifera*, and alcohol C12 (lauric, dodecyl) is found in lime. Alcohols do not have the same pungency as their corresponding aldehydes, although as alcohols get higher in molecular weight their odour intensity increases, until nonanol C9, when they start to weaken again. Hydroxy hydrogen atoms of alcohols tend to carry some of the odour characteristics of aldehydes, while maintaining the smoother alcohol notes [37]. Due to the polarity of alcohols they tend to be more soluble in water than most other aromatic compounds. Alcohols transform into other compounds including their corresponding aldehydes, acids and esters through methanol dehydrogenase catalylisation [38[.
- *Aldehydes*

  Aldehydes are found in fruits and many plants with their corresponding alcohols and esters. Aldehydes have more pungent odours than their corresponding alcohols. Long chain or aliphatic aldehydes are much more pungent than the other aldehydes of the homologous group, which are extensively used in perfumery, *i.e.*, *benzaldehyde*. Aldehydes are relatively unstable materials which are prone to oxidisation, polymerization and acetal formation within essential oils. Aldehydes, esters, alcohols and acids can be converted and can revert within plants through transformation and oxidation. These reactions are thought to be controlled through coenzymes. There is a close interrelationship between acids, aldehydes, alcohols and esters within the Krebs cycle originating from branched amino acids aldehydes are derived from corresponding acids through ð-oxidation where it is decarboxylated. Through further reduction the aldehyde will convert to its corresponding alcohol and later undergo esterification. This can reverse where the aldehyde can oxidise to a corresponding acid, later leading to the conversion to odd-chain esters [39]. This process is capable of producing a wide range of aromatic compounds (see Figure 4.5.).
- *Esters*

  Esters are formed from acids and alcohols, usually benzenoid, carboxylic and monoterpenic acids to form esters in essential oils. Esters are also found in fruit and vegetables. Examples of esters in essential oils are linalyl acetate, benzyl benzoate and benzyl isobutyrate. Esters are formed through exiting the β-oxidation acting on acetyl CoA during the Krebs cycle [40].
- *Ketones*

  Ketones are often present in small quantities in plants and provide fruity flavours in fruits. They are highly reactive to air and heat and will easily convert to their corresponding acetals and alcohols. Ketones are formed through the Krebs cycle through ß-oxidation of alcohols or with acyl CoA activation from carboxyl acids by hydrolysis causing decarboxylation.

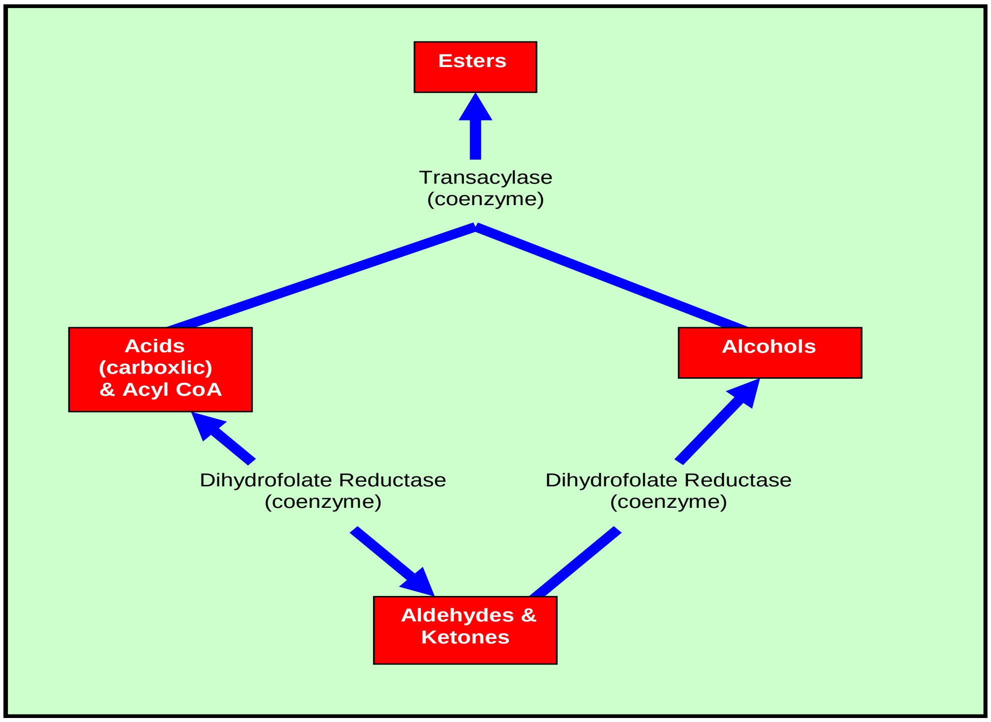


Figure 4.5. The Acetyl CoA Pathway for the Biosynthesis of Aldehydes, Alcohols and Esters.

- *Lactones*

  Lactones exist in essential oils as γ-lactones, a five membered cyclic ring and δ-lactones, six membered cyclic rings. Lactones are found in herbs, coffee, fruits, dairy products, with fruity, nutty and hay like odour profiles. Macrocyclic lactones also exist in a number of essential oils and are known as musk lactones. Coumarins, a lactone in tonka bean and hay is formed through hydroxylation of *trans*-cinnamic acid to coumaric acid and then glycosylation, which is stored in cavities of plant tissue where it undergoes light-dependent isomerization on rupture of the plant tissue, crystals form [41]. Further synthesis of coumaric acid will give rise to dihydrocoumarin. Coumarins are widely used in fragrances for grassy, hay like green spicy notes. Another form of lactones are benzofluran derivatives found as butylphthalides in celery and angelica [42].
- *Nitrogen Compounds*

  Methyl anthranilate is a very freshly scented citrus-floral odour compound. As secondary metabolites, amines maybe generally involved in growth regulation of plants [43] and along with other aromatic chemicals [44], methyl anthranilate has been found to be both a bird attractant and repellent [45]. Amines are very reactive to air and darken on exposure, as well as being photosensitive. They can also react with aldehydes to form aldimines. Amines are produced through a degradation pathway controlled by amine oxidase enzymes, within the amino acid pathway. Indole and skatole are two other nitro compounds aromatic compounds that are found in plants. They are heterocyclic compounds and act as hormones in plants [46].
- *Sulphur Compounds*

A few plants are known to contain volatile sulphur compounds such as dimethyl sulphide, dimethyl disulphide and dimethylthiophene in garlic, onion, leek and shallots. Blackcurrant *(Ribes nigrum)* and buchu *(Agathosma betulina)* also possess sulphur compounds, as well as some citrus fruits, coriander, ylang ylang, rose, peppermint, pepper, geranium, chamomile, hops and davana [47]. Little is known about the purpose of sulphur compounds in plants except they play some role against pathogens and nitrogen detoxication of plants [48]. Little is also known about the sulphur pathways in plants, even though sulphur is a necessary compound for amino acid, proteins, polysaccharides, lipids and other sulphur containing secondary metabolites [49]. Sulphur compounds are believed to be derived through a sulphur reduction pathway [50] (see Figure 4.6.).

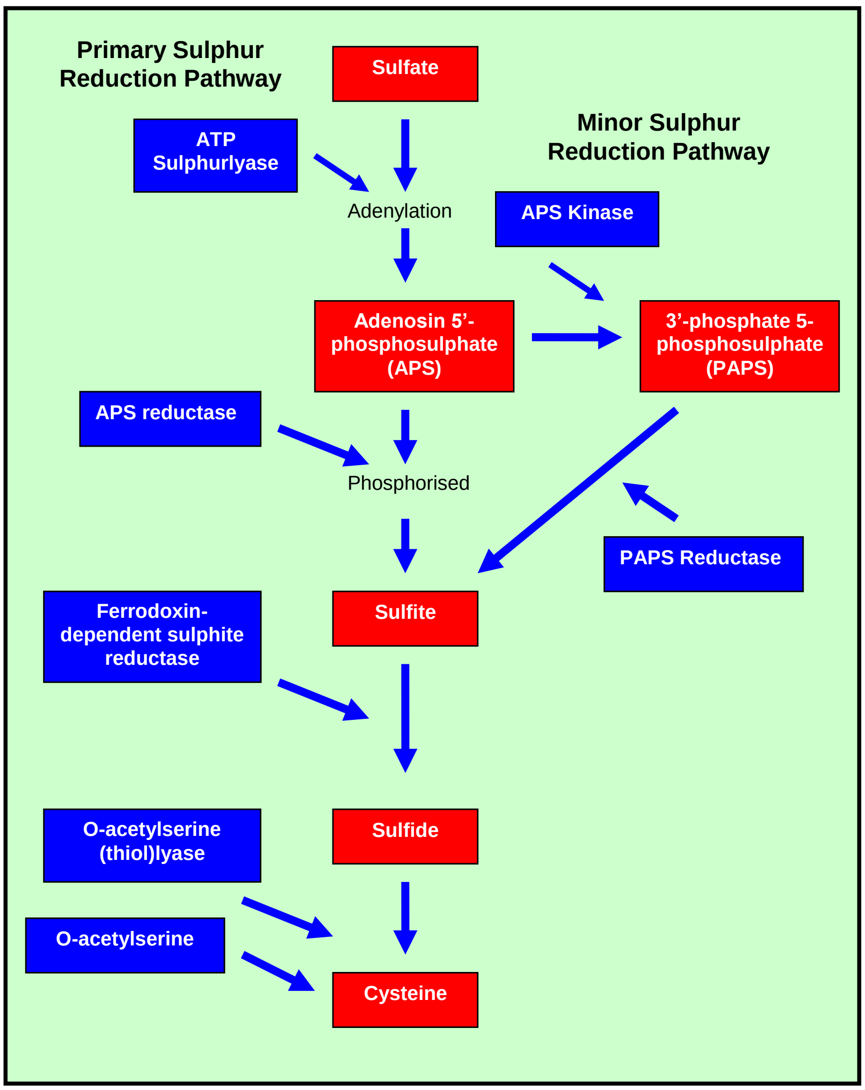


Figure 4.6. The Primary and Minor Sulphur Reduction Pathway.

Volatile aromatic compounds are found within the Apiaceae (Umbelliferae), Asteraceae (Compositae), Cupressaceae, Hypericaceae, Lamiaceae, Lauraceae, Myrtaceae, Pinaceae, Piperaceae, Rutaceae, Santalaceae, Zingiberaceae and the Zygophyllaceae families. The wide variety of different plant metabolisms producing a diverse range of aromatic compounds makes it difficult to meaningfully classify volatile oil plants according to these families. Due to the current accepted methods of plant taxonomy chemical constituents play very little role in plant family designation. A general description of the plant families bearing volatile materials are listed in Table 4.3.

Table 4.3. Major Essential Oil Bearing Plant Families

Family	Plant Examples	Characteristics	Chemical Groups
Apiaceae (Umbelliferae)	*Anethum graveolens (dill)* *Angelica spp.* *Coriandrum sativum (Coriander)* *Cuminum cyminum (Cumin)* *Myrrhis odorata (Fennel)*	A large group of aromatic herbs, quite widely distributed around the world. Apiaceae can be annuals, biennials or perennials. Plants vary in height from the few centimetres to a few metres.	Produce monoterpenes, sesquiterpenes and phenylpropanoid compounds, often in resins formed in glandular cells, where it moves into tubular ducts through the roots, stems, leaves, inflorescences and fruits. Also contain coumarins, benzofluran derivatives, non-terpene and alkaloid compounds.
Asteraceae (Compositae)	*Artemisia spp. (Armoise oils)* *Tagetes minuta (Tagetes oil)*	The largest plant family with over 30,000 species. A very diverse family containing evergreen shrubs, rhizomatous herbs, tuberous perennials and tree herbs. Semi-arid, tropical and sub-tropical distribution.	Monoterpenes through isomerization of geranyl pyrophosphate. Also coumarins,
Cupressaceae	*Juniperus communis (Juniper)*	A family of conifers distributed worldwide. A source of timber with many species. Genus also contains number of shrubs.	Trees and shrubs usually resinous with aromatic volatiles within the woods. Usually oils and resins high in terpenes.
Lamiaceae (Labiates)	*Ocimum basilicum (Basil)* *Mentha spp. (Mint)* *Rosemary officinalis (Rosemary)*	An extremely diverse family of around aromatic herbs and shrubs. Usually relatively short lived	Most accumulate terpenes and a range of other constituents, like coumarins. Oil is usually contained within glandular

	Thymus vulgaris (Thyme) Lavandula angustifolia (Lavender)	perennials, which turn woody during the later part of the lifecycle.	cells, hairs and scales which can be singular or multi cell protuberances on the surface of the epidermis of the leaves, stems and reproductive structures.
Lauraceae (Laurel Family)	*Cinnamomum verum (Cinnamom) Sassafras albidum (Sassafras) Litsea cubeba (Litsea oil)*	The laurel family consists of mainly flowering plants, mostly from sub-tropical and tropical areas. Also consists of a number of aromatic trees.	Volatile materials usually formed and stored in the cells within the bark and wood. Terpenes and their derivatives. Aldehydes, esters and alcohols.
Myrtaceae	*Eucalyptus spp. Leptospermum spp. (lemon tea tree and manuka oil) Backhousia citriodora (lemon myrtle)*	An extensive family of 3000 species of trees and plants, widely aromatic, including a number of fruits. The family consist mostly of flowering evergreens. Distributed around Australasia, the Pacific and Asia.	Aromatic materials mostly in leaves, include terpenoids, phenols, alcohols, aldehydes, etc.
Pinaceae	*Pinus spp. (Pine oil) Abies spp. (Fir (Abies) Oil*	Family of around 300 species including high growing conifers mainly in the Northern hemisphere.	Often resinous aromatic materials with acids, turpentine and terpenoids.
Piperaceae	*Piper nigrum (pepper oil)*	A small family of flowering plants.	Both terpenoids and oxygenated constituents.
Rutaceae	*Boronia megastigma (Boronia absolute) Citrus spp. (citrus oils)*	Contains plants ranging from shrubs to trees, including all the trees of citrus genus	Volatile materials usually formed in lysigenous secretory reservoirs inside the plant as the walls of secretory cells, which eventually disintegrate. Include coumarins, esters, terpenes, aldehydes, alcohols, etc.
Santalaceae	*Santalum spp. (Sandalwood oil) Pimenta oil (Pimenta racemosa)*	A widely distributed family of flowering plants and trees, of which only a few of interest for aromatic materials.	Resinous materials usually in the wood containing acids, esters, alcohols, aldehydes, etc.

Table 4.3. Continued

Family	Plant Examples	Characteristics	Chemical Groups
Zingiberaceae	*Zingiber spp. (ginger oils)*	The ginger family of many aromatic rhizomes herbs through tropical Africa, Asia and the Americas.	Mainly contain terpenes and sesquiterpenes in rhizomes and leaves.
Zygophyllaceae (Caltrop)	*Bulnesia sarmietoi (Guaiac wood oil)*	Family of around 250 species of flowering plants and trees, mostly around the Americas	Usually resinous phenolic, amines and nitrate compounds.

Aromatic compounds are formed and stored within the following parts of plants as a number of different materials.

a. As volatile liquid and odoriferous materials stored in various parts of a plant. These contain monoterpenes and sesquiterpens which are volatile at room temperature. They also contain phenolic compounds, terpene phenolic compounds and nitrogen based compounds. Sometimes these materials are mixed with carontenoid pigments, fatty acids and diterpene derivatives and glucosides within the plant cells, and,
b. As resins and oleoresins which are plant exudates containing many non-volatile diterpenes and triterpenes that are insoluble in water, plus volatile monoterpenes and sesquiterpenes. Resins are produced from cells lining resin ducts and believed to assist in inhibiting fungi and bacteria growth, deterring vertebrate herbivores and to repel bark insects. Turpentines are also oleoresins in the form of a sticky sap in some coniferous trees, which contain both non-volatile diterpenes and a number of other volatile materials. Balsams are another group of resins found in some of the Fabaceae (legume) family containing both non-volatile and volatile terpenes.

The actual natural products derived from plant or vegetative materials bear their name from the actual process that to some degree selectively extracts particular groups of materials from the cellular tissues. Distillation will extract volatile hydrocarbons as alcohols and their esters, aldehydes and volatile acids, ketones, phenolic and nitrogenous compounds. The solvent extraction process will collect both volatile and non-volatile materials including fatty acids and waxes to produce semi-solid materials called concretes. The non-volatile compounds are washed away through ethanol to produce an aromatic compound with only volatile ethanol soluble compounds, called an absolute. Resins can contain a number of compounds depending upon how they are processed, and for what purpose. Resins will contain both volatile and non-volatile compounds which can be separated into rosins (non-volatile part of the resin) and spirits (the volatile part of the resin).

Due to differing pant morphologies among the species, the volume of volatile oil each plant contains can vary greatly from parts per thousand to a couple of percent of the dry weight. The volume of volatile oil contained within different parts of the plant can also vary greatly [51]. The production of aromatic volatiles in a plant may only occur during a specific phase of the plant lifecycle in a specific part of the plant morphology (e.g. fruit, seeds, bark, leaves, buds, flowers, roots, stems). The production of specific aromatic compounds may be associated with a certain growth stage such as flowering [52]. Specific aromatic compounds can vary according to environmental and plant factors during the growth cycle [53]. Oil yields and volatile compositions can be influenced by irrigation, nitrogen application and cultivation practices, which will be discussed in chapter nine.

Some plant volatiles have a diurnal variation reflecting plant pollination requirements [54]. Thus plants have a biological rhythm that influences flower scents [55]. This appears to be influenced by temperature and light [56]. Yet some aroma chemicals within the flower scents remain stable, while others vary [57]. Figure 4.7. shows the rhythmic diurnal variation patterns of flower scents, with each line representing a volatile constituent. This pattern resembles the diurnal variation patterns of *Hoya carnosa*, tea Rose, Jasmine and rose, etc. [58]. This demonstrates the hourly change in the physiological and biochemical activities of flowers and plants [59]. Flowers will maintain their scent for 0.5-2.0 hours after picking, specific flower scent behaviour is critical to commercial scale harvest and extraction practices.

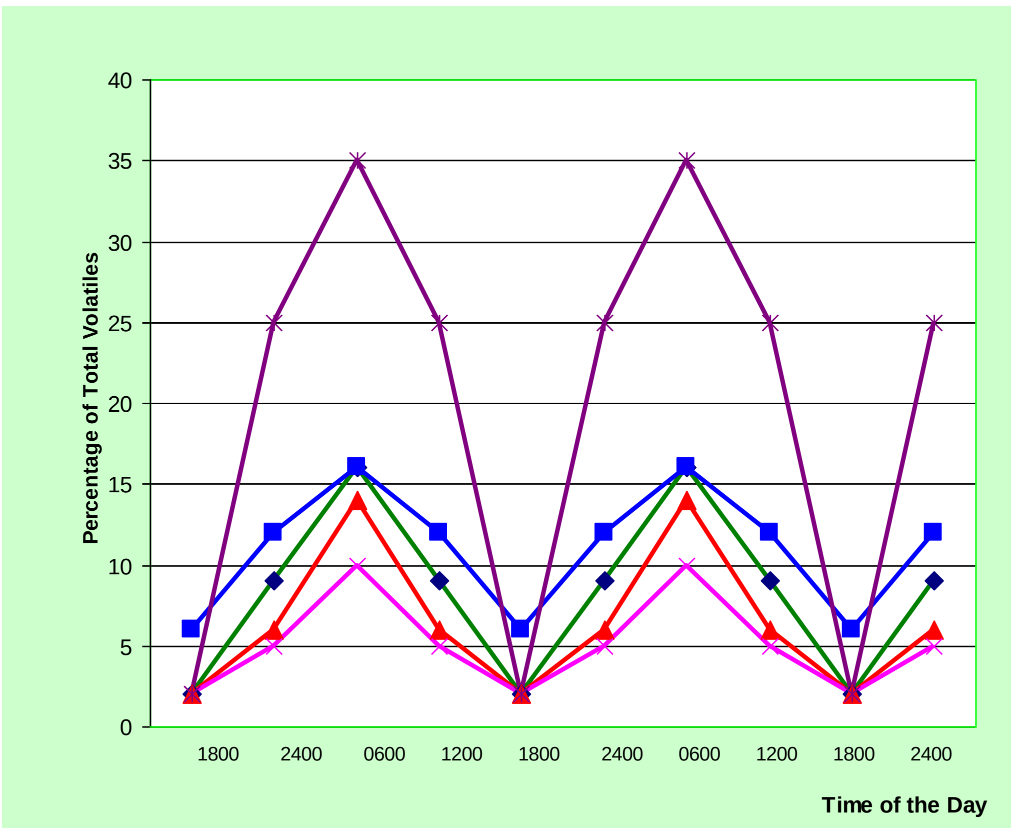


Figure 4.7. Diurnal Variation Patterns of Volatiles of Flowers over 48 Hours.

The way in which aromatic compounds are stored within plants will influence the method of extraction required. Steam distillation cannot be applied to all plant materials. This is due to both physical and thermal reasons. Often plant tissue (roots, tubers, wood, etc.) has to be broken down to expose the oil containing cells and cavities for extraction purposes. The oil bearing cellular structure of plants is very strong and must be broken to extract any volatiles [60]. Rose petals under steam distillation will form into a pasty clump where steam will cease to travel consistently through the material. Some aromatic materials are thermo-sensitive like many constituents in citrus oils, which are unstable and will convert into artefacts during extraction, especially under heat and pressure. Extraction processes like cold pressing without heat are required. Many materials High temperature extraction methods can destroy plant tissue leading to undesirable substances, while other materials can be lost through evaporation. Post harvest activities may also play a role in activating metabolic changes that take place through enzymic activity during wilting. Some compounds are transformed during the extraction process, especially distillation. Some materials stored in waxes and fatty acids require a solvent to dissolve the material out of the plant tissue. Solvent polarity and boiling temperature need to be carefully selected according the polarity of constituents within the plant. Resinoids require a two phase process. In the first process solvents are used to co-extract the aromatic materials with the waxes they are contained within. The second process then separates the aromatic materials from the waxes via another solvent that will dissolve the wax. Absolutes created through ethanol extraction from concretes and resinous materials will only contain ethanol soluble aromatic materials. Extraction methodology is a major consideration to prevent destruction of plant tissue during extraction [61]. All these factors may produce either desirable or undesirable reactions in the aromatic materials. These issues will be discussed in more detail in the next chapter.

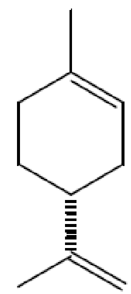
SOME IMPORTANT AROMATIC CHEMICALS

This section provides a short description of some important and common aromatic compounds found in essential oils. Aroma chemicals in their own right are commercial products with various applications, although many are synthesised rather than isolated from essential oils. Many accepted chemical names used in the essential oil industry are shorter than the nomenclature recommended by the International Union of Pure and Applied Chemistry (IUPAC), thus no specific system is adopted here. Some aromatic chemicals can fall into more than one group, *i.e., can be both a terpene and alcohol*. It is still not known what function all aromatic chemicals found in plants perform and their path of synthesis. The following examples represent about 10% of the common aromatic chemicals used in perfumery and flavour production.

Terpene Hydrocarbons

The terpene hydrocarbons consist of mono- and sesquiterpenes. They contain hydroxyls, carbonyls, and double bonds as skeletal themes. The size and functionality usually increases with the increase of boiling point [63]. Terpenes are involved in allelopathy, pollination and phenomenal activities within the secondary metabolite defense mechanism of the plants. It is still not understood what the purpose each terpene performs in a plant. These are mainly unsaturated hydrocarbons. The odours in terpenoids tend to be weak and not fully represent the essential oils they come from. Sometimes they are poorly soluble in solvents and can polymerize and oxidize easily, changing their odour and lessening their volatility.

Limonene



Chemical Name: 1-Methyl-4-(1-methyllethenyl)-cyclohexene
Chemical Formula: C10H16
Classification: Monoterpene hydrocarbon
Physical Characteristics: Clear colourless liquid, B.P. 320°C, occurs in two optically active forms *d* and *l*-limonene. A relatively stable terpene. Can be racemised to dipentene through heating
Source & Occurrence: Occurs up to 90% in some citrus oils, Orange, lemon and bergamot. Synthesized from geranyl pyrophosphate Through the terpenoid pathway in the plant [63].

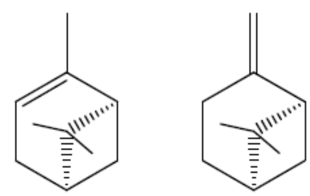
Odour Profile: A fresh citrus clean odour.

Solubility: Poorly soluble in weak aqueous ethanol.

Use: As low cost extender in low cost perfumes, some food flavourings, for household and industrial cleaning solvents, paint stripper and botanical insecticide.

Pinene

Chemical Name: (1S,5S)-6,6-diemthyl-2-methylenebicyclo[3.1.1]heptane
Chemical Formula: C10H16
Classification: Monoterpene hydrocarbon



a-Pinene ß-Pinene

Physical Characteristics: Clear colourless liquid, B.P. 157°C, occurs in two optically active forms *a*-. and ß-pinene and exists in forms *l*- and *d*-, and racemic forms.

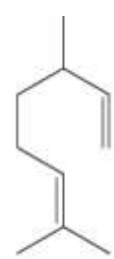
Source & Occurrence: Occurs in many essential oils as minor Constituent, also in fir, pine and turpentine oils. Extracted from turpentine Oils. Synthesized from geranyl pyrophosphate through the terpenoid pathway in the plant.

Odour Profile: A fresh pine odour

Solubility: Soluble in ethanol.

Use: Used in household perfumery and to synthesize a number of other aromatic Chemicals.

Myrcene



Chemical Name: 7-methyl-3-methylene-1,6-octadine
Chemical Formula: C10H16
Classification: Monoterpene hydrocarbon
Physical Characteristics: Clear colourless to pale yellow liquid, B.P. 165°C

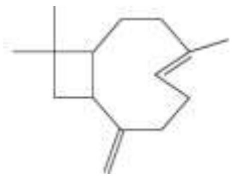
Source & Occurrence: Occurs in bay, verbena, lemongrass, Mandarin, thyme, and *Eucalyptus globules* oils.

Odour Profile: A fresh citrus odour.

Solubility: Soluble in ethanol.

Use: Used as an intermediate in the production of menthol, citral, citronellal, Geraniol, nerol and linalool.

Caryophyllene



Chemical Name: 4,11,11-triethyl-8-methylene-bicyclo [7.2.0]undec-4-one

Chemical Formula: C15H24

Classification: Sesquiterpene hydrocarbon

Physical Characteristics: A colourless liquid, B.P. 129-130°C

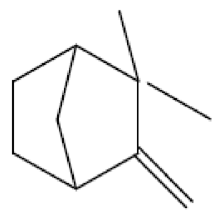
Source & Occurrence: Various essential oils, including basil, clove, sage, origanum, and lime oils. Occurs as either *alpha*- or *beta*- caryophyllene, usually together with Isocaryophyllene.

Odour Profile: A clove type-turpentine odour.

Solubility: Soluble in alcohol, chloroform and benzene

Use: As a material for flavours and fragrances

Camphene



Chemical Name: 2,2-Dimethyl-3-methylenebicyclo[2.2.1]heptane

Chemical Formula: C10H16

Classification: Sesquiterpene hydrocarbon

Physical Characteristics: A colourless liquid, B.P. 156-160°C

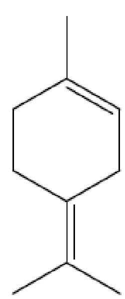
Source & Occurrence: Occurs in turpentine, cypress, camphor, Bergamot, citronella, neroli, ginger and valerian. White crystal Material.

Odour Profile: A mild camphoraccous odour.

Solubility: Moderately soluble in alcohol, chloroform and ether. Insoluble in water.

Use: As an intermediate used synthesis of other aroma chemicals.

Terpinolene



Chemical Name: *para*-Mentha-1,4(8)-diene

Chemical Formula: C10H16

Classification: Monoterpene hydrocarbon

Physical Characteristics: A colourless liquid, B.P. 184°C

Source & Occurrence: Occurs in tea tree oil and eucalyptus specie

Odour Profile: A sweet piny odour with citrus characteristics.

Solubility: Moderately soluble in alcohol, chloroform and ether. Insoluble in water.

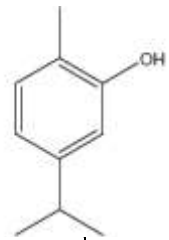
Use: As an extender in household perfumes, especially pine like and citrus odours.

Plant Metabolism: An anti-fungal agent against various pathogens [64].

Phenols

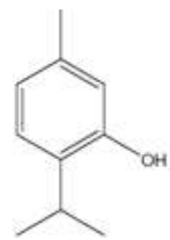
Phenols are compounds with one or two hydroxy groups, similar to benzyl alcohols. They tend to be caustic and exhibit some toxicity. Phenols are also prone to oxidisation. They have clean odours. Many phenols have anti-microbial and antiseptic qualities.

Carvacrol



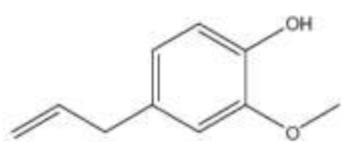
Chemical Name: 2-methyl-5-(1-methylethyl) phenol
Chemical Formula: C10H14O
Classification: Phenol
Physical Characteristics: A colourless liquid.
B.P. 236-237°C.
Source & Occurrence: Present in thyme, organum, caraway, marjoram and savoury oils.
Odour Profile: A dry medicinal, herbaceous, phenolic odour.
Solubility: Slightly soluble in water, soluble in ethanol and chloroform.
Use: In dental preparations, as an antiseptic.

Thymol



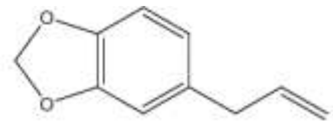
Chemical Name: 5-Methyl-2-isopropyl-1-phenol
Chemical Formula: C10H14O
Classification: Phenol
Physical Characteristics: A white crystalline powder.
Melting Point 48.5-49.5°C,B.P. 233°C.
Source & Occurrence: Present in thyme, origanum and ajowan oils.
Odour Profile: A mild phenolic and herbaceous odour.
Solubility: Slightly soluble in water, soluble in ethanol and chloroform.
Use: Used in some cosmetics as a fungicide and in traces for herbaceous
Fragrances in soaps and household products. Has fungicidal and anti-microbial properties.

Eugenol



Chemical Name: 4-Allyl-2-methoxyphenol
Chemical Formula: C10H12O2
Classification: Phenol
Physical Characteristics: A colourless to pale yellow liquid,
B.P. 253°C. (Darkens on exposure to air).
Source & Occurrence: Present in bay, clove, cinnamon leaf, pimento, sassafras, ylang ylang, patchouli, rose oils and asmine, osmanthus and violet absolutes.
Odour Profile: A medicinal clove like odour.
Solubility: Soluble in ethanol.
Use: Used in fragrance and flavours and in dentistry as a local anesthetic. Used in the production of *iso*-eugenol for the manufacture of vanillin.Used as an anesthetic for tropical fish. Also used for clandestine production of phenyllamines.
Plant metabolism: Something to do with insect attractant mechanism (attractive for male bees to produce pheromones) and UV absorption in plants.

Safrole



Chemical Name: 3,4-Methylenedioxyallyl benzene

Chemical Formula: C10H10O2

Classification: Phenolic ether

Physical Characteristics: A colourless to pale yellow liquid. Becomes a white crystalline powder at low temperatures. B.P. 232-234°C.

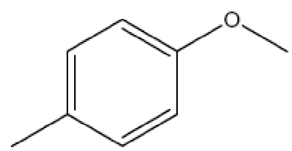
Source & Occurrence: Present in sassafras, camphor, nutmeg, star anise, cinnamon leaf, laurel and ylang ylang oils.

Odour Profile: A warm, spicy, woody floral note.

Solubility: Soluble in ethanol.

Use: Previously used in fragrances and as an additive in root beers, but due to mild carcinogenic properties, not recommended by IFRA for use. Banned as a food ingredient by US FDA. A precursor in the synthesis of piperonyl butoxide, an insecticide synergist. Used as the main precursor to synthesis the clandestine manufacture of MDMA (ecstasy).

Para-Cresyl methyl Ether



Chemical Name: 1-methoxy-4-methylbenzene

Chemical Formula: C8H10O

Classification: Phenolic ether

Physical Characteristics: A colourless liquid. B.P. 175°C.

Source & Occurrence: Present in ylang ylang and wallflower oils, Lilac and Jasmine Absolutes.

Odour Profile: A pungent sharp sweet floral (ylang ylang like) note.

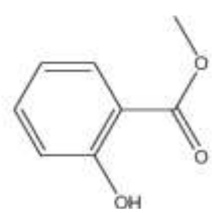
Solubility: Soluble in ethanol and most organic solvents.

Use: Used mainly in floral type soap fragrances. Also used in paints, both enamel and emulsion, printing inks, rubber products, leather, plastics, crayons and textile printing.

Alcohols

Alcohols can be classified as primary, secondary and tertiary, i.e., the number of carbon atoms they contain. There are also aliphatic alcohols. Polyhydric alcohols (2 or more hydroxy groups) are odourless, but can find application as solvents. Acyclic alcohols have faint odours and closely resemble phenols. Terpenoid alcohols are very important chemicals found in many plants. A number of alcohols have antiseptic, anti-fungal and anti-viral qualities.

Methyl Salicylate



Chemical Name: Methyl-2-hydroxybenzoate

Chemical Formula: C8H8O3

Classification: Alcohol Salicylate

Physical Characteristics: A colourless liquid. B.P. 223°C.

Source & Occurrence: Principal constituent of wintergreen oil, also

Present in cassie, rue, ylang ylang and carnation, mimosa and tuberose absolute. Numerous other plants contain trace amounts.

Odour Profile: A pungent but sweet, medicinal odour, reminiscent of wintergreen.

Solubility: Soluble in ethanol.

Use: Most methyl salicylate now synthetically produced. Used as an active ingredient in rubbing liniments, balms and toothpastes. Used as a minor ingredient in flavours.

Plant metabolism: Most likely a herbivore defence mechanism to recruit beneficial insects to kill herbivores [65] and as a pheromone to warn other plants of pathogens [66]. Also attracts bees for pollen collection [67].

Alcohol C8 (Caprylic alcohol)

Chemical Name: Octan-1-ol

Chemical Formula: C7H16O

Classification: Aliphatic Alcohol

Physical Characteristics: A colourless liquid.

B.P. 194-196°C.

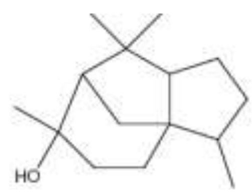
Source & Occurrence: Constituent in orange, grapefruit, green tea, *Heracleum villosum* oils, violet leaf absolute and a number of other essential oils.

Odour Profile: A sweet, waxy (fatty) odour, with a slight aldehydic and fruity nuance, somewhat balsamic.

Solubility: Soluble in ethanol.

Use: Used in cologne and fresh floral type fragrances.

Cedrol



Chemical Name: 8-betaH- cedran-8-ol

Chemical Formula: C15H26O

Classification: Alcohol

Physical Characteristics: A white crystalline solid.

B.P. 273°C.

Source & Occurrence: Constituent in cedarwood, cypress and origanum oils.

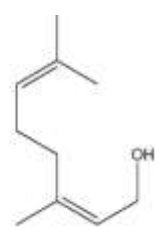
Odour Profile: A cedarwood, sweet soft odour.

Solubility: Soluble in ethanol.

Use: Used as a fixative for soap perfumes, especially household and industrial products.

Plant metabolism: Believed to be a defence against pathogens in plants [68].

Geraniol



Chemical Name: 3,7-Dimethyl-2,6-octadien-1-ol

Chemical Formula: C10H18O

Classification: Olefinic terpene alcohol

Physical Characteristics: A colourless oily liquid.

B.P. 230°C.

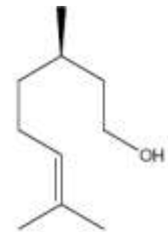
Source & Occurrence: A constituent of palmarosa, rose, geranium, citronella, lemongrass, rosewood, petitgrain, and a minor constituent in a number of other essential oils.

Odour Profile: A sweet rose-type odour.

Solubility: Soluble in ethanol.

Use: Used extensively in floral and oriental fragrances.

Citronellol



Chemical Name: 3,7-Dimethyl-6-octen-1-ol
Chemical Formula: C10H20O
Classification: Terpene alcohol
Physical Characteristics: A colourless liquid.
B.P. 244°C.

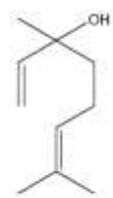
Source & Occurrence: A constituent of citronella, geranium, muguet, oakmoss, palmarosa, rose, verbena, and a number of eucalypt species. Formed via oxidization and formation of CoA ester converting into *cis*-geranyl CoA [69]. These compounds converted by geranyl-CoA carboxylase to an acetate which is hydrated to eliminate the acetate group, which is then oxidated via the leucine degradation pathway [70].

Odour Profile: A herbaceous rose-type odour.

Solubility: Soluble in ethanol.

Use: Used extensively in floral and rose based fragrances, as an insect repellent (is an attractant).

Linalool



Chemical Name: 3,7-Dimethylocta-1,6-octadien-3-ol
Chemical Formula: C10H18O
Classification: Terpene alcohol
Physical Characteristics: A slightly viscous colourless liquid.
B.P. 195-199°C.

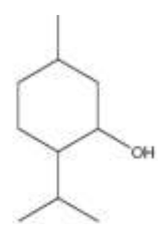
Source & Occurrence: A free constituent of cayenne, linaloe and ho oils. A main constituent in coriander, also in rose otto, lavender and bergamot oils. Occurs as a minor constituent in a large number of essential oils including geranium, tangerine, neroli, lavandin, clary sage, orange, jasmine, sweet pea, muguet, lilac, cinnamon and sassafras oils.

Odour Profile: A heavy floral scent reminiscent of lily of the valley/lavender.

Solubility: Soluble in ethanol.

Use: Used extensively in floral and non-floral fragrances, needs extensive blending with other materials. It is versatile in household fragrances. Also a good fixative. Linalool can be converted to terpineol, geraniol and citral. Also can be used in the synthesis of vitamin E.

Menthol



Chemical Name: 3-*p*-Methanol
Chemical Formula: C10H20O
Classification: Alcohol
Physical Characteristics: Colourless crystals.
Melting point 42-45°C. B.P. 212°C.

Source & Occurrence: Occurs in peppermint oil *(Mentha piperita)*. Also in *Mentha arvensis* and geranium oils.

Odour Profile: A cool refreshing peppermint odour.

Solubility: Soluble in ethanol.

Use: In perfumery in very small dosages as a lifting agent, although in South East Asia has been used in overdose to create cooling effect in shampoos. In after shave and eau de colognes. As a flavouring material, especially in gums, in toothpastes and many medicines such as balms, cough medicines, topical analgesics, mouthwashes. As a pesticide. In cigarettes as a cooling agent.

Phenyl Ethyl Alcohol

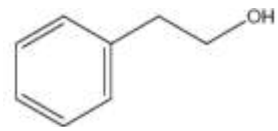
Chemical Name: 2-Phenylethylalcohol

Chemical Formula: C8H10O

Classification: Alcohol

Physical Characteristics: Colourless liquid.

B.P. 220°C.



Source & Occurrence: Occurs in rose, neroli, geranium, ylang ylang oils and absolutes of orange blossom, and champaca.

Odour Profile: A mild sweet rose odour.

Solubility: Soluble in ethanol, partly soluble in water.

Use: One of the most versatile aromatic chemicals used in floral, to lift the character of fragrances. As a preservative in agar preparations.

Terpineol

Chemical Name: 1-Methyl-4-isopropylcyclohex-1-en-9-ol

Chemical Formula: C10H18O

Classification: Alcohol

Physical Characteristics: A colourless to yellow viscous liquid.

B.P. 219°C.

Source & Occurrence: Occurs in cajuput, cardamom, cubeb, eucalyptus, linaloe, pine, juniper, cypress, nutmeg, rosewood, tea tree, citrus and petitgrain oils and jasmine and tuberose absolutes. Occurs in three isomers *alpha, beta* and *gamma*-terpineol. Usually found in plants with *a*-terpineol in the highest concentration.

Odour Profile: A pine like odour.

Solubility: Soluble in ethanol.

Use: Used in a wide range of household and cosmetic perfumes.

Terpinen-4-ol

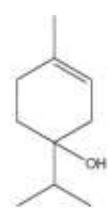
Chemical Name: 1-terpenin-4-ol

Chemical Formula: C10H18O

Classification: Terpene Alcohol

Physical Characteristics: A colourless to yellow viscous liquid.

B.P. 177°C.



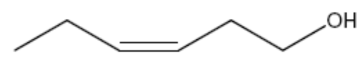
Source & Occurrence: Occurs in tea tree oil, also in juniper and *Pandanus odoratissimus* oil.

Odour Profile: A pine like tea tree odour.

Solubility: Soluble in ethanol.

Use: Used in pharmaceutical and cosmetic preparations.

Cis-3-Hexanol



Chemical Name: *cis*-3-Hexanol
Chemical Formula: C6H12O
Classification: Alcohol
Physical Characteristics: A colourless liquid.
B.P. 157°C.

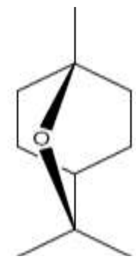
Source & Occurrence: Occurs in many leaves of plants, including geranium, *Mentha arvensis,* thyme, mulberry, tea, violet as a trace compound. Also in a number of fruits such as tomatoes, raspberries and grapes. Formed through the amino acid pathway [71].

Odour Profile: A refreshing green note reminiscent of cut grass, with some fruitiness.

Solubility: Soluble in ethanol.

Use: Used in heavy floral fragrances, herbaceous and some citrus notes.

Cineole (Eucalyptol)



Chemical Name: 1,8-cineol
Chemical Formula: C10H18O
Classification: Alcohol
Physical Characteristics: A colourless liquid.
B.P. 174-177°C.

Source & Occurrence: Occurs as a major constituent in many eucalyptus and cajuput (including tea tree *Melaleuca alternofolia)* species. Also occurs in tuberose and champaca absolutes, bay leaves, spike lavender, basil, rosemary, sage and bois de rose (wormwood) oils.

Odour Profile: A diffusive spicy, cooling camphorous note.

Solubility: Soluble in ethanol, slightly soluble in water.

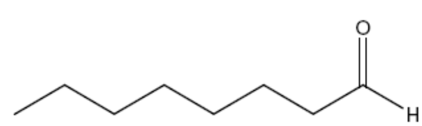
Use: Used as a flavour in some dental preparations, herbaceous, lavender and fougere fragrances to create refreshing notes at low dosages and medicated notes at high dosages. Used in a number of medicated balms.

Plant Metabolism: Believed to attract bees to assist in the production of pheromones.

Aldehydes

Aldehydes come in two types, cyclic and aliphatic (straight chain fatty). Fatty aldehydes usually exhibit pungent odours. They are used in flavours and fragrance in diluted forms. Aliphatics used in perfumery usually derived from synthetic sources due to costs. Aldehydes are very prone to oxidisation, polymerisation and acetal formation.

Aldehyde C8



Chemical Name: Octanal, capryl aldehyde
Chemical Formula: C8H16O
Classification: Aliphatic aldehyde
Physical Characteristics: A colourless liquid.
B.P. 170°C.

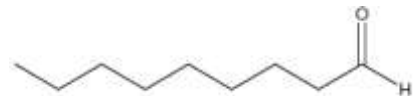
Source & Occurrence: Minor constituents in kesum (*Polygonum odoratum/minus)* and coriander seed oils. Trace constituents in lemon, lemongrass, pine, rose, orange and orange flower oils.

Odour Profile: A diffusive, pungent harsh fatty sweet, orange like odour. (becomes more orange on dilution).

Solubility: Soluble in ethanol, slightly soluble in water. Very readily oxidised.

Use: Used in trace amounts to give top notes for floral and citrus fragrances. Also used in food flavourings.

Aldehyde C9



Chemical Name: *n*-nonanal, pelagonic aldehyde

Chemical Formula: C9H18O

Classification: Aliphatic aldehyde

Physical Characteristics: A colourless liquid.

B.P. 191°C.

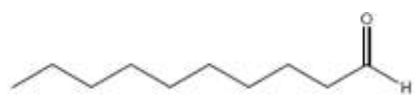
Source & Occurrence: Minor constituents in kesum (*Polygonum odoratum/minus)* and coriander seed oils. Trace constituents in rose, tangerine, cinnamom, ginger, pine, lemon and orris oils.

Odour Profile: A diffusive, pungent harsh fatty sweet, rose/lily like odour.

Solubility: Soluble in ethanol, slightly soluble in water. Very readily oxidised.

Use: Used in trace amounts to give top notes for floral and citrus fragrances. Also as a lifting agent. Also used in food flavourings.

Aldehyde C10



Chemical Name: *n*-decanal, capric aldehyde

Chemical Formula: C10H20O

Classification: Aliphatic aldehyde

Physical Characteristics: A colourless liquid.

B.P. 233°C.

Source & Occurrence: Minor constituents in kesum (*Polygonum odoratum/minus)* and coriander seed oils. Trace constituents in neroli, citrus, pine and lavender oils.

Odour Profile: A diffusive fatty sweet, fatty rose like odour.

Solubility: Soluble in ethanol, slightly soluble in water. Very readily oxidised.

Use: Used in trace amounts to give top notes for floral fragrances. Also used in food flavourings.

Aldehyde C11

Chemical Name: Undecanal

Chemical Formula: C11H22O

Classification: Aliphatic aldehyde

Physical Characteristics: A colourless to yellowish liquid.

B.P. 233°C.

Source & Occurrence: Minor constituents in kesum (*Polygonum odoratum/minus)* and coriander seed oils. Trace constituents in bergamot and sweet orange oils.

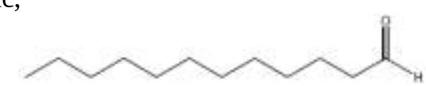
Odour Profile: A powerful waxy diffusive floral odour with fruity undertones.

Solubility: Soluble in ethanol, slightly soluble in water.

Use: Used in fragrance as a modifier.

Aldehyde C12

Chemical Name: Dodecanal, Aldehyde C12 Lauric, Lauric aldehyde



Chemical Formula: $C_{12}H_{24}O$

Classification: Aliphatic aldehyde

Physical Characteristics: A colourless to yellowish liquid.

B.P. 249°C.

Source & Occurrence: Major constituents in kesum (*Polygonum odoratum/minus)* and coriander seed oils. Trace constituents in pine needle, rue and bitter orange oils.

Odour Profile: A powerful waxy sweet herbaceous, earthy odour.

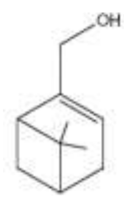
Solubility: Soluble in ethanol, slightly soluble in water.

Use: Used to impact character to violets, jasmines, muguet, lavender, lilac, and modern florals.

Myretenal

Chemical Name: 2-pinen-10-al, (1R)-(-)-myrtenal

Lauric aldehyde



Chemical Formula: $C_{10}H_{14}O$

Classification: Terpene aldehyde

Physical Characteristics: A colourless to yellowish liquid.

B.P. 199°C.

Source & Occurrence: Occurs around a 10% constituent in *Astartea lepophylla* [72]. Formed through degradation of alpha pinene from myrtenol dehydrogenase [73].

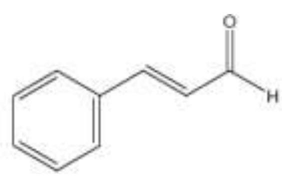
Odour Profile: A very powerful sweet hay like odour. (extremely powerful odour. Needs to be handled in 10% solution and stored under nitrogen)

Solubility: Soluble in ethanol, slightly soluble in water.

Use: Used in low dosage levels to impart natural hay like notes in floral fragrances.

Plant Metabolism: Believed to act as a repellent of herbivores in plants [74].

Cinnamic Aldehyde



Chemical Name: 3-Phenyl-2-propenal

Chemical Formula: C_9H_8O

Classification: Aldehyde

Physical Characteristics: A colourless to yellowish liquid.

B.P. 246°C.

Source & Occurrence: Found as a *trans* isomer in cinnamon species, cassia and patchouli oils. Also found in Ylang ylang. Produced through the shikimic pathway starting from sedoheptulose, which is converted to cinnamic aldehyde from *l*-phenylalmine. In most plants this pathway produces minute amounts, but in the cinnamon species, a kinetic bottleneck in the mechanistic pathways, results in large accumulation of cinnamic aldehyde in cinnamon species leaves [75].

Odour Profile: A powerful warm spicy balsamic odour suggestive of cassia.

Solubility: Soluble in ethanol, slightly soluble in water.

Use: Used in heavy florals and oriental perfumes. Used to *"sweeten"* fragrances. Mainly used in household and low cost perfumes. Used in flavours.

Plant Metabolism: Possible production of lignins [76].

Citral

Chemical Name: *cis* and *trans*-3,7-Dimethyllocta-2-6-dienal (neral and geranial)

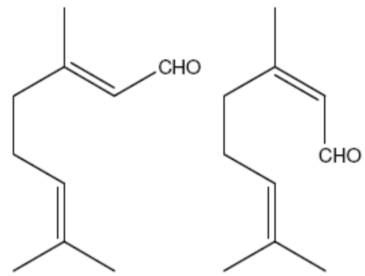
Chemical Formula: C10H16O

Classification: Aldehyde

Physical Characteristics: Consists of two isomers, geranial and neral. The difference in odours in various essential oils is the ratio of geranial to neral in each oil.

A colourless to yellowish liquid.

B.P. 228°C.



Geranial Neral

Source & Occurrence: Major constituent in lemongrass, verbena, lemon myrtle and *Litsea cubeba* oils. Major constituent in lemon, lime, orange and mandarin oils. Minor constituent in lavender, Melissa, rose, geranium, pepper, bay and ginger oils.

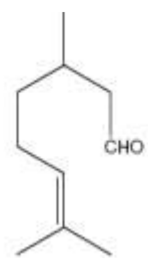
Odour Profile: A strong lemon citrus odour.

Solubility: Soluble in ethanol.

Use: Used in the synthesis of vitamin A and ionone. Used in low cost household fragrances. Also used in citrus flavours.

Plant Metabolism: Plant of the pheromone metabolism of plants [77].

Citronellal (Rhodinal)



Chemical Name: 3,7-dimethyloct-6-en-1-al

Chemical Formula: C10H18O

Classification: Aldehyde

Physical Characteristics: A colourless to yellowish liquid.

B.P. 201-204°C.

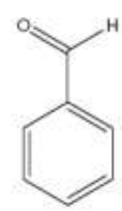
Source & Occurrence: Present in citronella, lemon scented tea tree *(Leptospermum petersonii)* and Eucalyptus *(Corymbia)* citriodora oils.

Odour Profile: A lemon citronella, somewhat rosy scent.

Solubility: Soluble in ethanol, very slightly soluble in water.

Use: Generally for household and industrial perfumes. Used in small proportions in fine fragrances. As an insect repellent and anti-fungal agent.

Benzaldehyde



Chemical Name: Benzaldehyde

Chemical Formula: C7H6CHO

Classification: Aldehyde

Physical Characteristics: A colourless liquid.

B.P. 178°C.

Source & Occurrence: Forms from degradation of amygdalin, a glucoside to benzaldehyde under enzyme catalysts [78]. Present in bitter almonds, peach, cherries, plum seeds and kernels. Also present in ylang ylang, cinnamon bark, cassia, and other essential oils.

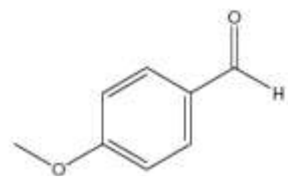
Odour Profile: A pleasant almond like odour.

Solubility: Soluble in ethanol, very slightly soluble in water.

Use: Used in traces for floral perfumes, usually for household and industrial products. Used in food flavours, industrial solvent, synthesis of organic compounds, i.e., pharmaceuticals and plastic additives.

Plant Metabolism: Benzaldehyde is an intermediate in the biosynthesis of benzyl benzoate and phenyl ethyl benzoate in plants through benzoyl-CoA, Benzyl alcohol, phenylethanol benzoyltranferase protein [79].

Anisaldehyde



Chemical Name: 4-Methoxybenzaldehyde

Chemical Formula: C8H8O2

Classification: Aldehyde

Physical Characteristics: A colourless liquid.

B.P. 248°C. Readily oxidises into anisic acid.

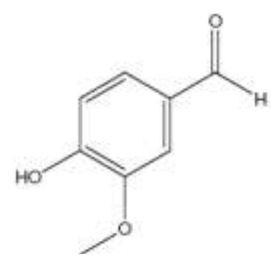
Source & Occurrence: Found in fennel, anis seed, star anise, mimosa, acacia, *Magnolia salicifolia* leaves, vanilla beans, buchu leaf oils.

Odour Profile: A powerful sweet floral resembling hawthorn.

Solubility: Soluble in ethanol.

Use: Used both floral and non-floral fragrances. Used as a stain in thin layer chromatography (TLC).

Vanillin



Chemical Name: 4-hydroxy-3-methoxybenzaldehyde

Chemical Formula: C8H8O3

Classification: Aldehyde

Physical Characteristics: A white solid.

Melting Point 80-81°C, B.P. 285°C. Slowly oxidizes in moist air.

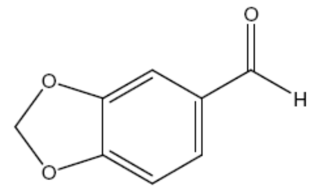
Source & Occurrence: Believed to be formed from ferullic acid through two possible pathways [80], (1) coenzyme A ester reaction of free acid through oxidisation, or through a similar reaction through coumaroyl coenzyme A, or (2) where hydration occurs to a b-hydroxy form, followed by cleavage of the aldehyde, releasing acetic acid [81]. Which reaction occurs depends on the particular precursors in the plant [82]. In the vanilla plant *(Vanilla planifolia)*, the first route occurs, where the vanilla pods needs to cure and ferment after harvesting. Found in vanilla bean pods, citronella, benzoin, peru and tolu balsam. Also in clove bud, and traces in a number of essential oils. Also found in raspberry and lychees. Through heat and time vanillin develops in wines, spirits, coffee, and some grains.

Odour Profile: A sweet odour typical of vanilla

Solubility: Soluble in ethanol.

Use: Used extensively in flavouring, to enhance floral fragrances, a fixative. Also used in pharmaceuticals to mask unpleasant flavours and as an intermediate in the production of fine chemicals.

Heliotropine



Chemical Name: 3,4-Methylenedioxybenzaldehyde

Chemical Formula: C8H6O3

Classification: Aldehyde

Physical Characteristics: A white crystalline powder.

Melting Point 36-38°C, B.P. 263°C. Slowly oxidizes in air.

Source & Occurrence: Occurs in pepper, vanilla, sassafras and other essential oils.

Odour Profile: A Very sweet floral spicy odour.

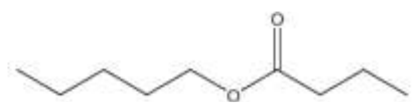
Solubility: Soluble in ethanol.

Use: In floral fragrances, not stable in soaps.

Esters

Esters are usually derived from acids and alcohols in reversible reactions which must be considered during harvest and distillation processes. They are usually named after the original molecules with alcohols dropping off *"ol"* and gaining *"yl"* and the acids dropping off "ic" and gaining "ate". Many esters display fruity notes but are not very pH stable.

Amyl Butyrate



Chemical Name: pentyl butanoate

Chemical Formula: C9H18O2

Classification: Ester

Physical Characteristics: A colourless liquid.

B.P. 186°C.

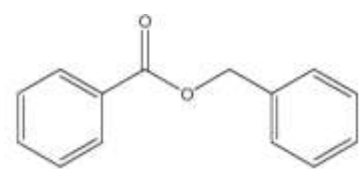
Source & Occurrence: Coconut and eucalyptus oils..

Odour Profile: An apricot like odour.

Solubility: Soluble in ethanol.

Use: Used in fruit and floral scents.

Benzyl Benzoate



Chemical Name: Benzoic acid phenylmethyl ester

Chemical Formula: C14H12O2

Classification: Ester

Physical Characteristics: A colourless liquid.

B.P. 324°C.

Source & Occurrence: Tolu and Peru balsam, jasmine, ylang ylang, tuberose, hyacinth, carnation, cinnamon leaves.

Odour Profile: A faint sweet balsamic odour.

Solubility: Soluble in ethanol.

Use: As a fixative and solvent for many fragrances. As an anti parasite insecticide, especially lice and mites, to alleviate scabies, a food additive, a plasticiser in cellulose and other polymers.

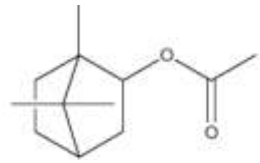
Bornyl Acetate

Chemical Name: 1,7,7-trimethyl-6-bicyclo[2.2.1]heptanyl-2-ol acetate

Chemical Formula: C12H20O2

Classification: Ester

Physical Characteristics: A colourless liquid or can be a crystalline mass.



B.P. 226°C.

Source & Occurrence: Found in levo and dextro form in oils of many *Pinus abies* species. Also in coriander, valerian roots, spike lavender, rosemary and sage oils.

Odour Profile: A sweet herbaceous odour reminiscent of pine needles, somewhat balsamic.

Solubility: Soluble in ethanol.

Use: As a pine, herbaceous and floral ingredient in fragrances to give a spicy, alpine, piny odour. Mainly in household products such as bath preparations, disinfectants, etc. Also as a nitrocellulose solvent and plasticiser.

Plant Metabolism: A sex pheromone mimic in plants [83] and a root growth hormone [84].

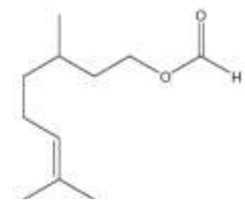
Citronellyl Acetate

Chemical Name: 3,7-Dimethylloct-6-en-1-yl acetate

Chemical Formula: C12H22O2

Classification: Ester

Physical Characteristics: A colourless liquid.



B.P. 229°C.

Source & Occurrence: Found in citronella, geranium and eucalyptus citriodora oils.

Odour Profile: A green citrus, herbaceous, woody odour, somewhat rosey and fruity.

Solubility: Soluble in ethanol.

Use: In floral household and industrial fragrances.

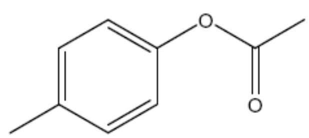
Para-Cresyl acetate

Chemical Name: *p*-Tolyl acetate

Chemical Formula: C9H10O2

Classification: Ester

Physical Characteristics: A colourless liquid.



B.P. 212°C.

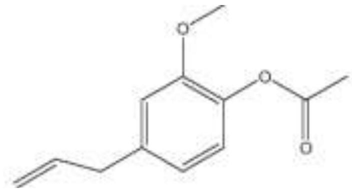
Source & Occurrence: Occurs in traces in ylang ylang, cananga oils and wallflower absolute.

Odour Profile: A penetrating odour suggestive of horse urine. Very diluted it has an odour reminiscent of narcissus.

Solubility: Soluble in ethanol.

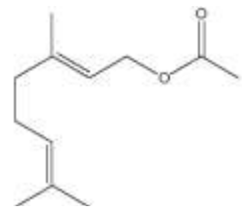
Use: Used sparingly to create narcissus fragrance. Also used as an antiseptic.

Eugenyl acetate



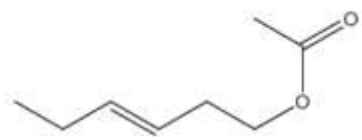
Chemical Name: 4-Allyl-2-methoxyphenyl acetate
Chemical Formula: C12H14O3
Classification: Ester
Physical Characteristics: A pale yellow liquid.
B.P. 282°C.
Source & Occurrence: Occurs in traces in clove oil.
Odour Profile: A mild sweet, balsamic and slightly spicy odour, reminiscent of clove.
Solubility: Soluble in ethanol.
Use: A fixative in carnation type fragrances and as an enhancer of herbaceous notes.

Geranyl Acetate



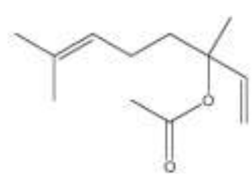
Chemical Name: *trans*-3,7-Dimethylocta-2,6-dien-1-yl acetate
Chemical Formula: C12H20O2
Classification: Ester
Physical Characteristics: A colourless to pale yellow liquid.
B.P. 245°C.
Source & Occurrence: Occurs in carrot, geranium, lemongrass, sassafras leaves, lavender, lemon, neroli, petitgrain and citronella oils.
Odour Profile: A sweet scent of rose and lavender, slightly woody.
Solubility: Soluble in ethanol.
Use: Used in floral fragrances to sweeten compositions. Used as a flavouring material.

Cis-3-Hexenyl Acetate



Chemical Name: *cis*-3-Hex-3-en-1-yl acetate
Chemical Formula: C8H14O2
Classification: Ester
Physical Characteristics: A colourless liquid.
B.P. 169°C.
Source & Occurrence: Occurs widely in the leaves and fruits of many aromatic plants. A trace constituent of many essential oils.
Odour Profile: An intensive green odour, reminiscent of unripe banana.
Solubility: Soluble in ethanol.
Use: Used in traces to add green notes to fragrances, either alone or in combination with the parent alcohol *cis*-3-hexenol.

Linalyl Acetate

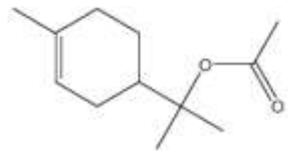


Chemical Name: 3,7-Dimethyl-1,6-octadien-3-yl acetate
Chemical Formula: C12H20O2
Classification: Ester
Physical Characteristics: A colourless liquid.
B.P. 220°C.
Source & Occurrence: Occurs in many essential oils including lavender, bergamot, orange, neroli, petitgrain oils. Also in jasmine and gardenia absolutes.
Odour Profile: A sweet, fruity, resembling terpenless bergamot oil.

Solubility: Soluble in ethanol.

Use: Used in extensively in floral fragrances and the reconstitution of lavender, bergamot, rosewood and coriander oils. Also has anti-inflammatory properties [85].

Terpinyl acetate



Chemical Name: *P*-Menth-1-en-8-yl acetate

Chemical Formula: C12H20O2

Classification: Ester

Physical Characteristics: A colourless liquid. B.P. 220°C.

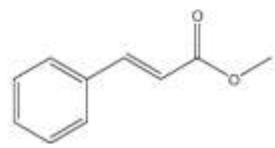
Source & Occurrence: Occurs in cardamom, cypress and many melaleuca varieties.

Odour Profile: A fresh, slightly herbaceous, citrus and lavender character.

Solubility: Soluble in ethanol.

Use: Used in lavender, eau de cologne, fougere and pine fragrances.

Methyl Cinnamate



Chemical Name: Methyl 3-phenylacrylate

Chemical Formula: C10H10O2

Classification: Ester

Physical Characteristics: A white crystalline solid. B.P. 263°C.

Source & Occurrence: Occurs in *Alpinia galangal*, eucalyptus, pine and basil oils.

Odour Profile: A balsamic fruity, heavy amber odour, under dilution takes on strawberry notes.

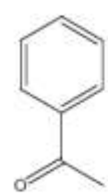
Solubility: Soluble in ethanol.

Use: Used as a fixative and blender in detergent perfumery.

Ketones

Ketones are structurally very similar to aldehydes and also tend to exhibit fruity aromas. Ketones are mainly responsible for the flavours in fruits and vegetables.

Acetophenone



Chemical Name: Methyl phenyl ketone

Chemical Formula: C8H8O

Classification: Ketone

Physical Characteristics: A colourless liquid, which solidifies in the cold. Melting point 21°C, B.P. 202°C.

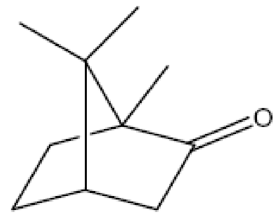
Source & Occurrence: Occurs in labdanum, green tea and some citrus oils. Also found in apple, apricot and cauliflower.

Odour Profile: A mimosa, sweet pungent somewhat citrus odour.

Solubility: Soluble in ethanol.

Use: Used in floral fragrances at low dosage levels, mainly for soaps and household products. Used in flavours.

Camphor



Chemical Name: 1,7,7-trimethylbicyclo[2.2.1]heptan-2-one
Chemical Formula: C10H16O
Classification: Ketone
Physical Characteristics: A white crystalline solid.
Melting point 175°C, B.P. 204°C.

Source & Occurrence: Occurs in *Cinnamomum camphora* in East and South East Asia. Also occurs in a number of other plants as a minor constituent.

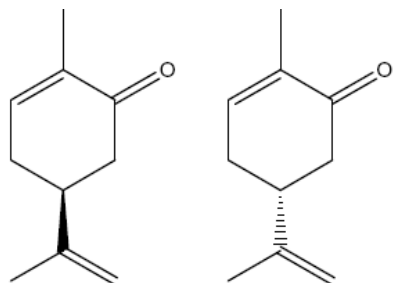
Odour Profile: A medicinal cooling odour.

Solubility: Soluble in ethanol.

Use: In medicinal preparations. Low cost perfumes, shoe polish, solvent for paints.

Carvone

Chemical Name: 2-methyl-5-(prop-1-en-2-yl)
Chemical Formula: C10H18O
Classification: Ketone
Physical Characteristics: A colourless to pale yellow liquid.
B.P. 231°C.



l-carvone *d*-carvone

Source & Occurrence: Formed through hydroxylation from limonene and subsequent oxidation [86]. Carvone occurs as two isomers *l*- and *d*-carvone. *L*- form occurs in *Eucalyptus* oils, gingergrass, mandarin, spearmint and *d*- form in caraway seed and dill oils.

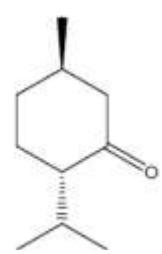
Odour Profile: A spearmint, caraway and dill odour.

Solubility: Soluble in ethanol.

Use: Used in food flavours and fragrances.

Menthone

Chemical Name: 5-Methyl-2-(1-methylethyl)cyclohexane
Chemical Formula: C10H18O
Classification: Ketone
Physical Characteristics: Crystal form.
Melting point 41-43°C, B.P. 207°C.



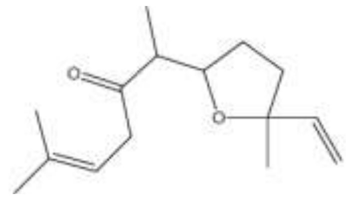
l-menthon

Source & Occurrence: Occurs in peppermint oil with menthol and menthyl acetate. Also in pennyroyal, geranium and other essential oils. Comes in four isomers but *l*- is mainly in essential oils.

Odour Profile: A refreshing menthol odour, reminiscent of peppermint, with slightly woody undertones.

Solubility: Soluble in ethanol.

Use: Sparingly used in flavours and fragrances.



Davanone

Chemical Name: 6-Methyl-2-(5-methyl-5 -vinyltetrahydro-2-furanyl)-5-hepten-3-one

Chemical Formula: C15H24O2

Classification: Irregular Ketone

Physical Characteristics: A colourless liquid. B.P. ???°C.

Source & Occurrence: A major constituent in davana oil, minor constituents in tansy, chamomile and Artemisia oils.

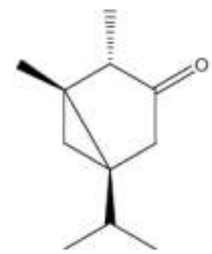
Odour Profile: A hay like, tea odour, reminiscent of davana.

Solubility: Soluble in ethanol.

Use: Possible use in flavours and fragrances for tea like notes. Used in fine perfumery.

Plant Metabolism: As an anti-fungal defence [87].

Thujone



Chemical Name: 1S-(1-,4-,5-alpha)4 -methyl-1-propan-2-yl-bicyclo[3.1.0]hexan-3-one

Chemical Formula: C10H16O

Classification: Irregular Ketone

Physical Characteristics: A colourless liquid. B.P. 201°C.

Source & Occurrence: A constituent in arborvitae (thuja), some junipers, mugwort, sage, tansy and wormwood.

Odour Profile: A herbaceous odour similar to Artemisia.

Solubility: Soluble in ethanol.

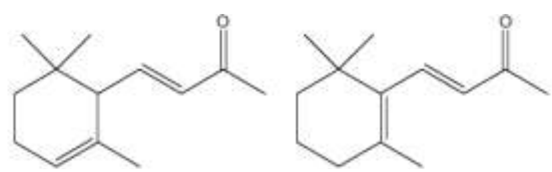
Use: Restricted use in flavours. Used in some fine fragrances.

Ionone

Chemical Name: 4-(2,6,6-trimethyl-1-cycohexen-1-yl)-3-buten-2-one

Chemical Formula: C13H20O

Classification: Ketone



alpha-ionone *beta*-ionone

Physical Characteristics: A colourless to pale yellow liquid. B.P. 237-239°C.

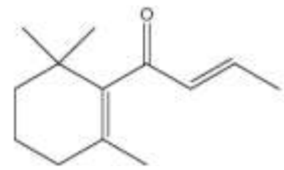
Source & Occurrence: Formed through the degradation of high molecular weight terpenoids (carotenoids) [88]. Occurs in two isomers *alpha*- and *beta*-ionone. A constituent in boronia, cassie and violet leaf absolutes.

Odour Profile: Varies depending on isomeric ratio: *alpha*-ionone is sweet violet and *beta*-ionone is more woody, fruity odour, along the lines of cedar and raspberries.

Solubility: Soluble in ethanol.

Use: In violet compositions and rose as a floraliser. Assists in producing powdery notes with vanillin and heliotropin. Used as a flavour material. Used to synthesise vitamin A.

a-damascone



Chemical Name: 1-(2,6,6-Trimethylcyclohex -2-en-i-yl)but-2-en-1-one

Chemical Formula: C13H20O

Classification: Ketone

Physical Characteristics: A colourless liquid. B.P. 266°C.

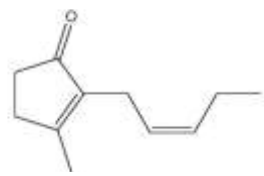
Source & Occurrence: Occurs in rose and tea.

Odour Profile: An intense fruity, reminiscent of plum and roses. On dilution it has a warm and intense lifting rose odour.

Solubility: Soluble in ethanol.

Use: Used in traces to impart depth into floral perfumes. Used in food flavouring.

Cis-Jasmone



Chemical Name: 3-Methyl-2-(*cis*-pent-2-en-1-yl)-cyclopent-2-en-1-one

Chemical Formula: C11H16O

Classification: Ketone

Physical Characteristics: A colourless liquid. B.P. 248°C.

Source & Occurrence: Two isomers but only *cis*- isomer known to occur in nature. Occurs in jasmine and orange blossom absolute. Also in neroli oil.

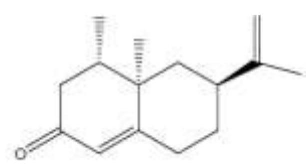
Odour Profile: A celery fruit like aroma, on dilution becomes reminiscent of jasmine and cherry blossom.

Solubility: Soluble in ethanol.

Use: Used in traces to impart depth into floral perfumes.

Plant Metabolism: Can be released during plant damage to protect against insect herbivory as a repellent [89].

Nootkatone



Chemical Name: 4-alpha,5-dimethyl-1,2,3,4, 4alpha,5,6,7-octahydro-7-keto-3-isopropenylnaphthalene

Chemical Formula: C15H22O

Classification: Ketone

Physical Characteristics: A colourless liquid, condenses to a solid at room temperature. Melting point 36°C, B.P. 170°C.

Source & Occurrence: Found in grapefruit.

Odour Profile: An intense citrus, grapefruit odour.

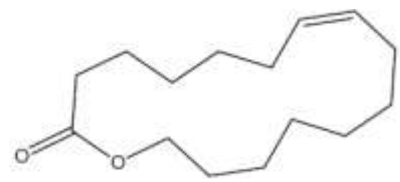
Solubility: Soluble in ethanol.

Use: Used at low levels with d-limonene in citrus colognes. As a citrus flavour enhancer.

Lactones

Lactones are very common in fruits and more are being discovered. The hydroxy group of alcohols most often react with carboxylic acids to form lactones. Lactones contain an ester functional group in the cyclic part of the molecule. They are not too unsimilar to ketones in skeletal structure. These compounds are important to fruit notes in flavour and fragrances.

Ambrettolide



Chemical Name: Cyclohexadecan-7-olide

Chemical Formula: C16H28O2

Classification: Lactone

Physical Characteristics: A colourless liquid, B.P. 291°C.

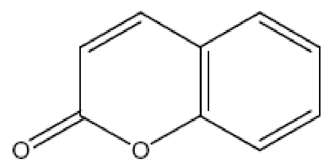
Source & Occurrence: Occurs in ambrette seed oil. Also present in some hibiscus species.

Odour Profile: A sweet musk like floral odour.

Solubility: Soluble in ethanol.

Use: As a fixative in perfumery to bring up fragrance.

Coumarin



Chemical Name: 2-chromenone, 1,2-benzprone

Chemical Formula: C9H6O2

Classification: Lactone

Physical Characteristics: A white crystal powder Melting point 68°C, B.P. 291°C. May undergo decomposition in light.

Source & Occurrence: Produced in plants through hydroxylation, glycolysis and cyclization of cinnamic acid. In a large number of plants including woodruff, lavender, tonka beans, peru balsam, cassia, cinnamon, some ferns and narcissus.

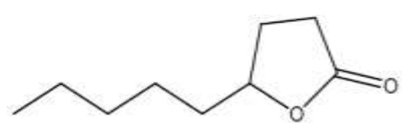
Odour Profile: A sweet, warm, herbaceous, hay like odour.

Solubility: Soluble in ethanol.

Use: Used in a wide range of fragrances to build strength. Used in tobacco products. Banned as a food additive.

Plant Metabolism: Coumarin helps to protect plants against feeding herbivores [90]. Also influence root growth in maize [91].

Ŷ-Nonalactone



Chemical Name: 4-Hydroxynonanoic acid lactone

Chemical Formula: C9H18O2

Classification: Lactone

Physical Characteristics: A colourless liquid. B.P. 243°C.

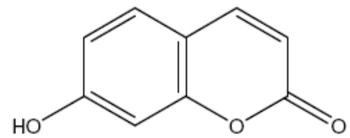
Source & Occurrence: Found in peaches, apricots and coconut.

Odour Profile: A creamy soft coconut odour.

Solubility: Soluble in ethanol.

Use: Used in a wide range of fragrances and flavours.

Umbelliferone



Chemical Name: 7-hydroxycoumarin

Chemical Formula: C9H6O3

Classification: Lactone

Physical Characteristics: Colourless crystals.

Melting point 225-228°C.

Source & Occurrence: Found in parsley, galbanum, carrot, coriander and tea leaves.

Odour Profile: A coumarin odour on heating.

Solubility: Soluble in ethanol and hot water.

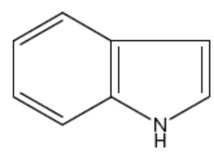
Use: Used as a UV block in cosmetics and as an optical brightener for textiles.

Plant Metabolism: As a stress metabolite in the plant *Chamomilla recutita* (L.) Rauschert [92].

Nitrogen Compounds

Amines are compounds in which one or more hydrogen atoms of ammonia are replaced by a hydrocarbon radical. They are classed primary, secondary or tertiary according to the number of hydrogen atoms of ammonia replaced. Simple amines tend to have animalic odours. The anthranilates are bifunctional as they contain both an ester and amino function group. These compounds have pleasant aromatic odours, however on exposure to air tend to darken due to reactions with aldehydes to form aldimines.

Indole



Chemical Name: 2,3-Benzopyrrole

Chemical Formula: C8H7N

Classification: Cyclic nitrogen compound

Physical Characteristics: A white crystalline powder.

Melting point 52°C, B.P. 253-254°C. (turn red-yellow on exposure to air).

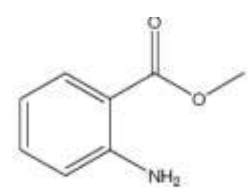
Source & Occurrence: Found in neroli, and some citrus oils, jasmine, orange blossom and wallflower absolutes.

Odour Profile: In concentrated form a fecal odour, but on dilution takes up floral characteristics.

Solubility: Soluble in ethanol.

Use: Used in a wide range of fragrances as a floraliser.

Methyl anthranilate



Chemical Name: Methyl-2-aminobenzoate

Chemical Formula: C8H9NO2

Classification: Nitrogen compound

Physical Characteristics: A colourless to yellowish liquid with a bluish fluorescence.

Melting point 24°C, B.P. 256°C.

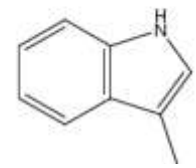
Source & Occurrence: Found in acacia, bergamot, champaca, gardenia, grapes, hyacinth, lemon, mandarin, neroli, orange flowers, rue, petitgrain, strawberries, jasmine, tuberose, wallflower and ylang ylang.

Odour Profile: A musky orange flower with a dry floral note, similar to petitgrain oil.

Solubility: Soluble in ethanol.

Use: A flavouring for soft drinks and candy. Used in small dosages in citrus-florals and oriental type fragrances. It is also used as a bird repellent.

Skatole



Chemical Name: 3-methylindole

Chemical Formula: C9H9N

Classification: Nitrogen compound

Physical Characteristics: Large crystals or fine powder.

Melting point 93°C, B.P. 265°C. (Turns brown on exposure to air)

Source & Occurrence: Found in orange blossoms and jasmine.

Odour Profile: A fecal smell (civet like) in concentration, floral in dilution.

Solubility: Soluble in ethanol.

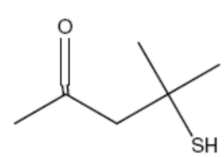
Use: A fixative in floral fragrances. As a flavour material for ice cream and cigarettes.

Sulphur Compounds

These materials have a varied occurrence and unusual properties. In plants they are based on amino acids and part of proteins, enzymes, coenzymes, vitamins and hormones. Most sulphur compound have very unpleasant odours, but organosulphur compounds found in many plants are very aromatically pleasant, such as those found in garlic, chive, leek, cabbage, radish, mushrooms, coffee, mustard and pineapple, etc. Sulphur compounds appear to be important to the plant defence system by introducing toxicity into tissue to hinder herbivore ingestion [93].

Within a number of vegetables, the action of enzymes upon broken tissue decomposes precursors to form sulphur compounds. Through the food baking process, other groups of sulphur compounds are formed. Thermal processes also break down glucosinolates in vegetables through hydrolysis into the formation of thiocyanates. Factors controlling these processes are influenced by the particular conditions, pH and presence of cofactors [94]. Research is showing that sulphur compounds play major roles in the flavours of vegetables, fruits, and processed foods and beverages and that continued research into this area is leading towards new routes and techniques of biosynthesis of aromatic compounds for flavours. A number of sulphur compounds are being identified in plants, that previously where not known to exist directly in nature [95], as the example below.

4-Mercapto-4-methyl-2-pentanone



Chemical Name: 4-Mercapto-4-methyl-2-pentanone

Chemical Formula: C6H12OS

Classification: Sulphur compound

Physical Characteristics: A colourless to pale yellow liquid.

B.P. 47-49 °C

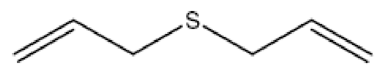
Source & Occurrence: Found in basil, *Buxus sempervirens* L and broom *Sarothamnus scoparius* (L) Koch,

Odour Profile: A very potent odour resembling blackcurrant and broom.

Solubility: Partly soluble in ethanol.

Use: Used as a flavour ingredient (biosynthesised).

Allyl sulfide



Chemical Name: Thioallyl ether

Chemical Formula: C6H10S

Classification: Sulphur compound

Physical Characteristics: A colourless to pale yellow liquid.

B.P. 139 °C

Source & Occurrence: Occurs in garlic.

Odour Profile: A garlic odour.

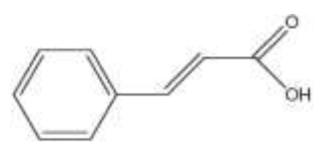
Solubility: Partly soluble in water, soluble in ethanol.

Use: Used in food and medicine.

Other Groups

When oxidation of an aldehyde replaces the hydrogen on a carbonyl atom with a hydroxy group, the conjunction of the carbonyl and hydroxy group forms the carboxyl group of acids. These are also present in plants. The odour of the carboxyl acid usually resembles its precursor in a degraded form. This acid group also contributes to the flavour of fruit and vegetables, *i.e., citric acid contributes to the flavour of citrus fruits*.

Cinnamic acid



Chemical Name: (E)-3-phenyl-2-propenoic acid

Chemical Formula: C9H8O2

Classification: Aromatic acid

Physical Characteristics: A white crystal powder.

Melting point 133°C, B.P. 300 °C

Source & Occurrence: A product of the shikimic acid pathway through the enzyme phenylalamine ammonia lysase. Found in several essential oils and gums, cassia, cinnamon, tolu, Peru balsams and Storax resin.

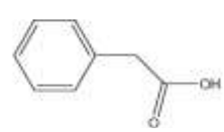
Odour Profile: A pleasant weak balsamic honey like odour.

Solubility: Partly soluble in ethanol, insoluble in hexane.

Use: As a fixative in soap perfumes. Used in flavours and for the synthesis of methyl, ethyl and benzyl esters.

Plant Metabolism: Inhibits the production of *a*-glucosidase [96].

Phenyl acetic acid



Chemical Name: *alpha*-toluic acid

Chemical Formula: C9H8O2

Classification: Aromatic acid

Physical Characteristics: A white crystal solid.

Melting point 76-77°C, B.P. 265 °C

Source & Occurrence: Occurs in neroli, acacia, jasmine, rose and tobacco leaf.

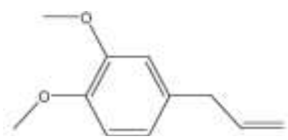
Odour Profile: A sweet animalic-honey like odour.

Solubility: Partly soluble in ethanol, slightly soluble in water.

Use: Used in floral perfumes and the basis of some honey compounds.

The structure of ethers is very similar to alcohols and phenols, except it has no hydroxyl group. A number of ethers exist in essential oils. Ethers are relatively un-reactive compounds.

Methyl eugenol



Chemical Name: 3,4-Dimethoxy allylbenzene

Chemical Formula: C11H14O2

Classification: Aromatic ether

Physical Characteristics: A colourless to pale yellow liquid.

Melting point 76-77°C, B.P. 265 °C

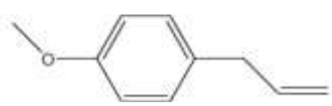
Source & Occurrence: Occurs in rose, basil, eucalyptus, ylang ylang, huon pine and minor constituents of a number of essential oils..

Odour Profile: A sweet spicy clove-eucalyptus odour.

Solubility: Partly soluble in ethanol, slightly soluble in water.

Use: Used in floral fragrances as a substitute for *iso*-eugenol. Used in insect traps to lure cockroaches.

Anethole



Chemical Name: 1-methoxy-4-(1-propenyl) benzene

Chemical Formula: C10H12O

Classification: Aromatic ether

Physical Characteristics: A colourless to pale yellow liquid, may condense to solid at room temperature. Melting point 21-22°C, B.P. 234 °C

Source & Occurrence: Occurs in anise, star anise and anise myrtle.

Odour Profile: A sweet anise odour.

Solubility: Partly soluble in ethanol.

Use: Used in liqueurs and soap perfumes. A precursor for paramethoxyamphetamine (PMA).

THE ANALYSIS OF ESSENTIAL OILS

The ability to undertake the analysis of essential oils and aromatic materials is an important aspect of essential oil research, project development and ongoing operations. Analysis is an aspect that is required not only as an aid to development, but also as a means to satisfy many regulatory requirements. This field of chemistry has advanced in leaps and bounds with the increasing sensitivity of equipment in recent years.

Analytical chemistry plays the following roles within essential oil development;

- Required during the bio-prospecting process to identify the various chemical constituents in plants,
- Required during genetic material selection to identify the most suitable planting materials,
- Required during field development trials to evaluate results in terms of essential oil quality,
- Required to assist in selecting harvest windows,
- Required to assist in optimizing extraction methods and techniques,
- Required to blend and 'bulk' oils (i.e., combine various oil batches after extraction into a uniform product) after the harvest season,
- During commercial cultivation as a quality assurance procedure,
- During commercial operations to provide data to clients and potential client, and
- During continued and ongoing research and development.

The analysis of essential oils falls into three basic categories, physical, olfactory and chemical. Secondini listed a range of tests generally accepted by the flavour and fragrance industry up to and during the 1990s [97] (see Table 4.4.). Although some of them are now outdated, this data is still required for some standards and pharmacopeia around the world. Many of these methods compensated for the lack of sophisticated analytic equipment during these times. However they still can play a role in essential oil development where some equipment may not readily be available and *'bench-top'* tests can be utilized to provide rough results. Langenau in chapter 4 of volume one of Guenther's classic monographs explains in detail how to conduct these *'bench-top'* tests [98]. Although most of these tests can be replaced with modern instrumentation they are still very useful.

In addition to the above physical characteristics, the essential oil or aroma material must satisfy the users olfactory and organoleptic expectations to be commercially accepted. However, two aroma materials with the same constituents, but with very minor proportional differences, can under subjective olfactory analysis exhibit different odour profiles, due to minor proportional constituent variances [99]. These minor variances could lead to buyer non-acceptance.

The olfactory analysis of essential oils will be covered later on in this book (chapter 11), and the rest of this chapter will briefly outline the various methods available to conduct chemical analysis of essential oils and other plant materials.

Chromatography and mass spectrometry are two of the most important techniques for the analysis of essential oils. Gas chromatography (GC) has had a great impact on the essential oil industry. Before chromatography, it took many days to undertake an analysis. Compound structures and identities could only superficially be identified, using fractional distillation where pure compounds could not be isolated and thus were contaminated with other constituents in the fraction. Gas chromatography-mass spectrometry (GC-MS) added further improvements to essential oil analysis where broad categories of monoterpenes and varying isomers closely resembling each other in terms of chemical structure could be individually identified. The GC-MS allows recognition of overlapping peaks on a GC and separately identify constituents.

Table 4.4. Tests Used to Ascertain if the Organoleptic characteristics of an Essential Oil Meet with Official Pharmacopoeia and other Industry Standards

Specific gravity	**Aldehyde and ketone determination**	**Polymerization**
Optical index	Ester and alcohol determination	Viscosimetry
Refractive index	Phenol determination	Colourmetry
Boiling point	Iodine determination	Spectrophotometry
Solidifying or freeze point	Acids determination	Chromatography
Solubility	Melting point	Microscopy
Saponification number	Absorption	Computerised automatic control
Acetylation	Flash point	Search for adulteration through fractional distillation

Chromatography as an analytical technique was first used by the Russian botanist Mikhail Tswett, who utilized a simple form of liquid-solid chromatography to separate plant pigments [100]. This technique was ignored until the 1930s when Martin and Synge experimented with liquid chromatography by using water as a stationary phase on a silica packed bed to separate acetyl amino acids [101]. Martin with James went on to recommend the use of gas as a replacement for liquid for faster and more accurate results, giving rise to gas chromatography [102]. The two were awarded the Nobel prize for their work in 1952. Figure 4.8. shows the usefulness of liquid and gas chromatography in the analysis of plant phytochemcials.

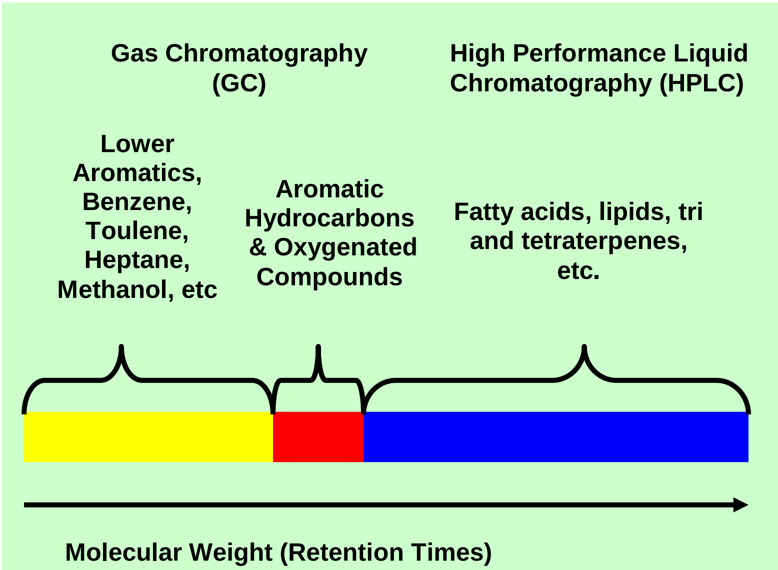


Figure 4.8. The Usefulness of Liquid and Gas Chromatography in the Analysis of Plant Phytochemcial Compounds.

Chromatography

Chromatography is essentially a separation process, where the constituents of a mixture are distributed between a stationary phase, which is usually a column and a mobile phase, which is a gas or a liquid. The mobile phase passes under pressure through the column where through molecular force the weak solutes are deposited in the column first and the stronger ones last. The parameters of the process are controlled by the phase system and physical properties of the column. Through this process, a mixture can be broken into individual components with a quantitative estimate. If the mobile phase is a liquid, the process is called liquid chromatography, if the mobile phase is a gas, the process is called gas chromatography.

The first gas chromatographs used packed columns which were inaccurate and inefficient. The development of capillary columns enabled the isolation of complex molecules within essential oils. Temperature programming also added to efficiency. The modern gas chromatograph is a complex instrument controlled by a personal computer, with auto-sampling protocols and results printed out in a standard format. A schematic diagram of a gas chromatograph is shown in Figure 4.9.

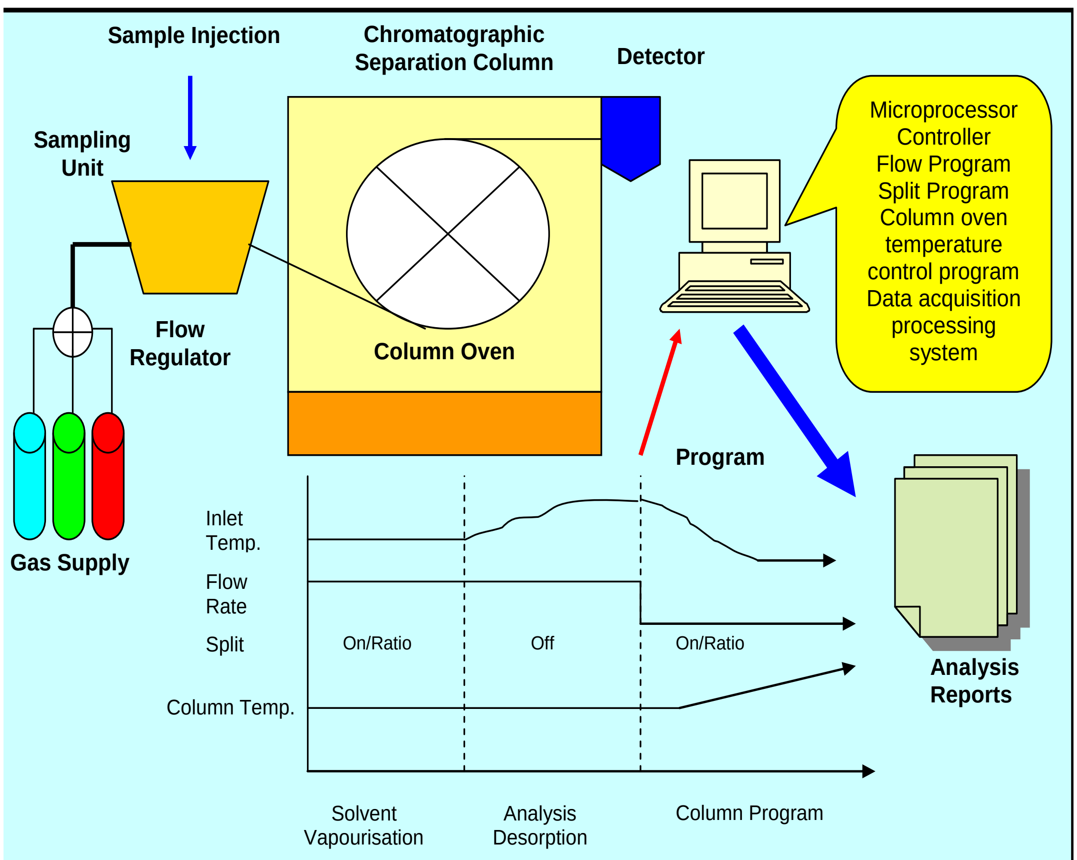


Figure 4.9. A Schematic Diagram of a Gas Chromatograph.

A gas chromatograph consists of four phases, the gas supply, the sampling system, the column and oven and the detector. These phases are controlled by a program to control the amount of sample that travels through the column (split ratio), the temperature and the flow rate. Columns are either packed or open capillary tubes and each type of column will require particular programming sequences to achieve the optimal sensitivity and efficiency. Capillary columns are very narrow hallow columns that are rolled around inside the oven, which can provide extreme sensitivity in separation. A number of detectors can be used in chromatography and sensitivity has to be weighed off against the noise it produces. One of the most common is the flame ionization detector (FID), which is less sensitive than many specific detectors. An FID detector on a gas chromatography system will utilize hydrogen as the carrier gas mixed with either helium or nitrogen as an inert gas, which burns and oxidizes fragments of the sample to generate electrons that are caught by an array of sensors. FID detectors are mass rather than concentration sensitive and can detect most carbon containing substances, which makes them very suitable for the analysis of the majority of essential oils. Other detectors such as the nitrogen phosphorus detector (NPD) would be more suitable for detecting nitrogen and phosphorus based compounds.

A report of each analysis shows each separated compound in the form of a peak, as shown in Figure 4.9. Each compound will have a specific retention time, measured in minutes to the crest of the peak. Each compound will have a specific retention time that is unique to it, although many compounds like terpenes have very close retentions times. The percentage of the compound in the total mixture is calculated by the area under the peak through the formula;

Area = Height x width at 0.5 the total height of the peak.

This is normally calculated automatically as "area" on a separate page to the report. The baseline of the peaks represents the mobile phase of the run. The recording of the run on the report starts at the time of sample injection.

Organic oxygenated compounds can be identified through their relative retention times in GC analysis. The retention index of a compound is calculated by a using a logarithmic number from a hypothetical standard *n*-alkenes, which is calculated using;

$$I = 100\left(\frac{\log X_i - \log X_Z}{\mathrm{Log}\ X_{(Z+1)} - \log X_Z} + Z\right)$$

X is the adjusted retention times, Z is the number of carbon atoms of the *n*-alkane eluting before, with (z+1) the number of carbon atoms of the *n*-alkene eluting after the peak. Where temperature programming is used the retention time index is calculated using direct numbers rather than logarithms and be calculated as:

$$IT = 100\left(\frac{t\mathrm{R}_i\mathrm{T} - t\mathrm{R}_z\mathrm{T}}{t\mathrm{R}(z+1)\mathrm{T} - t\mathrm{R}_z\mathrm{T}} + Z\right)$$

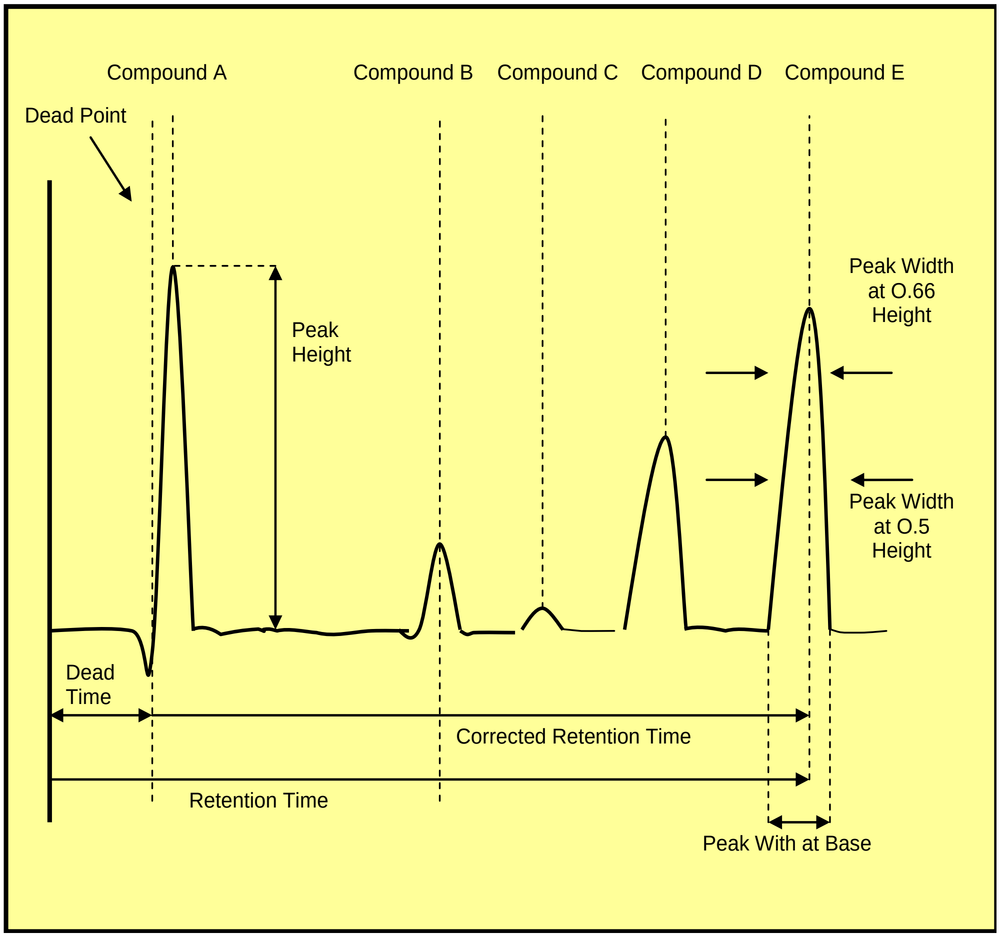


Figure 4.10. Gas Chromatograph Peak Index Report Format.

Figure 4.11. The Author's Gas Chromatograph in Perlis, Malaysia.

$_t$RT is the total retention time under the temperature programming schedule. *I*T is the same compound after isothermal adjustment. This is also called the Kovats retention index.

Gas Chromatography-Mass Spectrometry (GC-MS)

One of the weaknesses in gas chromatography is the separation of compounds will often show overlapping peaks, which make compounds difficult to identify. The gas chromatograph alone will not be able to distinguish the difference between impurities and other compounds. Through the coupling of a mass spectrometer at the end of a capillary column of a gas chromatograph, the detector can capture and ionize (bombard with electrons) each molecule and identify it according to the relative charge of broken molecule fragments (ions). Through combining retention time and ionization detections, most molecules can be accurately identified. Compounds are identified through comparing the spectrum to a library database of compound spectrums in a connected computer. The GC-MS quantifies the molecules in the mixture through comparing the relative concentrations among the atomic masses in the generated spectrum. The advent of the gas chromatograph Mass spectrometer (GC-MS) is a method that has revolutionized the analysis and identification of compounds within essential oils [103].

A GC-MS requires knowledge and experience to obtain accurate results. Programming requires prior consideration as to what types of compounds are in the sample mixture so that the column will not be overloaded during the analytical run. Knowledge of the molecular structures of compounds and the phytochemistry of the plant is necessary when interpreting the read-outs from the mass spectrometer, as the database will provide a number of probable compounds according to retention times and ionization parameters, rather than an absolute identification. Many young phytochemistry researchers have published incorrect results based on inexperience of GC-MS operation. To eliminate background traces from previous runs, a blank run to burn up any residual compounds is sometimes advisable. Existing libraries may have between 5000-15000 known compounds on their database and there is always the chance that a compound detected does not directly match any compound in the database and a number of probabilities will be suggested in the absence of that material on the database. Thus for work on new essential oils that have not had prior published analysis, alternative methods of analysis are required to confirm GC-MS results.

Other Methods of Analysis

The limitations of gas chromatography and mass spectrometry sometimes require additional methods to separate and identify compounds within essential oils. A number of other methods exist to analysis essential oils. These are mainly utilized in research laboratories.

Figure 4.12. A Gas Chromatograph-Mass Spectrometer (GC-MS) The Forest Research Institute of Malaysia (FRIM) in Kuala Lumpur, Malaysia.

Multidimensional Chromatography

Multidimensional chromatography is where two or more analytical devices are coupled together to enhance the separation power. These techniques are used when one method is weak at separating certain compounds, where another method may be stronger, and through coupling two techniques together the whole spectrum of a mixture can be investigated. This method is also used when mixtures are extremely complex where one column cannot on its own undertake an efficient separation [104].

Sometimes two different analytical techniques are coupled together in what is called comprehensive multidimensional chromatography. These methods are used where the separation of individual compounds in mixtures is difficult using a single method, and using two distinct methods of analysis aids in separation. Thus the configuration of a comprehensive multidimensional chromatography system will vary according to the target compound group. Usually in such systems a cut is made into the column of one method where the flow becomes the injected mixture into the second method of analysis. This increases resolution of part of a mixture where many peaks exist close together [105]. Various couplings in Comprehensive multidimensional chromatography would include;

- Liquid Chromatography x Liquid Chromatography: This coupling provides good complementary information to separate proteins, DNA and RNA [106].
- Gas Chromatograph x Gas Chromatograph: The coupling serves as a tool to selectively identify compounds in certain parts of a spectrum with much greater accuracy. This method can provide comprehensive two-dimensional data which assists in more accurate compound identification.

- High Performance Liquid Chromatography x Gas Chromatography: This method will collect a lot of compound data during a single run. This method can be utilized to improve separation of compounds in complex essential oils.

These methods have been used to amplify trace constituents in fruits and vegetables [107], flavouroids in coffee [108] and other grains [109], and authentication of essential oils [110].

Gas Chromatograph and GC- Mass Spectrometry Headspace Analysis

Headspace analysis was first developed in 1959 [111] but came into wider use with the advent of more sensitive GC-MS equipment during the following years. Headspace analysis is used in environmental protection and in flavour and food analysis [112]. The headspace analysis of aromatic mixtures enables the detection of highly volatile odourants which are not normally detected or are underestimated in standard GC analysis. Headspace analysis also allows the analysis of scents from living or picked plants that have not undergone extraction via distillation or solvent extraction, thus detailing a different constituent profile due to discounting the changes upon any chemical constituents, a method of extraction would produce. Thus headspace analysis is a method of comparing the natural odour profile of a plant with the extractive odour. Headspace analysis has played a role in identifying new aromatic compounds in plants that had not been previously identified through other methods [113]. Headspace analysis is usually the extension of a GC-MS configuration where the sample is enclosed within an airtight vessel with a gas flow to pick up the odourous constituents, which is injected into the inlet as a gaseous substance.

Thin Layer Chromatography

This technique is used to separate chemical compounds and identify the number of compounds within a mixture. It is also a good method for verifying a compound. TLC involves a stationary phase of absorbent material, usually silica gel on a flat glass slide where a liquid phase dissolved in a solvent is drawn up the slide by capillary action, separating the components through the different polarity of the components in the compound. The plate will then be analysed with a UV light to detect colour changes in the gel. TLC was first used to determine the pigments in plants and is now used in the detection of pesticides in foods.

Figure 4.13. An Infrared (IR) Spectrometer at Walailak University, Nakhorn Si Thammarat, Thailand.

Infrared (IR) Spectroscopy

Spectroscopy is a general term to refer to instruments that detect structural information about molecules. Infrared spectroscopy involves the passing of an infrared light through a sample to detect a unique compound vibration due to the energy level of the molecule. The resonant frequency that a molecule vibrates at is determined by the molecular shape and the strength of the bonding between each atom in the particular molecule. The distorted wavelength of the light that is detected is checked against a database which will provide an identification of the compound. IR spectroscopy is used to quickly determine different plant chemotypes [114], quality control and adulterant determination of essential oils [115], the identification of non-volatile constituents in essential oils (particularly cold-pressed citrus oils) [116], component specific identification of compounds in fruits and vegetables [117], and the qualitative and quantitative assessment of plant material, like tea leaves [118].

Nuclear Magnetic Resonance (NMR)

Nuclear magnetic resonance (NMR) detects low energy radiation in the radio spectrum emitted from atomic nuclei of a molecule. Most atomic nuclei exhibit an external magnetic field. When a molecule is placed inside a magnetic field, in a low energy form it aligns itself with the field and in a high energy form it aligns against the magnetic field. The NMR runs a strong static magnetic field with an alternating one and the difference between the magnetic energy levels is measured. This measurement provides very specific structural molecular information. A variation of NMR is proton nuclear magnetic resonance, which utilizes solvents to allow chemical shifts and spin-spin couplings where the molecule nuclei influence each other thereby changing the energy and frequency of surrounding nuclei. Signals from these reactions are detected by the NMR and identified. Another variation is carbon-13 magnetic resonance spectroscopy. Most carbon atoms are 12C, with a small percentage of 13C which exhibit magnetic resonance that can be measured in organic compounds to identify the carbon skeleton in organic molecules. NMR methods and CG and GC-MS are often used as complementary system in the analysis of essential oils [119].

Atomic Absorption Spectroscopy

Atomic absorption spectroscopy is principally a technique for the determination of metal concentration in a mixture, however it is being utilized in essential oil analysis to determine arsenic [120] and heavy metal contents [121]. Atomic absorption spectroscopy uses a furnace to vapourise the material into a gas, where a charged cathode and anode energise the sample which can be measured and a metal element identified.

Figure 4.14. Part of a Nuclear Magnetic Resonance (NMR) At Walailak University, Nakhorn Si Thammarat, Thailand.

Figure 4.15. An Atomic Absorption Spectrometer at Walailak University, Nakhorn Si Thammart, Thailand.

Figure 4.16. A UV Spectrometer at Walailak University, Nakhorn Si Thammarat, Thailand.

Ultra-Violet (UV) Spectroscopy

UV spectroscopy is used in the quantitative analysis of mixtures where metal ions can be coloured by solution and seen through their UV spectrum. This absorbed UV can be detected and compound concentrations determined in a mixture. UV spectroscopy works upon the Beer-Lambert law, where the absorbance of a solution increases with its concentration. Liquid chromatographs sometimes utilize UV detectors for complementary analysis with other detectors. UV spectroscopy can be used for quick chemical group quantification and applied to quantitative compound analysis in plants [122].

Electronic Nose (E-Nose)

The concept of the electronic or e-nose evolved from the use of gas sensors in the mining industry. Its principal was laid in the need to develop objectivity in the sensory evaluation of aromatic materials, which is subjective due to human interpretation of odours. The e-nose is a fast method for assessing volatiles for their identification, authentication, process control and product blending.

E-nose instrumentation comprises a sensory input device with a receptor to transmit data to a data acquisition and interpretation system [123]. Most sensors are chemically based with a catalytic of metal oxide coating of a ceramic pellet where changes in electrical charge are transmitted to the data acquisition receptor for interpretation. Some sensors utilize polymers which pick up variances in conductivity when in contact with different gasses. Compound polarity is thus critical to sensitivity. Other sensors are based on quartz which oscillate according to changes in the surrounding mass. The data acquisition receptor transmits data to a database which recognizes volatile compounds through pattern recognition algorithms.

Usually an e-nose is very spectrum specific depending upon the range variance that each type of sensor can provide and the algorithms programmed into the database. However the advantage of the e-nose is that it can provide a quick detection test without suffering human fatigue, providing objective results each time. The e-nose has found application in;

- The US FDA has used the device to detect the freshness of fish through monitoring the level of amines in samples,
- The baking industry has used the device to control the blending and roasting of food products where amino acids and reducing sugar reactions can create a number of aromatic compounds, some desirable and some undesirable in the product,
- The monitoring of cheese maturity and their authentication,
- The prediction of food shelf life,
- In microwave ovens to detect overcooking, and
- In agriculture to detect insect damage and mold growth on crops.

The e-nose is being developed as a tool in food processing where the aroma profile of food is influenced by the variation of raw materials which influence aroma/taste profiles, time and freshness, temperature, and the reducing activity of sugars and amino acids on constituents within the food during storage and processing. The e-nose is also being developed to assist in agriculture in applications such as the identification of different hop varieties [124]. However, this technique must be used with knowledge of the influences of climatic, soil, growth and nutrient factors upon the aromatic constituents of crops, so that correct correlations can be made between the selected markers, harvest maturity and variety etc [125]. One of the challenges for e-nose development for agriculture is the creation of standardization so results can be compared and correlated with specific crop conditions.

The field of analysis of essential oils is rapidly changing with a number of techniques taking on more importance. Researchers are finding new methods to gain better sensitivity, better separations and solve selectivity problems. This is leading to the growing importance of additional chromatography and spectroscopic methods as well as the increased utilization of UV spectroscopy, nuclear magnetic resonance, atomic absorption spectroscopy and infra red spectroscopy as standard essential oil analysis methods in the industry [126].

However researchers have made many mistakes and errors with modern analytical techniques in the identification of new compounds [127]. Even though modern analytical techniques can identify 30-40 compounds in essential oils in under an hour, which would have taken years to do, GC-MS have great limitations in identifying new compounds [128]. The old *benchtop* organic chemistry techniques still offer some advantages in isolating specific compounds, which greatly assists in their positive identification. Important organic *benchtop* tests to determine chemical properties of essential oils include;

- The determination of acids,
- The determination of esters,
- The determination of alcohols through acetylation,
- The determination of tertiary alcohols,
- The determination of aldehydes and ketones,
- The determination of phenols, and
- Specific tests for individual compounds [129].

Some understanding of the plant metabolism, the pathways and the relationships between plant and chemical will provide great insights in the field development stage of an essential oil as well as the extraction procedure. This is still a subject where knowledge is in its infancy and there maybe some keys in this knowledge for creating a regime of optimal production. The key is to look for relationships in the plant metabolism with propagation, cultivation, pre-extraction, extraction and storage practices. Knowledge of essential oil chemistry is also necessary for selecting essential oils to produce in identifying potential and dealing with users in the industry.

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Chapter Five
The Extraction of Essential Oils

The theory and practice of essential oil extraction has a long historical basis and evolution. Although these practices are long standing and appear simple, they are based on a number of complex principals. It is important to have some basic understanding of these principals. The selection and setting up of an extraction system for essential oils is one of the most important decisions that could be made in establishing any new venture. This chapter provides a very brief overview of some of the basic fundamentals of essential oil extraction, including distillation, solvent extraction, supercritical fluid extraction, enfleurage, cold expression and brief update on some other methods.

The choice of extraction method for the recovery of essential oils and other volatile materials from plants has great bearing on the composition and quality of the crude product and the viability of the whole enterprise. There are a variety of methods available for extracting volatile constituents from plants. The chemical composition and yield of the extract will vary greatly according to the chosen method of extraction. True essential oils are extracted through various distillation methods. However a number of volatile constituents of plants are very fragile and susceptible to heat, reactive to moisture during extraction and are difficult to liberate from the surrounding plant material, thus other more situational effective methods of extraction are also utilized.

Enfleurage was a process once used that is not heat sensitive, using fat as a medium to absorb and trap aromatic materials from plants. This method was utilized before solvent extraction was available in the early part of the Twentieth Century. Solvent extraction has an advantage over distillation in that the process operates in the temperature range of 50°C where minimal damage occurs to most volatiles. The problems of hydrolysis and creation of artifacts also does not occur during the solvent extraction process, thus the resulting aromatic extract is closer to the scent of the source material. Solvent extraction is more suitable for materials with higher boiling points, which distillation struggles to extract from plant material. An alternative to solvent extraction is supercritical fluid extraction using mainly carbon dioxide as a liquid solvent. CO_2 has a very low viscosity, thus it is very effective in diffusing aromatic materials, which are deep in the plant tissue. CO_2 is also an inert material, which prevents unwanted artifacts developing, thus producing an essential oil with very close organoleptic properties as the parent plant material. Citrus oils are expressed from the fruit as part of the integrated production of fruit juices in the citrus industry.

Distillation

The practice of distillation goes back to ancient times, perhaps as early as 484 BC, when Herodotus recorded the production of turpentine oil in his writings [1]. Strong evidence also exists that the Arabs understood the distillation process, where the words *chemistry, alcohol* and *alembic* have their origins. It is most likely the Arabs inherited their knowledge of distillation techniques from the Syrian Empire [2]. However, almost all distillation until mid way through the Nineteenth Century was water distillation. Water distillation is where plant material is totally immersed in water, which is brought to a boil by a direct fire. Once the water is at boiling point steam begins to pass through a usually copper cooling coil to condense the distillate. Oil would then be collected from the top of the collection vessel upon separation with the water. Oils distilled within the geographically centered and artisan based perfumery industry at the time included rose, lavender, lavandin, rosemary, and herbs like thyme.

Mid way through the Nineteenth Century the Germans and French in Grasse began experimenting to improve the distillation process. Equipment and techniques for water-steam and vacuum distillation were developed, greatly improving upon yields that were achieved through simple hydro or water distillation. Pre-distillation techniques like comminution were enhanced and fertilizers were applied to aromatic crops with dramatic results [3]. However it was only in the beginning of the Twentieth Century that steam from an external source to the charge bin was introduced, bringing in the method of steam distillation.

The equipment and skills used for the distillation of aromatic materials from plant material is still very basic in many parts of the world. Many production centres like the Australian eucalyptus and tea tree industries in the first half of the Twentieth Century, utilized available items like ship water tanks as charge bins to hold foliage during distillations [4]. Even today in remote parts of the world, many stills adopt primitive designs and utilize very basic techniques in production, sourcing steam from direct fires.

Figure 5.1. An old simple "bush" distillery in Australia
(Photo courtesy Mr. John Bax)

The distillation of aromatic materials from plants is a field that has lacked the intensity of research that other issues in essential oil production have received. The subject has also tended to be ignored by books on the industry of late. Although the distillation of essential oils appears to be a simple process, there are a number of principals and reactions acting upon the process that must be understood in order to obtain good yields and quality. Experience in the distillation of a few selected essential oils without knowledge of the fundamental principals and understanding the specific requirements of a particular plant, would most probably lead to limited results in terms of oil yield and quality.

The Fundamental Principals of Distillation

Any understanding of the principals of distillation requires an understanding of the principals of the laws of thermodynamics and physical chemistry. The practice of distillation on herbaceous materials is influenced by;

a) latent heat,
b) the behaviour of gases,
c) vapour pressure, and
d) steam.

Distillation is also influenced by the nature of any physical plant material and characteristics of volatile materials contained within it, which may vary the application of these laws.

Essentially, distillation enables the separation of volatile constituents contained in some form of plant material, through a parent carrier vapour (water) capturing other volatile materials from the plant material in the charge. To achieve this, the parent vapour must somehow capture these aromatic materials from the plant's surface, through some form of contact and carry them up through the charge to the condenser for rectification.

A number of fundamentals govern the behaviour of the dynamics of distillation. These can be summarized as follows;

Heat is a form of energy which converts water into a vapour. In distillation, heat is therefore converted energy in the form of steam. This energy drives the distillation process and according to the first law of thermodynamics, this energy cannot be created or destroyed in a system of constant mass. Therefore, energy as heat must dissipate as it cannot disappear. Heat can only travel from a hot body to a cooler body, according to the second law of thermodynamics. Thus heat from a carrier vapour can only dissipate into the plant material (and sides of the still) during distillation. Fourier's law of heat conduction specifies that heat conducted from one surface to another will occur at a rate proportional to the contact area and the magnitude of the temperature differential between the two surfaces. Thus the transference of heat energy requires a temperature gradient.

Liquids will change into a gaseous state at a specific temperature according to a certain pressure. Below boiling point the liquid will store the energy as heat. According to Fourier's law the addition of energy through plant material surfaces will cause the temperature of the liquid inside the material to rise. With the absence of additional energy, heat will dissipate through contact surfaces to the surrounding atmosphere, causing the temperature of the mass to decrease. The heat stored in the liquid is called latent heat.

When a liquid is heated, its molecules become more active according to the temperature until a point where they separate from the parent liquid into the vapour space above the liquid. If the surrounding space is closed, the new vapour molecules will exert pressure. This is called vapour pressure. The actual vapour pressure created will depend upon the physical characteristics of the liquid/gas at prevailing temperatures. At constant temperatures, the number of molecules escaping as vapour from the liquid will equal the number of vapour molecules returning to the liquid. This is an equilibrium state where the vapour is saturated. A decrease in temperature will cause more vapour molecules to condense and reduce the vapour pressure and an increase in the temperature will cause more molecules to vapourise than condense, thus increasing the vapour pressure. Increases in temperature thus increase the saturation level of the vapour space.

The above behaviour is consistent with Charles law which states that the volume of a given gas is proportional to its absolute temperature under constant pressure.

If the temperature of a saturated vapour is higher than the boiling point of the parent mixture, it is called a superheated vapour. When superheated vapours come into contact with their parent liquid, the liquid will tend to vapourise until the saturation equilibrium is once again achieved. In essential oil distillation, when steam enters a still with greater space, its pressure becomes lower, which allows it to expand. The surplus heat will dissipate to the surrounding surfaces (both plant material and still walls) and vapourise surplus liquids until the steam becomes saturated again at a lower temperature.

Steam is a two-phase mixture of air gases and moisture molecules. Saturated steam carries microscopic particles of liquid which give the gas a 'cloudy' appearance. Wet steam will carry more of these particles than dry steam. These liquid cloud particles will vary between 1-3% of the total steam mass. Superheated steam does not carry microscopic liquid particles, as they are completely vapourised and thus appears completely clear and invisible.

The aim of passing steam through a charge bin of plant material is to capture and carry the volatile compounds with the steam through the charge to the condenser. Thus distillation must create a mixed vapour which behaves according to Dalton's law. Dalton's law states that the total pressure of a mixture of two or more gases will be equal to the sum of all the individual pressures each component would exert, if it was alone as a single gas. This allows the boiling temperature to drop according to the vapour pressures of the two mixtures, where boiling points will vary according to the surrounding pressure. This is significant as oil vapour pressure will always be less than water, thus enabling high boiling aromatic materials to vapourise at lower temperatures.

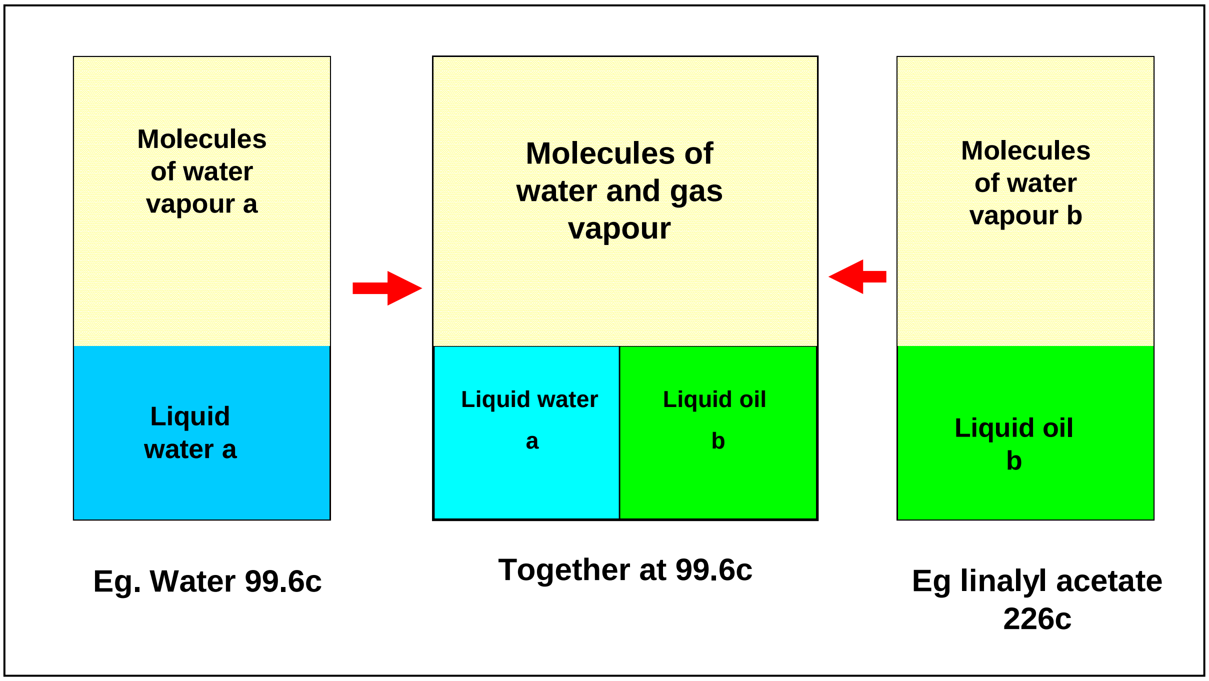

Figure 5.2. The composition of mixed vapours from immiscible liquids

Generally all aromatic molecules of a mixture exposed to the vapour space in the still will vapourise in similar proportions to the liquid mixture. However, due to some aromatic molecules being more volatile than others and becoming more active in the liquid mixture because of the application of heat, they will tend to escape into the vapour space more quickly than the less active ones. Thus in the early parts of a distillation there is a tendency for lower boiling compounds to vapourise more quickly than the higher boiling compounds. The vapour mixture will therefore have a higher proportion of lower boiling than the parent liquid [5]. The extent of this fractionation phenomena depends upon the relative volatility of the respective compounds, which in the case of for many terpenes for example is very low. Increasing distillation temperatures also change the relative volatility of different aromatic molecules, thus preventing distillation occurring in a fractional manner. Other factors relating to the way volatiles release themselves from plant material also distort the principal of relative volatility.

To extract volatile compounds during distillation from plant material requires liberation of the oil from the glands and tissue. Latent heat must be transferred from the steam to the plant material in the still. This heat is transferred by tiny water droplets or vapour carried by the steam which settle on the plant material, (see Figure 5.3). However plant material acts as a barrier between the volatiles and steam, preventing them forming a mixed vapour. In the case of many flowers, leaves and non-fibrous plant materials, the process of hydro-diffusion assists in bringing aromatic volatiles to the surface.

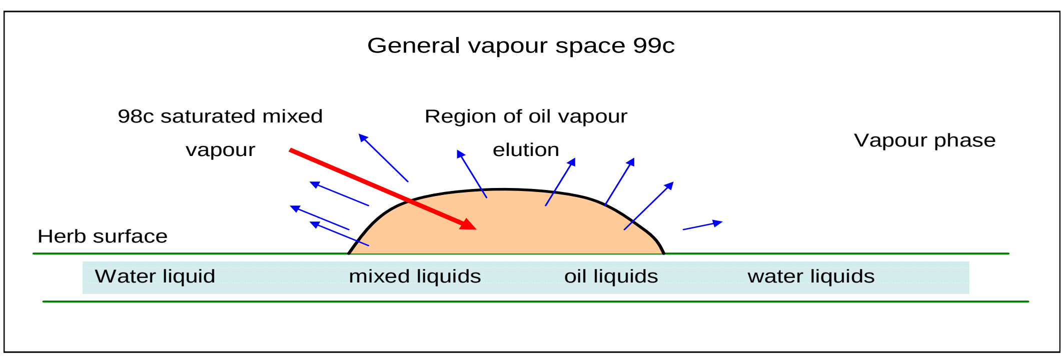

Figure 5.3. Method of Oil Release through latent heat transfer through plant material

Many plant materials are able to act as a membrane through swelling that allows volatiles to escape the oil glands and moisture to enter. This is the process of osmosis promoted through the high temperatures of the distillation process, the permeability of the plant material and the solubility of the oil with water. This allows the formation of an oil-in-water emulsion, which can permeate through the membrane to the surface for vapourisation, once in contact with the water or vapour droplets on the surface of the plant material. This process most probably commences with existing moisture within the plant material and is continued with new moisture penetrating the membrane until all volatile materials have been exhausted from the oil glands. Thus to some degree, the speed of constituent vaporization in the still is not so much dependent upon volatility, but solubility in water.

A disadvantage of hydro-diffusion is the effect of hydrolysis on some volatile constituents within the plant material. With prolonged heat, chemical reactions between water and a number of constituents of essential oils react and convert to new compounds. For example, esters which are formed from their parent acids under hydrolysis can convert back to their parent acids and alcohols. This problem is most acute in water distillation. Steam distillation can lessen this reaction.

The process of hydro-diffusion is very effective in assisting the exhaustion of volatile constituents from plant material during distillation. This is particularly so of plant material where the oil glands are superficial to the plant material and exposed to the surface. These herbs would include the mints and lavenders. Steam flow rates with these oils need not be fast, as time is needed to condense water droplets on the plant material for the hydro-diffusion effect to set in. Wet and superheated steam would be the most effective in the distillation of these types of plants.

Other plants store their oil well inside their tissue and are considered subcutaneous, as the oil is not exposed to the surface. This would include the bark of cinnamon and cassia, woods like sandalwood, cedarwood and huon pine, dried flower buds like clove, seeds like caraway and cardamom, roots and rhizomes like ginger, angelica, orris, calamus and vetiver and tough leaves like eucalyptus and tea tree. With these plants, the distillation process has to be assisted through chopping, grating or crushing the material, so as many of the plants oil glands are exposed directly to steam during distillation. This is called comminution.

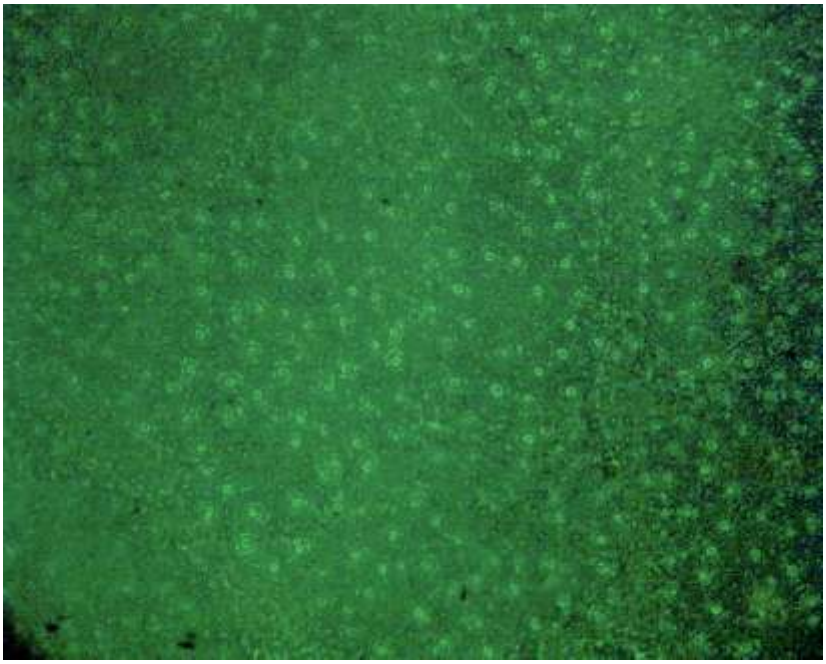

Figure 5.4. The subcutaneous **leaf and oil glands of *Eucalyptus citriodora* magnified 200x** (Picture taken by Ms. Teoh Ai Ling, School of Materials Engineering, University Malaysia Perlis)

Within a still charged with plant material, the vapourisation of volatiles into mixed vapours with the carrier steam vapour, occurs in layers. Thus charge height plays some importance in the distillation process. Oil is vapourised at a low layer in the plant material and carried vertically to a higher layer, where a proportion of the mixed vapour re-condenses. This condensate will rest on the surface of the layer. With highly absorptive plant material, hydro-diffusion will occur through osmosis, where some condensed vapor will be absorbed into the plant material, until it becomes saturated. Once the plant material is saturated, successive waves of mixed vapours will pick up more oil and re-vapourise and move up to the next layer (see Figure 5.5.).

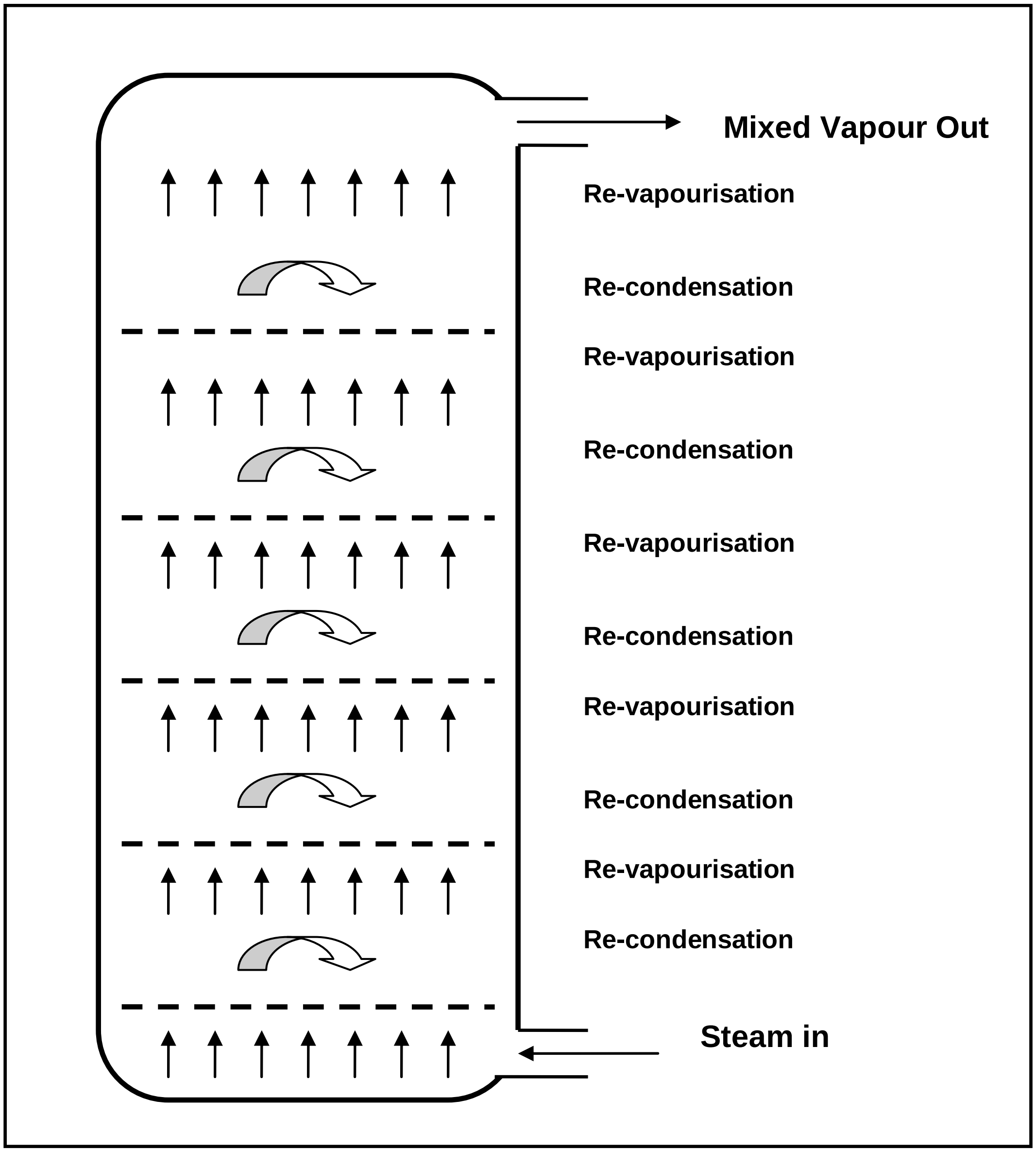

Figure 5.5. The Vapourisation and Re-condensation/Re-vapourisation Process During Distillation

As oil is removed through the vapour to each successive layer, the plant tissue slowly exhausts its oil content into the re-condensing and re-vapourisation. Each successive re-vapourisation will carry less oil from the bottom layers, the oil-to-water ratio will decrease, until all oil has been exhausted. This process occurs at varying rates according to the absorption capacity of the plant material and height of the still. Thus as the height of the still increases, distillation time will also increase. Figure 5.6. shows the time-steam-yield rate relationship for a distillation [6].

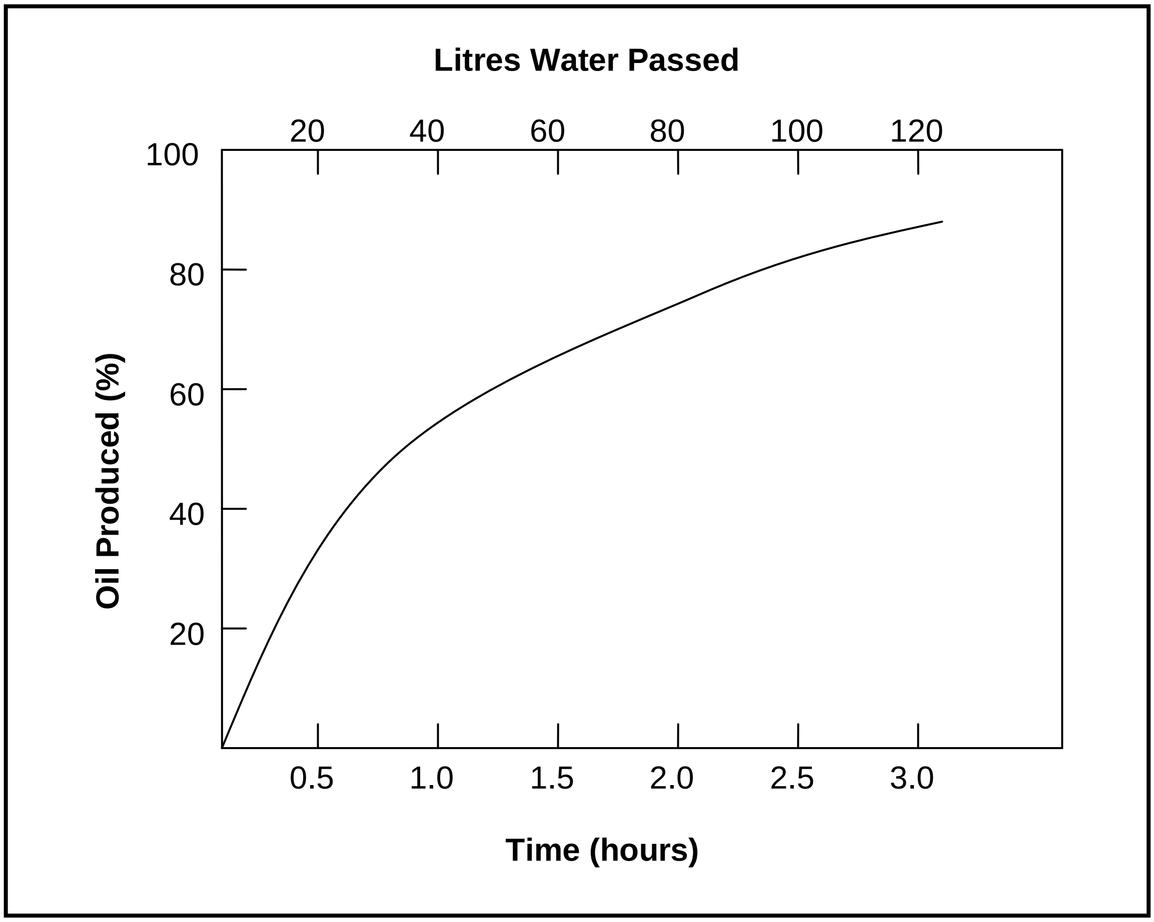

Figure 5.6. The Time-Steam-Yield Rate Relationship for a Distillation

The Stages of Distillation

Distillation occurs in a number of definable stages. During the first stage, initial heating occurs through the charge where the plant material has been placed. Plant material will not be saturated with moisture and the temperature differential between the steam and the plant material will allow quick dissipation of latent heat from the steam to the plant material. The initial steam, particularly if it is wet will tend to cool throughout the lower layers of the charge, where some condensation may occur. This has to be watched carefully, as too much condensation may flood the lower parts of the charge. Dry superheated steam may have the effect of drying out the plant material. Both flooding and drying out of the plant material are detrimental to efficient distillation. At this early stage steam is the only contributor to vapour pressure until saturation occurs and the layering process, discussed above begins.

The second stage begins when the vapour reaches the condenser. At this point the oil-to-water ratio will be at its highest. During the second phase the distillation process will go through three sub-phases.

1. In the early stage, due to some effect from relative volatilities of the various constituents, the most volatile constituents will tend to vapourise first and carry a higher than proportionate weight in the distillate as compared to the normal oil. It is also reported that oxygenated constituents also have a tendency to distill over before hydrocarbons [7].
2. During the middle stages, the oil will be distil over in the same proportions as the normal oil, and
3. During the third stage, the least volatile constituents of the oil will contribute a higher than proportionate composition in the distillate.

The distinct stages of the second stage distillation can be seen in Figure 5.7. showing the change in composition of sweet basil oil during distillation [8].

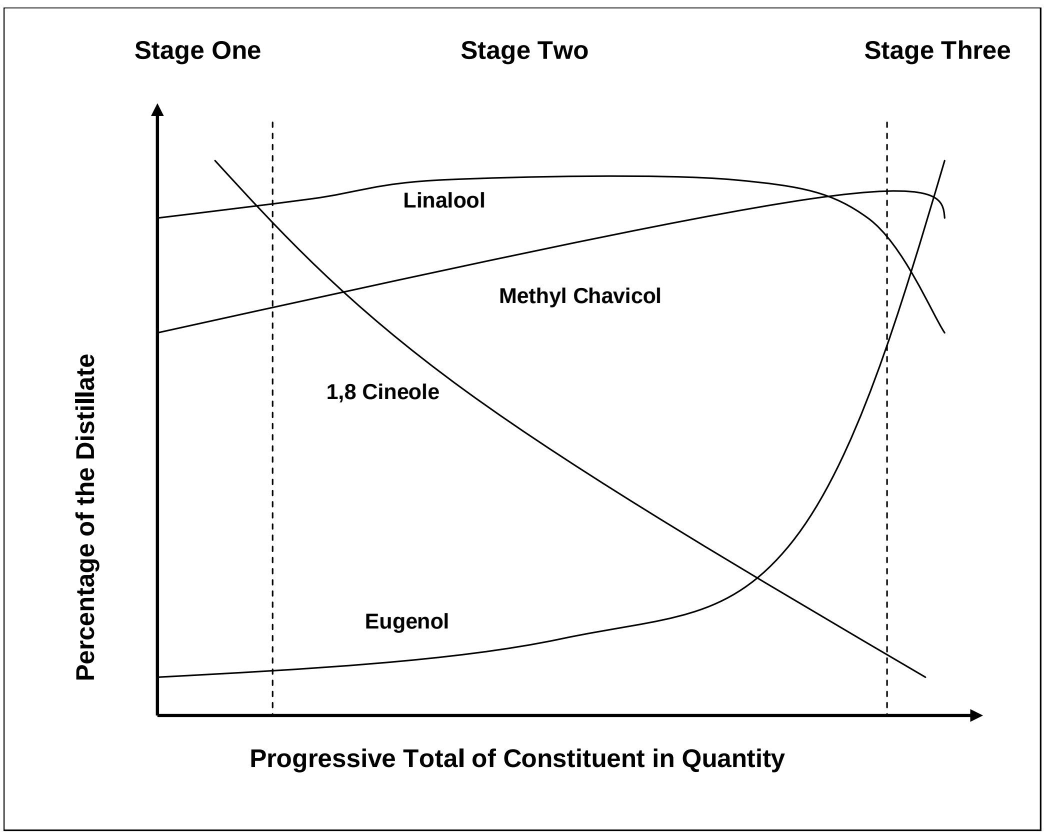

Figure 5.7. The Distinct Stages of Distillation and During the Second Phase for Sweet Basil Oil

The height of the still will influence this phenomenon. High stills tend to negate this effect because as the more volatile constituents from the bottom layer reach the top layer, the less volatile constituents from the bottom layer will have already started distilling over and reaching the upper layers of the charge.

The final stage of distillation occurs when the water-to-oil ratio is very high as the charge becomes exhausted of oil. It will no longer be economical to continue with the distillation.

Steam and Pressure

For efficient distillation, i*.e., achieving the maximum amount of oil with the minimum quantity of steam*, requires the maximum exposure between the steam flowing into the vat and the plant material surfaces area within the charge. The rate of steam flow per hour is subject to the amount of plant material in each charge. Daily throughput is thus limited by the amount of steam that can be generated on an hourly basis at a distillation plant. Steam must also be adjusted to suit the absorptive capacity of the plant material. This greatly varies between different herbs and the condition they are in before distillation.

Steam produced by high pressure external boilers is usually very dry and can often be superheated. Steam produced by medium pressure boilers around 3 atmospheres pressure will contain moderate moisture content, but will not tend to superheat. Steam produced from evaporators at atmospheric pressure is relatively moist. In water-steam distillation array where steam is produced in the same vessel that the plant material is stored will produce very wet steam.

Different steams can be utilized as a control mechanism to correct the conditions within the still housing the plant charge.

Wet steam is a saturated vapour is suitable for most distillation. In most cases, wet steam from a water bath produces '*a richer oil'* with much shorter extraction time than other forms of steam [9]. This is particularly the case with plant material that contains superficial oil glands. Increasing steam rates does not speed up distillation, especially if the process of hydro-diffusion is required. As plant material is already saturated with moisture and there is a constant diffusion rate. If herbs contain a lot of moisture, then there would be sufficient moisture in the plant material to commence hydro-diffusion and dry steam would be the most suitable to apply. However dry steam has less mass than wet steam and as such reduces the latent heat of steam, thus prolonging the distillation period.

A superheated steam occurs when the temperature of the vapour is higher than that of the same saturated vapour at the same pressure. Superheated steam is independent of pressure and therefore advantageous in a number of situations, as it can be utilized at any temperature without increasing pressure, *i.e., can increase the temperature of distillation without having to change the steam flow-rate due to changes in pressure.* Superheated steam can be used for drying out a flooded charge vessel, where there is too much liquid around the plant material. However superheated steam is not advisable for general distillation as it would dry out the plant material, preventing the hydro-diffusion process occurring and is a poor conductor of latent heat – two of the important processes needed for efficient distillation. Superheated steam is most suitable for the distillation of glabrous herb material and can increase yields substantially.

High boiling oils exert less vapour pressures and require relatively large temperature gradients to extract them during distillation. This leads to prolonged distillation periods. If the constituents are stable under long periods of heat, distillation can be performed under pressures above the atmosphere, which increases temperature. This cuts back on distillation time and saves energy. As increasing the still pressure, increases temperature, the temperature gradient will also increase between the vapor space in the still and the plant material. This assists in the vaporization of high boiling volatile constituents. The advantage of pressure is that the temperature gradient increases, thus increasing the effects of latent heat exchange and reduces the likelihood of hydrolysis. However the use of high pressure distillation is limited by the extent that prolonged high temperatures will damage the composition of the essential oil.

Inversely, as operating pressure is reduced, so does the temperature of the distillation. This method can be used for the extraction of heat sensitive constituents that would normally be damaged through exposure to excess heat. However distillation under reduced pressure has a number of limitations. Steam under reduced pressure is less dense, so requires more steam to carry out a distillation than under normal atmospheric pressure. The condenser system would need to be almost twice the size of a conventional still or a refrigeration system required in condensing the distillate. The recovery vessel and separator would have to be sealed within the closed system, which would lead to design and engineering difficulties.

Recently a variation on the operation of pressure in steam distillation has been reported a number of times, utilizing a technique called instantaneous controlled pressure drop (DIC). This is a technique where the foliage is first exposed to saturated steam and then the pressure drastically dropped to a vacuum level of around 5-50 KPa to provoke auto-vapourisation of the superheated volatile compounds through expanding and breaking up the cell walls with instantaneous cooling [10]. Experiments have shown that results can be varied through changing time, pressures and the amount of moisture in the leaves [11].

Wilting Crops Before Distillation

As the moisture condition of the herb is a factor in the efficient distillation of the herb, wilting is often carried out to dry the crop before processing. The objective of wilting is to dry the herb enough to increase its absorptive surface. Many practitioners believe it is to dry out excess moisture so that distillation will be shorter and more efficient. However this is a fallacy. For example, with tough leaves like eucalyptus and tea tree, wilting does little to dry them out or increase their surface absorption, so wilting will have no benefit to the distillation process. Moisture in the plant material is actually of benefit to the distillation process [12]. In fact there are risks with wilting in that the process may lead to losses in oil, not through evaporation, but through chemical reactions like oxidization, resinisation and the formation of glycosides and enzymes in the materials. Excessive drying of moisture can remove necessary moisture breaking the contact between the oil component and surface of the plant material, thus hindering the promotion of hydro-diffusion during the distillation process.

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Figure 5.8. Mint foliage Laid on the ground for being picked up by the for distillation at Victoria (photo courtesy of Fred Bienvenu)

Which crops require wilting before distillation generally depends upon their natural surface absorption capacity. Non-absorptive herbs like mint and basil need some wilting to promote absorption during distillation, as wilting to promote partial breakdown of the surface cellular structure of the leaf. In this case distillation would then commence with a wet steam fraction, followed by slightly drier steam once moisture has permeated into the leaf structure. Herbs with absorptive surfaces like lavender don't need to be wilted. In fact they do not have enough moisture to link the oil glands to the surface via a water interface, so wet steam fractions are needed during distillation. Grass crops like lemongrass and citronella contain enough moisture within their leaf structure to create a water-oil-surface interface for hydro-diffusion to occur during distillation, so wilting is not necessary. As moisture content is already sufficient in the leaf, dry steam would be suitable for the distillation process.

Water Distillation

Water distillation involves distilling plant material totally immersed in water. Depending upon the specific gravity and charge mass in the still, the material will either float or sit totally immersed in the water. Heat is introduced by direct heating of the sides of the vat, a steam jacket, a closed system coil or in some cases a perforated steam coil. Water distillation was the only method used before the Twentieth Century.

Water distillation is useful for the distillation of flower materials which would normally congeal and form lumpy masses under steam distillation, where steam would not penetrate, like rose petals and orange blossoms. This method is also useful for fruit kernels that would form glutinous masses under steam distillation and powdered forms of plant material which need to be comminuted before distillation, like almond powder and huon pine saw dust.

In water distillation there are a number of simultaneous processes that act to extract volatile constituents from plant material that are different from steam distillation.

Essential oils contain a number of oxygenated constituents that are relatively soluble in water. This would include phenols, alcohols and some aldehydes. During the early stages of a water distillation, these compounds would dissolve in the surrounding water and become part of the boiling mixture and resulting mixed vapour.

As water boils and converts to steam at the bottom of the vat and rises through the plant charge, it will come into contact with the plant material. Some oil is exposed on the surface of this material will be vaporized by the rising steam as it comes into contact with the plant surfaces. This steam carrying some volatile vapour will rise to the surface and carryover into the vapor space above the water until it reaches the still condenser.

The boiling temperature of water at the bottom of the vat in water distillation is slightly less than the boiling point of water, due to the mixed liquid of solublised volatiles and water. Heat applied to the still will cause the creation of a small bubble of saturated mixed vapour from the liquid phase, where upon formation it rises to the top of the water in the charge. During the rise, it’s the bubble’s pressure, temperature and proportion of oil to water decreases. The condensing volatiles, mostly being less dense than water, float to the top of the water and form a film on the surface of the water in the vessel. This lost oil tends to remain on top of the surface and cannot revaporise easily due to its higher boiling point and the generally cooler temperatures at the water surface. Most of the oil recovered in water distillation is the portion of the oil that does not condensate through this action.

Observation shows that distillation undertaken with vigorous boiling produces better and quicker yields than mild boiling. Some distillers even install small propellers intruding into the side of the still to assist in agitation. This is most probably effective because the agitation in the charge tank prevents oil droplets clinging to the herb surfaces. It is necessary to generate enough steam in the water so that it will come in contact with as much of the oil on the plant surface material as possible during the distillation.

The effects of hydro-diffusion are much slower in water than other types of distillation. Consequently, especially for wood materials extensive comminution must be undertaken so that particles in the charge are fine and as much oil as possible is exposed on the surface of the material.

In water distillation, plant material is placed in a sealed vessel or retort that connects directly to a condenser. From the condenser the distillate runs into a separator. The rate of distillation is controlled by the intensity of the fire, the pressure of the vessel or retort and/or the rate of introduction of steam. As many woods contain high boiling compounds, pressure is vital to create high enough temperatures to vaporize the volatile constituents. These constituents may take many hours to boil out. Hydro-stills should generally be wide to maximize the evaporation area. Where particles are fine such as saw dust and powders some form of mesh or "P" shape pipe arrangement should exist at the entrance to the condenser to prevent plant material from entry and possible clogging. Heavy charges and where heat coils are used in the still require a perforated grid to prevent plant material from directly coming into contact with the heating coils.

With many materials, part of the oil dissolves in the water during distillation and forms a milky emulsion, as a number of aromatic constituents are soluble to some degree in water. This loss could range up to 25% of the essential oil [13]. This means that the recovery of oil is incomplete and the recovered oil will be deficient in some constituents that would be the case with the oil recovered through steam distillation. Upon separation in water distillation, the water distillate is returned directly to the charge vessel to replace the decreasing water level due to evaporation. This is called cohobation. Sometimes the water distillate is redistilled in another vessel to extract the volatiles in emulsion. Salt is often added to the distillate to reduce the solubility of water. Whether this process is undertaken depends upon the probability of the constituents being damaged by further heat and the economics of redistillation. Another method to recover the dissolved aromatic materials from the water distillate is to add a solvent. The mixture is then vigourously shaken to pick up dissolved constituents from the water into the solvent. These materials are then recovered through vacuum distillation of the solvent which results in a secondary essential oil [14]. Some common water soluble aroma chemicals in essential oils are listed in Table 5.1. below.

Table 5.1. Some Common Water Soluble Aroma Chemicals in Essential Oil

Slightly Soluble (<500ppm)	Moderately Soluble (501-1999ppm)	Very Soluble (>2000ppm)
Aldehyde C11	Calamene	Benzlaldehyde
Aldehyde C12 (lauric)	1,8-Cineole	Benzyl acetate
Aldehyde C12 MNA	Nerol	Cinnamic alcohol
Amyl cinnamic aldehyde	Neryl acetate	Citronellyl acetate
	Rose oxide	*a*-copanene
Amyl salicylate		Eugenol
Benzyl salicylate		Geranial

Cedrol		Geraniol
Citronellol		Limonene
Citronellyl butyrate		Linalool
Citronellyl formate		Mentone
Eudesmol		Myrcene
Geranyl formate		*(E)*-β-ocimene
Limonene		Phenylethylacetate
Linalyl acetate		Phenylethylalcohol
α-Pinene		Sabinene
		Terpinen-4-ol
		α-Terpineol
		Terpinolene

Another method that will contribute to minimizing oil loss due to oil solubility in water during the separation phase is to control the outgoing distillate temperature from the condenser. Where oils are less dense than water, there will be an optimal temperature range where oil particles will freely float to the top of the distillate upon condensation. Some literature on distillation practices misses the point about the effect of condensation temperatures on oil yields [15]. Based on private work [16], the higher the temperature of the outgoing distillate, the freer will be the oil particles to float to the top. For example, tea tree oil droplets will float to the top of the water distillate twice as fast at 60°C than at 40°C. The upper temperature limit will be restricted by the potential loss of low boiling volatiles during condensation. This has implications on the design of the specific condenser for specific crops and set range limits upon the temperature that distillation can take place, to achieve a specific outgoing distillate temperature range.

Water and Steam Distillation

Water and steam distillation involves the storing of the plant material above a water bath situated in the bottom of the charge vessel and heating the water either through direct fire, a steam jacket or a closed or open steam coil. Water and steam distillation produces saturated wet steam at the prevailing vessel pressure, which is usually atmospheric pressure. Within this configuration, unlike water distillation, only steam comes in contact with the plant material.

Water and steam distillation is not very suitable for fine materials as steam will find a path of least resistance tending to create channels. This means that steam will not flow through the whole mass of plant material and an incomplete distillation will take place. If the plant material is loosely packed, the same effect will happen, as the material will offer no resistance to the steam.

Water and steam distillation may take a long period of time to reach operating temperature as the plant material needs to be heated up with only saturated steam. This may cause early condensation and wetting of the plant material.

Due to the limits on pressure that can be built up in the charge vessel, water and steam distillation will have only a limited effect on extracting high boiling materials from plant materials. However there is less opportunity for hydrolysis to occur than with water distillation. Water and steam distillation has another advantage over steam distillation as there are fewer decomposed products during the process due to less chance of plant material drying out. However water and steam distillation will take a lot longer. Water and steam distillation can produce very good results under reduced pressure.

Water and steam distillation is much cheaper to set up than steam distillation facilities and lends itself to portable stills that can be transported from place to place.

Steam Distillation

Steam distillation employs an external steam generation system, external to the charge vessel. This configuration provides much more control (depending upon the boiler capacity) than water and steam distillation. This is because in steam distillation the wetness fraction, temperature and pressure can be manipulated according to needs and conditions. However, it is a misconception that greater steam volumes and increased pressures have positive effects on the process in all cases. As mentioned previously, dry and superheated steam has the effect of drying out plant material, which potentially halts distillation through the stopping of hydro-diffusion process. Faster steam flow rates do not necessary mean quicker recovery times. Fabricated steam boilers cost much more to run than water baths and may lead to high distillation costs, especially if they require petrochemical feed stocks. However if steam distillation facilities are designed and built with the correct steam ratings, they are much more economical to run than water and water and steam distillation systems. A comparison between water, water and steam and steam distillation is shown in Table 5.2. below.

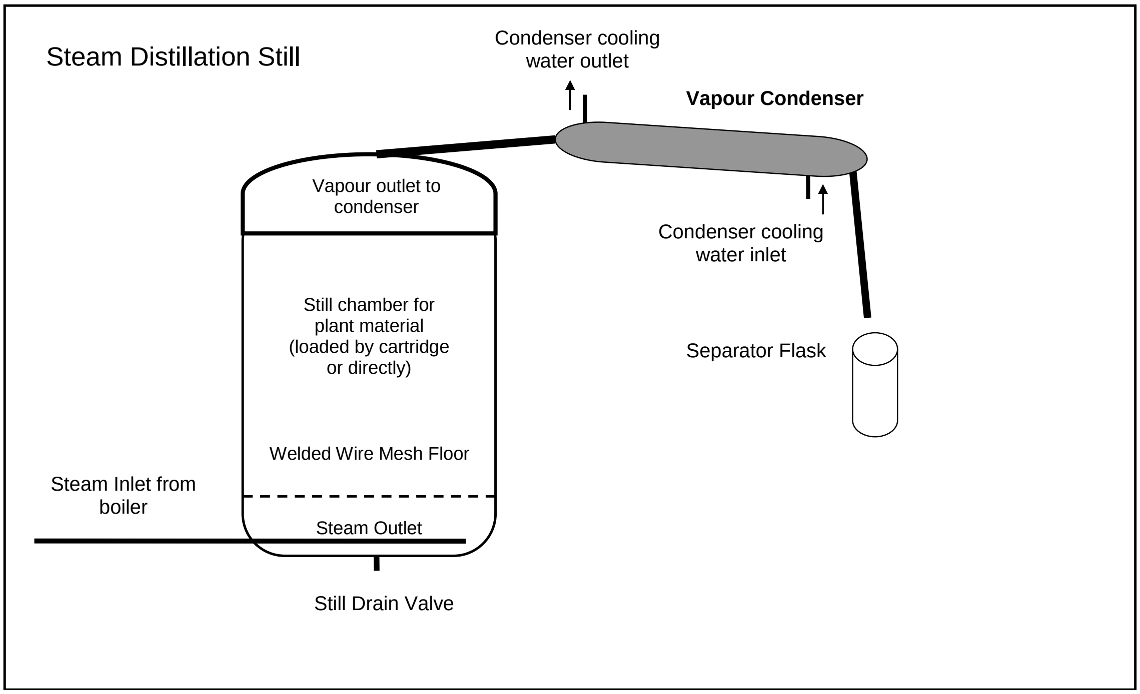

Figure 5.9. Diagram of a Steam Distillation Still

Table 5.2. A Comparison between Water, Water and Steam and Steam Distillation.

	Water Distillation	Water & Steam Distillation	Steam Distillation
Construction	Usually simply constructed, based on ancient designs.	Inside vat contains a grill where plant material rests above the water	Utilises an outside steam source
Plant Material Suitability	Finely powdered materials such as woods and rhizomes, flowers that congeal with steam. Not suitable for materials that contain acidic material which can saponify, water soluble or high boiling constituents.	Can be used for most herb and leaf materials. Material must be packed in a uniform manner to avoid channeling of steam.	Most materials, except fine powders. Good for high boiling materials. . Material must be packed in a uniform manner to avoid channeling of steam.

	Material must be completely covered with water.		
Hydro-diffusion	Excellent	Good	Steam should be slightly wet to promote diffusion. Superheated or high pressure steam can dry out the plant material and inhibit diffusion.
Available Pressure	Atmospheric pressure	Atmospheric pressure	Can be adjusted for both high and reduced pressures.
Available Temperature	100°C, but care must be taken not to burn the plant material from direct heat on the sides.	Approximately 100°C	Can be increased or reduced according to pressure used.
Hydrolysis Condition	Usually a high rate of ester hydrolysis.	Hydrolysis is usually low, however excessive wetting of the plant material through prolonged distillation can promote hydrolysis during later stages of distillation.	Slight hydrolysis.
Rate of Distillation & Yield	Slow rate of distillation. Low rates of yield due to hydrolysis and loss of water soluble constituents into the water. High boiling constituents often left undistilled.	Moderate distillation rate. Good yields if no channels occur in charge. Usually good yields.	Fast rate of distillation. Good yields if no channels occur in charge. Usually good yields.

The Condenser System

A condenser in an essential oil distillation system is a heat exchange or dissipating device. The condenser must not only cool the condensate vapour into a liquid, but also cool the condensate to the temperature range where the oil will separate spontaneously from the water.

The usual array for a condenser system is a tube or set of tubes running through a sealed water reservoir to cool the pipes. It is immediately attached to the top of the charge vessel to collect all vapour exiting the vessel. The design of the condenser must ensure that the vapour flow is turbulent inside the tubes to prevent high velocity vapour freely flowing through the condenser and maximize exposure to the cooler walls. A baffle is usually installed at the beginning of the condenser to disrupt a straight steam flow for this purpose. Failure to achieve those conditions would result in some vapour failing to condensate. Within the condenser system the flows of vapour and cooling water should be in opposite directions at the maximum possible speed. The condenser must be sensitive enough to react on the vapour flow very quickly. The required number of tubes and length of the condenser depends on, the rate of distillate flow, the pressure, the temperature of the cooling water and the desired exit temperature range of the distillate.

Figure 5.10. Photo showing the condenser with the end manifold removed to expose the internal cooling pipes at the Author's property in Perlis, Malaysia.

The condenser must remove the equivalent amount of heat that is needed to vaporize the distillate, plus the additional amount of heat to reach the optimal distillate temperature range of the condensate distillate exiting the condenser. The rate of which heat would be removed from the distillate can be represented by the following equation;

$$Q = UA\Delta t$$

Where Q = the heat removed by unit of time

U = a constant determined by operating conditions (condensing and cooling made up
of a number of factors) usually a constant is used.
A = the area available for heat removal
Δ*t* = the temperature difference between the vapour and the cooling medium.

U is made up of a number of factors including the flow rates of cooling water and vapours, the material that the condenser is constructed, and usually a constant is used due to the difficulty to calculate. The value of *U* increases as these factors increase. Thus according to the equation, the surface area can be as large or small as desired, as long as the other factors compensate. However the overall capacity of the distillation system will have great bearing on the condenser area. Condenser sizes will also vary in size according to the temperature of available cooling water on site, thus condensers in temperate and tropical areas will reflect this in size.

Using a condenser system with the wrong capacity for the distillation system will have a number of operational consequences. A too efficient condenser system will deliver the distillate at a temperature below the optimum range, which could lead to cool air outside being sucked into the system. This outside cooler air in the condenser tubes could create expansion and contraction of vapours in the condenser leading to splattering and intermittent distillate outflow. This could also occur is the cooling water is too cold. If the condenser is too small for the distillation system, then the still must be operated with lower steam rates, which would lengthen distillation times and open up the possibility of hydrolysis to occur within the vessel.

The Separator System

Before leaving the subject of distillation in this chapter, some words about the separator system must be mentioned. The function of the separator is to as quickly as possible separate the oil from the distillate water. As distillate water volume is much greater than oil, it is important that water can be removed continuously. Oil and water separates according to specific gravity forming two layers. Lighter than water oils will float to the top and heavier than water oils will sink to the bottom. This must be considered in separator design for water removal.

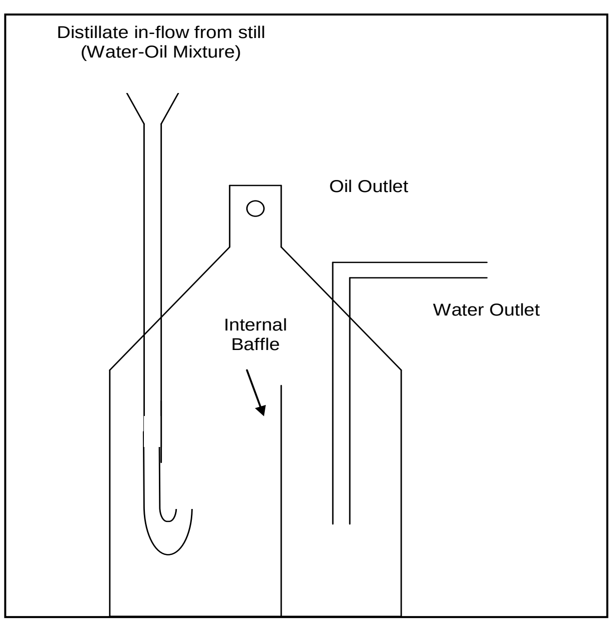

Figure 5.11. Oil Separator Design Used in Perlis, Malaysia

If the specific gravity of oil and water is very close, the two components will not separate immediately. Distillate flowing into the separator must therefore not disturb the surface area and flow into the body of the water to prevent surface turbulence. The separator must also be large enough so that drained water does not carry away microscopic oil droplets. Temperature plays a crucial role in separation, where it should be moderately warm to increase the relative specific gravity differential of the oil and water. Raised temperature of the distillate water will allow the small oil particles to rise to the top of the separator quicker in a similar manner to the condenser exit temperature range where there will be an optimal separator water temperature range to promote oil-water separation [17].

During distillation, the more volatile constituents tend to vaporize quicker and the less volatile constituents vaporize later in the distillation. This leads to an oil that will vary in constituents during the distillation period. By changing separation flasks at particular points during a single distillation, oils of different constituent profiles can be collected. This is important in *ylang ylang* and *lavender* distillation, where different oils profiles will have different uses and values to particular customers. Many distillers also use this principal to collect specific fractions during the distillation, which can later be blended together to create a whole oil that meets with certain specific specifications, such as a standard.

The water distillate will always be saturated in oil and directly dumping it would lead to a loss in yield. For this reason some distillers (water and water and steam distillation) will channel the water distillate back into the still vessel for re-distillation in what is called cohobation, mentioned previously. For this purpose the separator must be placed higher than the still vessel proper so distillate water in the separator can be fed back into the still through gravity.

More on the design and practical application of distillation will be discussed in chapter nine.

Hydro-Diffusion Distillation

Hydro-Diffusion distillation is a variation on steam distillation where steam is introduced on the top of the vessel and condenses through the plant material in the still, where the distillate is collected and condensed under the plant material which rests on a grill or perforated tray. Through steam traveling down the still, there is more time for the volatiles and fatty acids floating on the plant material. In the case of wood and seeds that have many high boiling compounds, which are difficult to vaporize in an ordinary still, this system may be effective. This would be valuable when fatty acids contribute to the flavour of a material and it is desirable in the oil. Thus, hydro-diffusion distillation may return an oil more representative of the plant's natural profile [18].

It is reported that hydro-diffusion distillation gives quicker distillations with lower steam consumption than conventional steam distillation [19]. However this process is governed by the physical laws that govern any other type of distillation and the fact that the steam travels downwards whilst cooling may effect the transfer of latent heat and thus increase, rather than decrease distillation time. The tendency to saturate the plant material near the bottom may also lead to hydrolysis and lead to lesser yields. However, hydro-diffusion distillation appears popular within the aromatherapy industry in Europe.

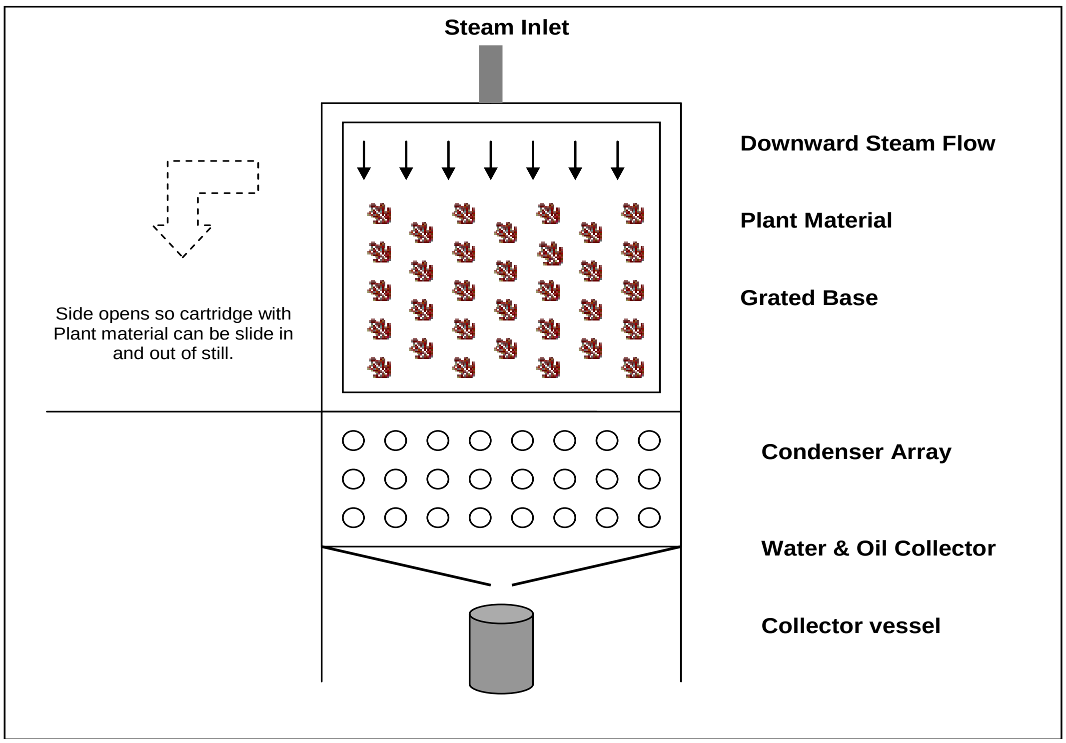

Figure 5.12. Schematic View of a Hydro-diffusion Distillation System

The Extraction of Aromatic Materials Using Volatile Solvents

The extraction of aromatic materials from plants was first experimented with in the early 1800's. Various solvents like chloroform, benzene, carbon disulphide, methyl and ethyl alcohols were used. One of the major problems was the loss of solvent through evaporation. With the advent of light fractions of petroleum and the development of a closed apparatus, most technical problems were solved and the process became commercially viable as an alternative to enfleurage. Interest in the process grew with a number of independent groups in Grasse utlising the process around the mid 1850's.

A solvent extraction system consists of an extraction tank, a solvent distillation unit under vacuum, a washing tank for ethanol extraction and another vacuum distillation unit. The process utilizes a pure solvent to wash and penetrate the plant material, which dissolves the volatile constituents, resins, waxes and some pigments within the tissue. This is done either in a stationary tank where the solvent is circulated around the plant material or with a slow rotary mixer array to stir the plant material with the solvent. Some systems may undertake the washing process a number of times to ensure all the aromatic material are removed from the plants. After the washing is complete, live steam is injected into the system to vaporize any solvent remaining on the plant material, where it is filtered, re-purified and used again. The washing process occurs at room temperature.

In the second stage, the solvent is pumped into a vacuum distillation camber, where the solvent is then vacuum distilled away leaving the semi-solid material previously dissolved from the plant material, during the washing. The vacuum distillation is conducted at the lowest temperatures possible, usually around 50-60°C. The remaining material is called a concrete, which contains up to around 50% waxes, resins and fats, along with some natural pigments.

As waxes and fats are not very soluble in perfumes and fragrances, the waxy materials need to be removed from the concrete. This is achieved through repeated washing of the concrete in warm alcohol and then in a further process, a gentle distilling away of the alcohol under vacuum to leave a substance called an absolute. The absolute maybe an almost pure aromatic substance, but may also still contain some natural plant pigments. The absolute can be treated with activated charcoal to absorb pigments like chlorophyll. However, this process does not absorb all pigments, leaving the colour of many absolutes with a tinge of red-brown.

The selection of solvent is critical to the whole process. Ideally, the solvent must be non-flammable, non-toxic, environmentally acceptable, non-odorous, highly volatile with a uniform boiling point that does not leave any residual behind, inert and non reactive to the volatile constituents of plants and absorb moisture remaining in the plant material. No solvent meets all the above criteria and different solvents will display different properties on various materials in plants. The weakness of hydrocarbon solvents is that they dissolve waxes, pigments and other unwanted organic materials in plants. Thus compromises must be made in the selection of solvent for the process.

Petroleum ether fractions consist of saturated paraffin and dissolve minimal amounts of waxes and pigments. Hexane and pentane are chemically inert and completely volatile, and thus suited for the extraction of volatile components of flowers. Hexane is preferred over pentane, because of its slightly safer properties in usage. Hexane usually contains traces of naphthalene, sulphur and benzene derivatives, which have questionable odours. It is important that a very pure grade is used. Hexane is usually rectified and purified until it is almost totally odourless. This used to be undertaken by the operators before using in the extraction process, but most companies now supply a specially purified grade for solvent extraction. Benzene, a coal tar derivative was once used as a solvent. It is less selective in dissolving waxes and produced higher concrete yields. However, due to the carcinogenic properties of benzene, use is but all discontinued.

Alcohol has very limited potential for the washing of flower material. This is due to the partial solubility of water in alcohol, where it tends to pick up moisture in the plant material. However, pure and diluted alcohols are suitable on some dried plant materials, such as barks, woods and gums. Water's partial solubility in alcohol is an advantage in the extraction of resinous exudates of trees, as it assists in the penetration of the material. The alcoholic solution of washed material contains a mixture of aromatic and other organic plant material, called a tincture. Through vacuum distillation, the alcohol is evapourated away from the remaining product which is called a resinoid or oleo-resin. These materials are solid or semi-solid substances of dark colour, due to the organic materials and pigments present. Products produced through this process include resinoids of olibanum, labdanum, myrrh, opopanax and benzoin, and oleo-resins of vanilla, ginger, capsicum and celery seed

Solvent extraction apparatus vary in capacity from a few litres to more than 1000 litres. The size of the system will depend upon how much plant material can be harvested on the daily basis. Solvent extraction systems must be very sturdy in construction, usually of stainless steel with pressure welding of the joints. Glass panels may exist in the washing tanks and the vacuum distillation equipment may also be constructed of stainless steel and/or glass. The pumps must be insulted against sparks to prevent any ignitions occurring and are often powered through compressed air. The system is almost completely closed.

Solvent extraction is not a replacement for steam distillation due to the much higher complexity of operation, the need for specialized skills and the much higher capital and operating costs. However, there are a number of plant materials like jasmine, tuberose, hyacinth, acacia, mimosa and violet, where the process of steam distillation fails to extract the aromatic materials. Thus solvent extraction is used for much higher value plant materials, especially where a *close to nature* odour profile is desired.

CO2 and Supercritical CO2 Fluid Extraction (SCF)

CO2 and Supercritical Fluid (SCF) extraction displays great benefits over solvent extraction in that this process does not leave behind any solvent residuals. CO_2 is an inert and non-flammable material, so is considered both safe and *'green'*. This method also produces very close to nature extracts due to the absence of heat in the process, thus leaving high volatile constituents intact in any extract, which are often absent in the top notes of oils extracted through different methods such as steam distillation. The lack of heat and inertness of the solvent also prevents the creation of any artifacts such as sulphur compounds. The powerful penetrating and diffusion properties of CO_2 also pick up high boiling compounds with high molecular weights between 200-400, which are difficult to extract through distillation and contribute to the *backnotes* of oils. CO_2 and SCF extraction save time over other methods [20] and are much cheaper to operate due to the wide availability of CO_2 and the ability to recycle it.

Supercritical fluid extraction allows selectivity through changing the solvent density during the extraction. The critical point for CO_2 is 31°C at approximately 24 bar, sub-critical liquefied CO_2 (between -55°C and 31°C through 5 to 74 bar) where it acts as a non-polar solvent. Thus, CO_2 can have the density of a liquid solvent and the diffusion properties of a gas, which allows very good permeation through plant and organic materials. Thus the extraction process can be carried out with CO_2 as a liquid or gas, according to temperature and pressure limits set during the extraction, as shown in Figure 5.13. The solubolisation characteristics of CO_2 increases with the density of the fluid, which can be controlled through changing pressure, where higher pressures will enable the diffusion of large quantities of organic compounds. Dissolved compounds are recovered through reducing the carrier density by decreasing pressure or increasing temperatures. Because of the high vapour pressure of CO_2 at room temperature and atmospheric pressure, all traces of the gas can be easily removed from the volatile oil through lowering the pressure.

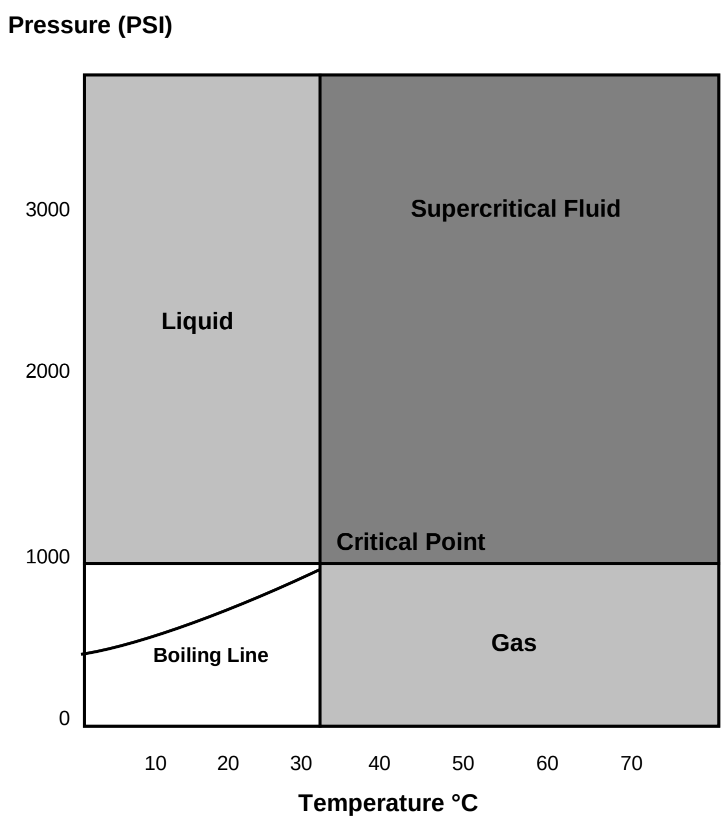

Figure 5.13. The Physical States of CO_2 Under Temperature and Pressure

One of the weaknesses of CO_2 extraction is the lack of solvent polarity which makes the extraction of certain polar materials difficult. This however can be solved through the addition of a polar solvent like methanol or ethanol to increase the polarity of the carrier [21]. CO_2 extraction would in many cases produce aromatic extracts that are lower in some terpenes, as they are sometimes produced through chemical reactions in the distillation process. Likewise, extracts produced through CO_2 extraction may be higher in esters due to the absence of hydrolysis in this process. CO_2 extracts tend to be produced for specific specialized flavour and fragrance applications, due to the high capital costs involved in setting up a plant, but is a technology that is creating a lot of interest.

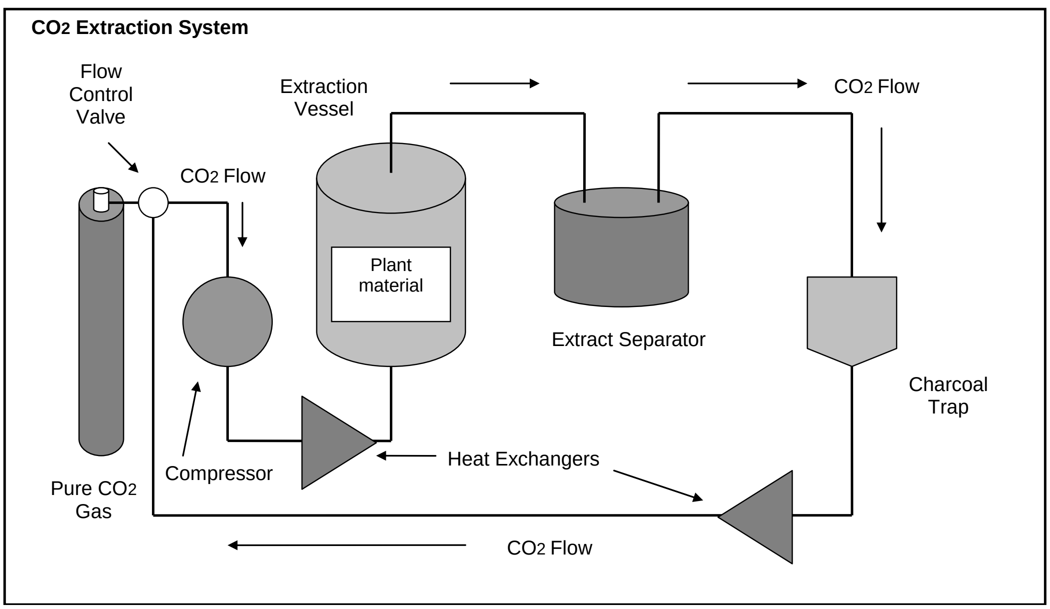

Figure 5.14. A Simple Diagram of a CO_2 Extraction System

Other solvents have been used for the extraction of flower oils. Robertet and Cie perfected a process utilizing butane as a solvent to extract aromatic materials out of delicate flowers. Where conventional solvent extraction has sometimes given unsatisfactory results from many perfumers point of view, butane extracts have been considered to be closer to nature in olfactory profile [3]. However the process is costly and very dangerous due to the caustic and flammable nature of butane. The plant extracts from this process, called '*butaflors*' have also been criticized for not being '*green*' products, due to the environmental undesirability of butane [22].

Dr. Peter Wilde developed a method of solvent extraction utilizing refrigerant Hydroflurocarbon 134a in the early 1980's in the United Kingdom [23]. This process is called phytonic extraction and extracts called *'florasols'.* Phytonic extraction utilizes HFC-134a (1,1,1,2-tetrafluoroethane) as a solvent which is non-flammable gas under normal conditions and accepted as a food grade extractive solvent. The process involves permeating the solvent as a gas through the biomass a number of times to extract aromatic materials until it is saturated, when it is pumped into an evaporator. In the evaporator the gas is compressed resulting in the solution boiling and producing a very quick separation with the solvent as a liquid with the extracted material. The evapourated gas is cooled and recycled back through the bio-mass [24]. The process does not emit any effluents like other processes and the equipment is cheaper than CO_2 systems because of the very low levels of pressure used in the phytonic process. This technology has been utlilised in the commercial production of flower oils in Thailand (see chapter 3).

Superheated Water Extraction

In attempts to reduce the use of organic solvents and develop more environmentally acceptable methods of extraction, there has been some significant research on extracting aromatic materials from plants utilizing superheated water. Superheated water is between 100°C and the critical temperature of 374°C under pressure in liquid form. The process works on the principal that when water is heated, its solubility due to the loss of polarity dramatically increases to the point that substances usually insoluble in water become soluble.

When superheated water is applied to the extraction of aromatic materials the temperature range should be kept between 100-200°C to prevent any thermal sensitivity of target aromatic compounds. At these temperatures water is not very compressible, so pressure has little to do with extraction. However at high temperatures water viscosity and surface tension decrease greatly [25], where the water becomes ionized. The vapour pressure of the water is also much higher than water at ambient temperatures. All these factors decrease water's dielectric constant or relative permittivity, where the characteristics of water begin to resemble those of organic solvents like methanol, increasing its solubility many times of magnitude over water at ambient temperatures [26].

Superheated water extraction extracts oxygenated compounds very well from plant material, but is poor at picking up monoterpenes. The superheated water extraction process produces a product with different chemical profiles than other extraction methods. Clifford argues that this process is similar to the process of producing terpenless oils, which are valued in flavour applications for their superior odour profiles [27].The process is also reported to have higher yields when compared to steam distillation. This is in part because of the ability of superheated water to penetrate the plant material and in part to the mutual attraction of superheated water and oxygenated constituents due to relative polarity [28]. Superheated water extraction uses much more water than the distillation process, but through efficient heat exchange it is still a much more efficient process [29]. The process is also much quicker than steam distillation where for example the usual 3 hour distillation time of marjoram can be decreased to 15 minutes with superheated water extraction [30].

At this point of time the process is still in its infancy with a number of technical problems that still need to be sorted out. For example, the separation of the desired components from the extraction effluent at the end of the process is difficult as many desired components are water soluble. Problems like constituent oxidation and hydrolysis occur in superheated water extraction like in the distillation process.

High Pressure Extraction (HPE)

Another recent method of extracting essential oils and other materials from plant bio-mass is through a technique called high pressure extraction (HPE). High pressure extraction involves the mixing of plant bio-mass with a solvent and then exerting isostatic ultra high hydraulic pressure (CIP). This extreme high pressure increases the solubility of most natural materials. Cellular material under large differential pressure will rupture allowing solvent to permeate through the cells very quickly, leading to shorter extraction periods [31]. High pressure extraction is undertaken at ambient temperatures so heat sensitive materials will not be placed under thermal stress. Extraction sensitivity is modified through using solvents with different polarity, utilizing different pressures and times [32]. This method is still in an experimental stage for essential oil extraction.

Microwave Extraction (ME)

The use of microwave to create thermal heat in essential oil extraction has been developing over the last decade, although most application is on laboratory and pilot scale. There are many different methods used for microwave extraction which either use a solvent or are solvent free.

Microwave extraction using a solvent involves immersing the pre-treated plant material inside a glass container that is connected to a condenser. If the solvent is radiation transparent, the steam created by the oven is the actual heat source. If the solvent is not transparent the microwaves will heat it directly. Through the heating of the solvent the cellular structure of the plant material will collapse and release the aromatic components [33]. The evapouration of the solvent will leave an extract.

Another method without solvents is based on the principal that the existing moisture within the plant material is enough to rupture the plant cells when heated through microwave radiation. The free oil combined with plant moisture will be collected and condensed outside the oven. The excess moisture is continuously refluxed back in to the oven to assist in freeing of the aromatic material from the plant [34].

There are a large number of commercial laboratory units now on the market based on the above concepts with variations in the processes. A number of these are patented.

Microwave technology applications are being actively experimented with. For example microwave energy is being used as a source of thermal heat to produce steam to pass through lavender foliage without the need to use hydro-distillation dramatically cutting down distillation times [35]. At this stage this concept largely remains within the domains of the laboratory with little pilot scale usage.

Enfleurage

Enfleurage is worthy of some discussion, as this process was utilized in Grasse, Southern France before the advent of solvent extraction for use in high grade cosmetics. Products from this process are still offered today by a very few producers for aromatherapy applications. Flower scents can be extracted through fats and washed down with alcohol to produce floral extracts. This process is called enfleurage. Enfleurage was traditionally used on tuberose and jasmine, because after harvest they continue physiologically to produce their scent for around 24 hours [36]. However, this process can be applied to a number of other flower materials. Enfleurage can be carried out using cold or hot fats.

Enfleurage is carried out by preparing a mixture of fat and smearing a sheet of glass with it in a rectangular wooden frame called a chassis. The flowers are deposited on top of this chassis, which are pressed together and stored to allow the aromatic materials in the flowers to diffuse into and saturate the fat. This process is continued on a daily basis until the fat is completely saturated with the scent of the flowers. Flowers must be changed over before their scent becomes objectionable and diffuses unwanted materials into the fat. This process can continue as long as eight weeks. This process should be undertaken in a cool room free of excess humidity.

The quality of the fat used is very important. It must be odourless and clean of any impurities. The preparation of the fat is a painstaking task, where it is cleaned of any impurities and usually mixed in some ratio of tallow to lard, and a preservative added to prevent the fat turning rancid. Although mineral and vegetable oils can be used, the truest to nature scents are created using a 2:1 ratio of tallow to lard. If the fat is too hard, flowers will have difficulty releasing their aromatic materials into the fat, as the fat surface will form a barrier. If the fat is too soft, it will tend to absorb and stick to the flowers, thus making it difficult to change them over. Flowers must be applied to the chassis free of any attached moisture to prevent it from turning the fat rancid.

Once the fat becomes saturated with the aromatic materials of the flowers, the fat is scrapped off the glass plates and very gently heated and poured into a closed container. This material is called a pomade. Pomades are usually called pomade No. "XX", with "XX" representing the number of times flowers have been changed over during the enfleurage process.

Pomades can be washed with ethanol to extract the aromatic materials from the fat. This process is usually undertaken through stirring the pomade in a 50:50 solution with ethanol in sealed containers to prevent ethanol evapouration for several days. The same ethanol can be used in successive batches of pomade to absorb more material. This process does not require heat, so the extraits retain their natural floral scents. However, due to some fat solublising into the alcohol, there maybe some background ‘fatty’ notes, as approximately 1.0% of alcohol soluble fat will be in the extrait. This can be partly eliminated through freezing the extrait and filtering it. These alcoholic extraits can be vacuumed distilled to vaporize the ethanol to create a concentrated flower oil, called an absolute of enfleurage. The crude extraits are usually dark in colour due to the higher concentration of fat due to the evaporation of ethanol. This can be further filtered.

During the enfleurage process, the spent flowers are not discarded as they still contain some aromatic materials, especially the higher boiling compounds. These can be extracted through solvents; however, the odour profile of these absolutes are vary different from the absolutes of enfleurage, due to their different constituent profiles. In theory through combining the absolute of enfleurage with the absolute from the spent flowers, the combined product will provide a very close odour resemblance to the scent of the natural flower.

Extraction of aromatic materials utilizing hot fats is more suited to flowers that cease their physiological activities inside the tissue immediately after harvest. These would include rose, orange blossom, acacia and mimosa. Using cold enfleurage on these material would only produce yields of about 5-10% that could be achieved through steam distillation. Hot enfleurage was also used before the invention of solvent extraction on flower materials that were not suitable to stream distillation.

Under hot enfleurage, flowers are immersed in a hot fat mixture around 60-70°C to penetrate the plant material and absorb the aromatic constituents. This process would take around 30 minutes, and then the fat would be drained of the flowers and used repeatedly on further batches of flowers until the fat became completely saturated. The saturated fat forms a pomade, which can be processed the same way to produce an alcoholic extrait and absolute like cold enfleurage.

Finally, a variation on enfleurage is maceration, which is used to produce aromatic extracts for aromatherapy lotions and massage oils. Plant material is soaked in a vegetable oil such as olive oil to absorb some of the aromatic constituents. This infusion scents the parent vegetable oil with the odour of the plant material. This is a low cost process, which can create scented oils. It is particularly useful for producing oil mixtures from aromatic plants that are very low yielding under other extraction methods and extremely expensive flower materials.

The Expression of Citrus Oils

The citrus industry is based around plantations of various citrus fruits, including oranges, lemons, limes, grapefruit and mandarins. Over many years the industry has become a very integrated one utilizing the ‘zero waste’ concept in its processing methods, producing a wide number of products which include fresh fruit, fresh, concentrated and pasteurized juices, and canned fruits at the higher end. Lower end products from the waste materials include the extraction of pectin, citric acid and processing wastes into cattle feed and molasses. Citrus oils are extracted from the peels of the fruits and thus a by-product of an integrated and capital intensive process. It would never be profitable to process citrus fruits for their oil alone.

The distillation of citrus peels usually results in poor yields due to the structure of the plant tissue surrounding the oil sacs. Fine cutting of the peel before distillation can lead to great losses of oil through the knives splitting the oil sacs, allowing the oil to spurt out of the tissue. Steam distillation also can have detrimental effects on many citrus oil constituents, especially if traces of citric acid exist in the plant material, from cutting whole. Steam distillation also tends to reduce the citral content of citrus oils, as compared to their expressed counterparts.

One of the oldest citrus industries is in Sicily, Italy, along the Mediterranean, which was developed in artisan fashion until after the Second World War. Two primary methods were used, the sponge and ecuelle processes. These began as hand methods, being continually modified and updated by engineers to improve upon these basic processes, where some of the basic principals were eventually incorporated into modern machine processes, utilized today.

The sponge process was undertaken entirely by hand using the peels cut in halves. The pulp is first removed from the peels with a special purpose spoon with sharpened edges. The peels are soaked in water for a few hours and then pressed with a sponge on the top of the peel to collect the expelled emulsion of oil, moisture and colloidal materials. The sponge is then periodically squeezed into a bucket, where the oil quickly separates from the water and oil can be drawn off and separated from the other materials.

The other hand method, the ecuelle process was also formally used in Southern Europe and its principals used in machines that were developed by engineers after the Second World War. A ecuelle is a small hollow copper bowl with holes impregnated over the surface to act as funnels for collecting expelled oil from the peel. The peels are rubbed across the copper bowl in a manner that creates both pressure and abrasion, thus lacerating and breaking the oil sacs. The oil and other aqueous material drops through the holes in the copper bowl, which is collected in a decanter, where the oil will separate from the other materials.

Due to increasing production volumes and the rising costs and scarcity of labour, new labour saving methods of production based on the sponge and ecuelle methods were developed. Through innovative designs and experimentation, many new ideas and practical concepts such as reaming the peels were put into operation throughout various fruit processing centres around Southern Europe. In the late 1940's in the United States machines that extracted the oil from the whole crushed fruit were developed. Each progression in citrus oil extraction had benefits over other accepted extraction methods, but also disadvantages due to the physical and chemical nature of the fruits.

Citrus oils are contained in numerous balloon like sacs which vary in size from 0.4 to 0.6 mm in diameter throughout the top and middle layers of the peel. The oil sacs have no connecting ducts to surrounding cells or the exterior of the peel. The surrounding tissue of the peel also acts as the walls of the oil sacs. This material called the albedo which is under the coloured peel layer is made up of lignin, pectin, pentosans, sugars, glycosides and naringin (in grapefruit). The cells of these materials are elongated which gives the peel its spongy texture. During any expression of citrus oils from the peels, if the extruding oil comes into contact with the spongy cellular material, it will be absorbed into it.

The spongy texture of the peel varies according to the fruit maturity. Due to the cell walls being the same material, they are not readily broken. However, if broken, oil will energetically spurt outwards. This rate of ejection decreases as fruit matures and is less fresh. Thus it is easier to express citrus oils in fresh and immature fruits. Therefore the yield rate in citrus oil extraction will tend to decrease as the fruit season advances and fruit becomes ripe. Older peels become inelastic and tough, making laceration of the oil sacs more difficult. This is due to drying cellulose and pectin.

Oil sac rupture and extraction of the oil is easier in the presence of water. Cells surrounding the oil sacs contain colloids in aqueous solutions. This creates an osmotic environment where oil can seep out of its cell through diffusion in the water. As the albedo of the peel can absorb up to 50% of its weight in moisture, as oil sacs are broken it will also absorb oil.

Water also affects the chemistry of the oil. The oxygenated constituents of citrus oils are soluble in water. Citral is often lost during expression due to its relatively high solubility in water. Pectin often breaks down to methyl alcohol, which has a solvent action against citral. On exposure to both air and water, citrus oils can develop hydrolysis, oxidation and/or resinification with the colloidal substances accompanying expressed oil. Enzymes carried through the extraction process can begin fermentation in the oil emulsion.

The above issues cause a number of problems during citrus oil expression. For example, some proportion of the oil during expression will remain on the presses and absorbed into the peels. Sometimes the oil is washed away with water to prevent re-absorption into the peels. However soluble citrus constituents then need to be removed from the water, under these conditions. Small quantities of oil will remain in the juice where the whole fruit is crushed. This could amount to over 30% of the oil. The oil must be separated from the juice as quickly as possible after pressing, as prolonged oil contact with juice that is acidic will have detrimental effects on the oil. Also where oil and juice is extracted from the fruit crushed as a whole, the colloids will have an emulsifying effect upon the oil. Some chemicals like sodium bicarbonate are used to buffer up pH to weaken potential emulsification. Other pre-treatment methods include treating peels with enzymes to assist in breaking down the flavedo can assist in increasing oil recovery [37].

Today, two methods of juice and oil extraction are used. One is to cut the fruit in half by a reamer and extract the juice leaving the peels for processing and the other is to grind up the whole fruit. The reaming process is the favoured of the two methods. Through the reaming process, the fruit is first washed, halved and juice pressed out. The peels are then grated to open the oil glands with spurting oil being washed away with a water spray. Waste peels can be further processed through steam distillation to extract more oil. Due to its difference in odour to the pressed oil, this residual oil can be utilized for solvent applications for paint and household uses. The left over pulp can also be soaked in a hot solution to extract pectin, where after that peels are dried out comminuted and sold as cattle feed. Alternatively through grinding up the whole fruit, crushers reduce the whole fruit to pulp and liquid. The effluent will consist of juice, the citrus oil and other cellular material. Solid parts will be removed through a system of screens and eventually an emulsion of juice and oil is centrifuged to separate them. Juice in this process also has to be de-oiled, as terpenes in juices have a tendency to oxidize, creating *"off-notes".*

The production of citrus oils has been advanced more by experimentation rather than by theoretical foundations. Many novel and efficient machines have been developed which separates the peels from the juice components of the fruit, to prevent juice containing residual oils. Citrus oils will vary in olfactory and flavour profiles according to the geographical location of the fruit source, the variety, the maturity of the fruit, the condition of the fruit and the method of expression.

Cold pressed citrus oils contain terpene hydrocarbons which do not contribute to the flavour and fragrance profile of the oil. These materials are also undesirable in a flavour oil as they are susceptible to degradation through exposure to the heat, light, humidity and the air. The oxygenated components of a citrus oil provides the bulk of the profile, usually comprising alcohols, aldehydes, ketones and esters [38]. Terpene hydrocarbons are removed through vacuum distillation and fractionation of the oil, usually after removing the waxes through winterization, although other methods like CO_2 and membrane extraction could be used [39]. The parameters of the fractionation process can be manipulated to produce specific oxygenated component concentrations to match the chemical profiles of folded oils. Folded oils with higher concentrations of oxygenated constituents are a value added product from the citrus oil. They are also less susceptible to oxidation and the process can remove components like furancoumarins that are unwanted in the oil. The residual terpene components are sold as separate products for applications like low cost perfumery.

Finally, some processes have been developed which assist existing methods of extracting aromatic materials from plants. For example, enzymes can be used to degrade plant materials through hydrolysis and solubilisation of carbohydrates and other organic materials, to open up oil cells in plants so extraction is easier. In particular pectinase and cellulose have been successful in this application [40]. After enzymatic treatment, the aqueous solution and plant material can be treated with solvents to extract the oil. It is claimed that yields far surpass yields obtained through steam distillation [41].

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Chapter 6

DEVELOPING ESSENTIAL OILS

This is the first of four chapters outlining the essential oil development process. This chapter lays down the early conceptualisation steps that must be undertaken before an essential oil can be selected for development. This chapter looks at issues of information, knowledge and learning as ingredients towards successfully developing a new essential oil. The chapter briefly outlines some strategy, size and organisation issues before the following chapters discuss screening and development.

INTRODUCTION

In the past, discussions about the feasibility of developing an essential oil enterprise would centre upon economic appraisals of aggregate market demand and supply, comparative costs of production, and access to the market. Analysis would focus on the question of whether one more producer would create a supply glut in the market [1]. Potential development was usually based on the premise and assumption that a new venture would sell its output along traditional channels in the flavour and fragrance industry [2]. Vertical integration along the supply chain was rarely considered.

Essential oil development was seen through this economic paradigm until the early 1980s, when aromatherapy rose in popularity. Some industry commentators dismissed aromatherapy as a fad. Yet this emerging industry at the time created new avenues of distribution, marketing and opportunity to potential growers. New entrepreneurs came into the essential oil industry, where many appeared to become successful overnight. However the hype of aromatherapy also created casualties. This reminded people that essential oil production, no matter what the end use, is a business activity that must be approached with prudent and sound business development practices. This chapter, along with chapters 7, 8 and 9 will outline the essential oil development process, showing how to identify opportunities and avoid the pitfalls at planning stage.

Opportunities to produce essential oils for the flavour and fragrance sector still exist, although growth in demand for essential oils is not increasing in real terms. Essential oil demand is growing naturally in accordance with increasing World population. New venture failure rates are high due to fundamental mistakes, which will be mentioned in this and subsequent chapters. The new EU regulations also potentially hinder development. However, at the same time, countries like Vietnam have managed to develop their industry. Tasmania and New Zealand have managed to find niche markets for specialised products through using capital intensive technologies as a strategy. The production of essential oils for aromatherapy doesn’t present the same opportunities as it did in the 1990s, but through careful market analysis, planning, and innovative business models, opportunities can still be exploited. The growth of essential oil usage in cosmetics is currently hindered by definitions of what is an organic product, but once this is resolved, higher growth rates should occur. Organically certified essential oil based agro-chemicals like fungicides, pesticides and herbicides is also new growth areas.

EXPLORING THE POTENTIAL OF ESSENTIAL OIL PRODUCTION

Essential oil development fits into the traditional discipline of new crops, a field of agriculture which looks at the potential introduction of new species or varieties being placed in new locations, with new technologies for producing a product, with a new market, or a combination of all these factors. New essential oil production has also developed in this way. Thus, for a new essential oil production venture to be successful, the application of new breeding techniques, efficient production systems, development of new products and markets are all required. In the majority of cases, the knowledge to achieve all the above is strange and unknown to the new producer. On the sales side, new customers, whatever position they are in the supply chain, need to be satisfied in terms of product, price, quality and service level. This product must be produced competitively enough to cover propagation, growing, crop maintenance, harvesting, processing, marketing and administrative costs, as well as allowing for enough profit margin for each member in the value chain.

Developing and managing a successful essential oil venture requires understanding the technical disciplines of botany, natural product chemistry, plant physiology, propagation methods, agronomy, agricultural and distillation engineering, and analytical chemistry. Many technical problems require solutions that can be only partly solved through individual disciplines, thus requiring an interdisciplinary approach [3]. In addition, farm to consumer supply chain knowledge, planning and market development is necessary. Both areas of knowledge and expertise must be developed in tandem to create a venture that is successful. Ignoring either side of the new venture development, will most likely lead to failure.

In many cases, those setting out to develop a new essential oil venture will usually have little previous farming, processing and/or market experience. This immediately sets out a number of challenges. Firstly the degree of success will be directly related to what crop is chosen. Selecting the right crop to grow (and this also has much subjectivity), will depend upon the access to good information which can lead to the making of informed decisions. Usually the first exposure to knowledge is news passed on from a friend, conference or seminar or some form of media, electronic or otherwise. There is no shortage of media reports and internet information about essential oils, which can lead to ideas. However one must be extremely cautious as most media reports, internet information and even many conference and seminar papers which are sometimes developed for publicity purposes and can be full of ‘hype’ and enthusiasm, rather than factual information and knowledge. Technical and scientific papers although often of great use in technical development, however they are not marketing documents The potential producer needs to be aware of the limitations of published information.

The above sources of information can lead to no shortage of ideas, which sometimes carry emotive wishes. These ideas must be filtered through the use of more factual information to screen the facts from the ‘hype’. Decisions need to be made on the best factual information available, which can lead to accurate knowledge. This can only be achieved through discussions with potential customers and trial and error in field trials, so knowledge can be developed into the wisdom needed to develop a successful enterprise. Figure 6.1. shows the hierarchy of information that one has access to aid the essential oil development process [4]. This process must eliminate wishful thinking and excitement to convert mindful enquiry into a more rational and objective frame to be able to observe the realities of technical and market issues, before preceding to the next stage.

THE LEVEL OF COMMITMENT

A new essential oil venture requires time, patience, finance and aversion to risk. The level of commitment to seeing through the project is of great importance to success. Most new ventures in Australia, New Zealand and elsewhere were developed and built on commitment to seeing the project through. There are a number of reasons why different people and groups are attracted to new crops such as essential oils. Some of these include [5];

- The desire to introduce new crops to change the lifestyle forced upon them by what they are already growing. They see essential oil production as a means to become free of existing supply chains where they are price takers and have no control over the market.
- The desire to achieve a higher return from their land by taking up entrepreneurial opportunities through value added downstream activities based on essential oil cultivation.
- Others see challenge and seek a *'sea change'* from urban life. They are attracted to essential oils as something inspiring, taking the enterprise up as a hobby or fulltime undertaking.
- Some people have seen essential oil production as an opportunity to create a rural tax reduction scheme (in Australia), to make quick returns. This has led to a lot of controversy, as many involved have lost their investments due to the project being based on false market and technical premises, promoters lacking the personal skills required and the product failing to fulfil a true market need [6].
- Community essential oil projects have been developed to generate income as a means to assist in the elimination of poverty and create empowerment for remote communities.

Many people have entered the industry out of a strong passion for essential oils, particularly in the aromatherapy area. Other essential oil projects have been developed to substitute tobacco cultivation, like the peppermint industry in North-East Victoria and the Dill industry in New Zealand. Community projects aimed at improving incomes have been developed in Northern Thailand, Papua New Guinea and Malaysia. How economically successful they have been is not certain, but some of these projects have added a sense of pride to the communities involved.

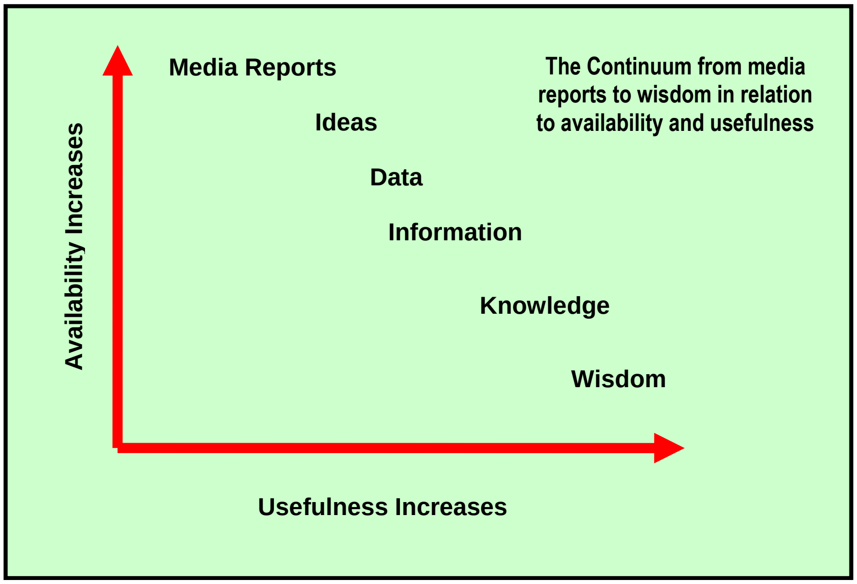

Figure 6.1. The continuum from media reports to wisdom in relation to availability and usefulness.

Whatever the source of commitment, it must be strong enough to drive the individual or group through the challenges and risks of the new venture development. The best way to explain the commitment needed is to outline the individual and group attributes required to develop a project;

- The group must be willing to seek out all information required so that good judgements can be made. This may involve talking to other individuals and groups who have succeeded or failed, searching for information through all sources available and seeking connections with all organisations through the value chain.
- Learn about all techniques and equipment required, so they are knowledgeable about the technology,
- Think holistically about the potential enterprise and industry, so supply chain opportunities are identified,
- Realise that the venture will not produce short term profits and take a number of years to yield positive returns,
- Be prepared for setbacks. Some setbacks will be within control such as propagation and field issues, while other issues will be outside control, like market issues and the weather. and
- Be willing to learn from mistakes through the process of trial and error, where learning can be applied to solving the issues.

The whole process of essential oil development is a learning process, starting from the conceptualisation process, through the screening process and to the actual work done on the ground to develop the enterprise. Failure to learn will inevitably lead to failure of the enterprise. The learning process is very important during the development stages, where failure to achieve positive results from research will lead to new knowledge.

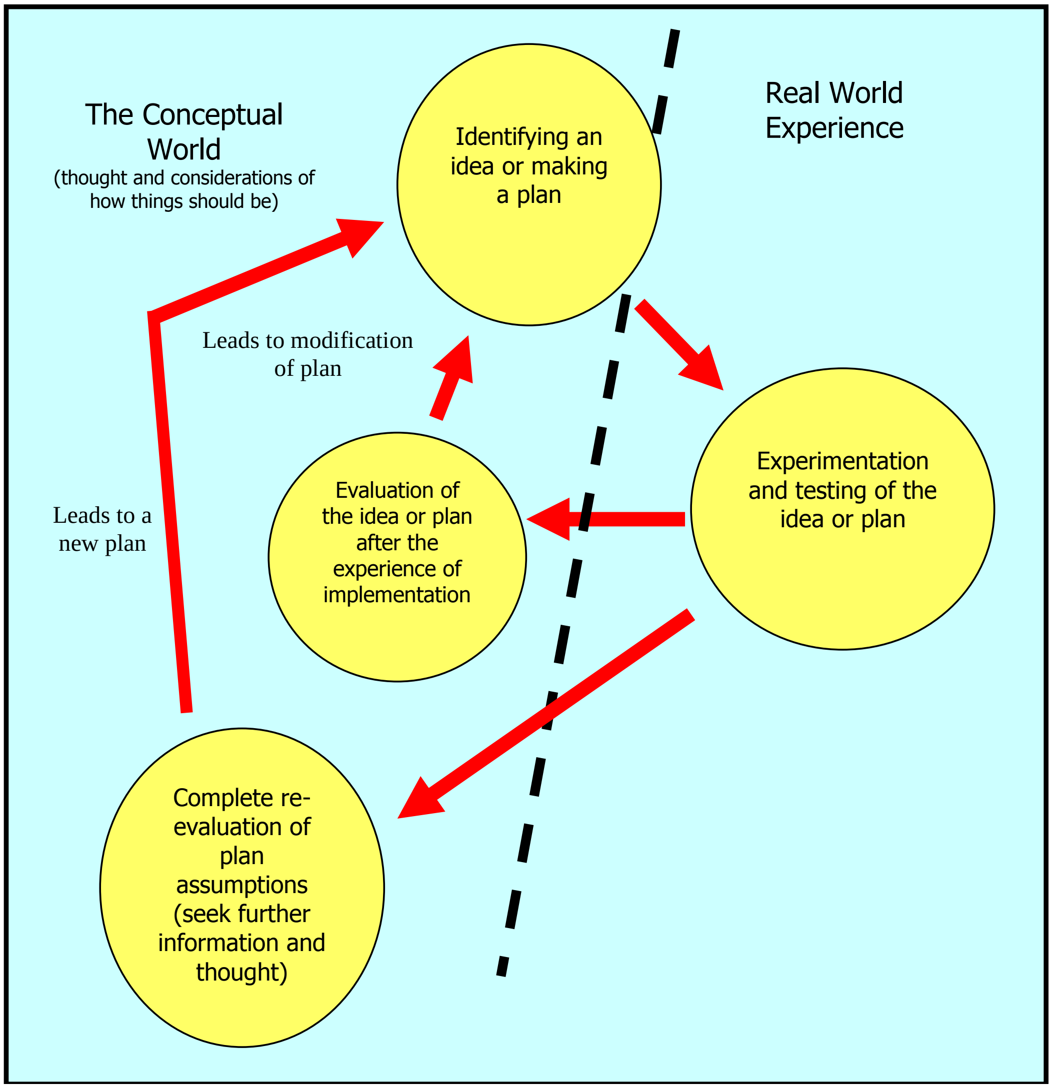

Figure 6.2. The Learning Process.

The learning process enables a linkage between the actual world based on real experiences and the conceptual world of how things ought to be. Figuring out concepts to implement in the real world based on past actual experiences is how learning is undertaken and greater knowledge and wisdom is developed [7].

The first step of the learning process is to plan, fact find and reflect upon the information at hand to make a decision about what actions will achieve the desired outcomes. The results of these actions will create concrete experiences which can be assessed about their success or failure to achieve the desired objectives. This can trigger another round of reflecting upon the results, which will either result in making adjustments to the existing experimental parameters or prompt the seeking of further information so that a new plan of action can be developed and implemented. This process continues around these three (or sometimes four) basic steps of planning, experimentation and evaluation. This process is shown in Figure 6.2.

The concept of trial and error in agriculture implies continual setbacks (either in the basic parameters set or in the assumptions made). The individual and group must be motivated enough to take setbacks as being a necessary part of a learning cycle that will deepen insight into potential optimum crop practices.

Challenges and Failure

Experimenting with essential oil crops involves overcoming challenges, risks and uncertainties before any opportunities can be exploited. Although alternative crops like essential oils may increase the possible options for a primary producer, the further away from conventional crops one looks, the higher will be the challenges and risks especially in a pioneering situation within the area or region.

Alternative crops may not necessarily provide higher returns than conventional crop opportunities, but they will certainly provide greater challenges and risks. Firms diversifying along the supply chain to primary production will face issues that may negate any benefits from controlling their own essential oil production. For example, where an essential oil might be a raw material in a cosmetic product, the extra development and indirect operational costs may add increased costs to the core business. Developing essential oils and producing them commercially, requires considerable research and planning, the utilisation of limited resources (including time), taking away focus from the core business strategy, with no guarantee that what is produced in the end is better than what can be purchased.

The major challenge for a new essential oil producer is that the crop development involves not only agronomic and new product development, but also entry into a new industry, all at the same time. Most areas in the South-East Asian-Pacific region are geographically remote from the major consuming markets of Japan, Europe and the United States, while the local market may be a very small one. Therefore, if any essential oil is developed for the domestic market, opportunities will be very limited. This all dramatically increases the complexity of the product development process.

There are numerous reasons why essential oil projects fail. All these reasons usually come back to poor project and business planning and failure to take certain issues into consideration. A summary of potential reasons for failure are listed below.

- *Market:* Unfortunately many ventures fail due to poor understanding of the market. These include misunderstanding elasticity of supply from existing producers, access to channels of distribution glossed over, failure to identify and engage potential customers from the outset and misunderstanding the reasons why customers purchase certain products. These are all critical issues. Sometimes a project begins to produce commercial quantities at a time when the market begins a downswing, where early business analysis failed to make allowances and contingencies for.
- *Limited Product/Market Knowledge:* End product markets for essential oils are often not fully understood. This includes the olfactory profiles required of essential oils which standards may not fully explain. Likewise not understanding solubility and skin irritancy issues in cosmetic formulations may lead to developing essential oils which cosmetic chemists find too difficult to use, as was the case with Australian

Blue cypress oil [8]. Finding out market and agronomic information such as World acreage for minor crops is very difficult. Without extensive experience and knowledge, identifying potential market uses for specific aroma chemicals is almost impossible.

- *Finance and Patience:* Sometimes the development time and costs involved have been totally underestimated and funds are depleted before the development stage is completed leaving an undercapitalised project. Accurate estimation of the research time required to develop an essential oil is extremely difficult. Some simple replicated field experiments may highlight critical issues that early planning did not identify at the beginning of the project. Likewise patience runs out and the project fails to complete the necessary research and development required.
- *Lack of Relevant Core Competencies:* An essential oil development project requires expertise in a number of disciplines in both the technical and marketing areas. Lack of expertise in either aspect can lead to failure.
- *Regulation:* Regulation and registration requirements for new natural materials and finished products are increasing. The cost of registration may be more than the potential market is worth. Failure to register the material or finished product may only legally allow sales of the essential oil within a very limited market, too small to sustain the venture.
- *Poor weather and unsuitable climate:* Many projects fail because of poor weather. Although climate statistics exist for regions, climate change and the *el Nino* effect bring irregular weather patterns, which may prevail during the development stage of the project. These conditions may be different from the original project assumptions, such as situations where prolonged drought or extremely high or low temperatures prevail over a long period of time. Although these variables are outside the control of the potential producer, they must be planned for.
- *Incorrect Plant Varieties and Chemotypes:* Many ventures have failed because of cultivating incorrect varieties or different chemotypes of the generally accepted commercial variety. For example, basil may have many different sub-varieties, all with different chemical compositions and olfactory profiles [9], rendering them unsuitable for commercial trade to existing customers. This problem occurred in the Ord River project in North-Western Australia during the 1980s. Many lavender oil producers face this problem of producing an oil that is not accepted internationally because of cultivating unsuitable varieties [10].
- *The Availability of Raw Materials from the Wild:* Growing scarcity of wild material and Governments banning wild collection of many species renders many producers inoperative, forcing them to go out of business. This is certainly an issue facing many essential oil producers in Indonesia today [11] and also a reason for the decline in sandalwood production in that country [12].
- *Politics:* Brian Lawrence lists politics as one of the major reasons for project failure in many countries [13]. This does not include issues with political figures but usually more to do with misunderstood agendas with Government agencies, corporations and individuals that potential producers may have to deal with.

Additional barriers to development are summarised further below.

- *R&D Barriers:* Public funding for essential oil R&D is extremely scarce within the South-East Asia-Pacific region. Existing R&D not be enough to cover all the required technical aspects in any single project. For example, crops that need to be domesticated require extensive plant breeding programs which public funding may not cover. This could be a critical issue in oil quality, yield and the underlying economics of the whole project.
- *Infrastructure Barriers:* Many sites where essential oils are intended to be produced lack any infrastructure on site and are geographically remote from any support services like analytical laboratories. Developing drainage, irrigation and dam systems are expensive and dramatically add to the capital costs of development [14]. In a community geared to the production of conventional crops, any existing agricultural infrastructure may not be of any assistance to the potential new venture, *i.e., an area based on fruit production may not have suitable infrastructure and equipment for essential oil production*.
- *Policy and Attitude Barriers:* Policy barriers usually arise because Governments focus on supporting major crops at the cost of minor and alternative crops. This leads to little financial and public funded R&D support which adds risk to any new crops venture outside national priorities. Consequently attention to minor crops by public officers and farmers is usually very low and may prevent new initiatives.

Table 6.1. Issues and Challenges in New Crop Development (Essential Oil)

Issue	Comments
Focus Paradigm	• Requires focus on concept of product application where current focus is on cultivation • This requires research • This requires an entrepreneurial approach • Concepts not readily understood by conventional farmers
Basic Research	• Needs access to Worldwide data • Requires availability of suitable genetic planting material • Requires basic R&D to determine where crop technically suitable • Requires R&D to determine whether potential crop is economically feasible • Very difficult to get R&D assistance • Shortage of skills and expertise in many areas
Crop Management and Processing	• Propagation technologies • How to plant, cultivate and manage the crop • How to harvest, extract, store and handle • How to process • How to package • Transportation and storage
Marketing Infrastructure	• Require coordination of production with demand (important with new essential oil production) • Require correct channels of distribution (critical) • Requires a marketing strategy (change of paradigm from producing orientation)

Economics and Logistics	• Requires enough volume to economically transport and distribute (especially in low to medium value oils) • Requires a solution to inconsistencies of quality and production
Organisation	• Need committed people with strong leadership and trust
Government	• Need to translate support into action • Need funding allocations for research & development • Need infrastructure
Regulation	• Need to fund infrastructure to meet EPA & HACCP, etc • Need to identify and fulfil the requirements of various regulatory bodies
Finance	• Very difficult to obtain funding for these projects
Customers & Consumers	• Need to identify who are the customers in which part of the value chain • Need to work closely with selected customers

To succeed, the potential producer has to face a number of issues and challenges in new crop development [15] summarised in Table 6.1.

RISK AND UNCERTAINTY

Risk and risk taking is a subject that is greatly misunderstood in current entrepreneurial literature. Many argue that an entrepreneur is a risk taker when starting a new venture. Drucker would argue that an entrepreneur through his or her actions works towards minimising risk, rather than taking risks [16]. The essential oil development process is in fact a sequence of activities that reduces risk though creating knowledge at each step of the process.

Risk is a situation where there is some probability of an event happening (or not happening), which may cause determential damage to something or some process. This means that the probability of risk can be calculated and thus accounted for in plans and operations. Risk can therefore be decreased with informed knowledge and experience about issues where risk can be attached. Therefore the level of risk greatly depends upon the information available to an individual or group, the factualness of information available and the wisdom they develop from the utilisation of that information from their own experience. Thus risk will vary from individual to individual and group to group based on the factors just mentioned. The greatest contributor to risk is the lack of sufficient and factual information. Many people want to believe in the 'hype' about a subject and consequently take actions based on emotion. This is a recipe for failure. Experience, attitude and financial status also change the relative weight of risk, depending upon how critical a failure would be to an individual or group.

A research development program must pre-identify potential risk in all areas and work towards potential future solutions, so eventuality of events occurring with undesirable outcomes occurring is minimised. This is the role that research and development in both the technical and market areas contributes to risk management – evaluating and acting to minimise potential risk. Therefore potential risk is related to lack of skills, lack of understanding and application of technical fundamentals - propagation protocols, planting, harvesting and processing technologies, choice of unsuitable land locations, lack of financial sustainability, supply chain issues, selecting the wrong crop or variety and/or chemotype.

These are all internal issues which the individual or group can exercise almost full control over with the correct knowledge.

There are also external precipitators of potential risk which are primarily outside the control of individuals and groups, such as weather – rainfall, high temperatures, drought, excessive rainfall, etc, adverse natural events, political events on an organisational or macro scale, and unforseen or unknown market supply and demand issues. Commercial, weather and other events although appearing chaotic and unpredictable, are influenced by a number of factors, which are continually changing and influence each other. Very small changes in one factor can have a large influence on others. These factors operate within a system relevant to the potential venture where past behaviour influences present behaviour. Through understanding these events in an historical and holistic manner, with an understanding of the influences of the *el Nino* phenomenon and climate change, patterns can be seen which can be planned for with contingencies. Risk to a great degree can be measured and managed. There will always remain some uncertainty as some events occur without probability on a random basis, which cannot be foreseen and potentially managed, like extraordinary floods, or an earthquake, etc.

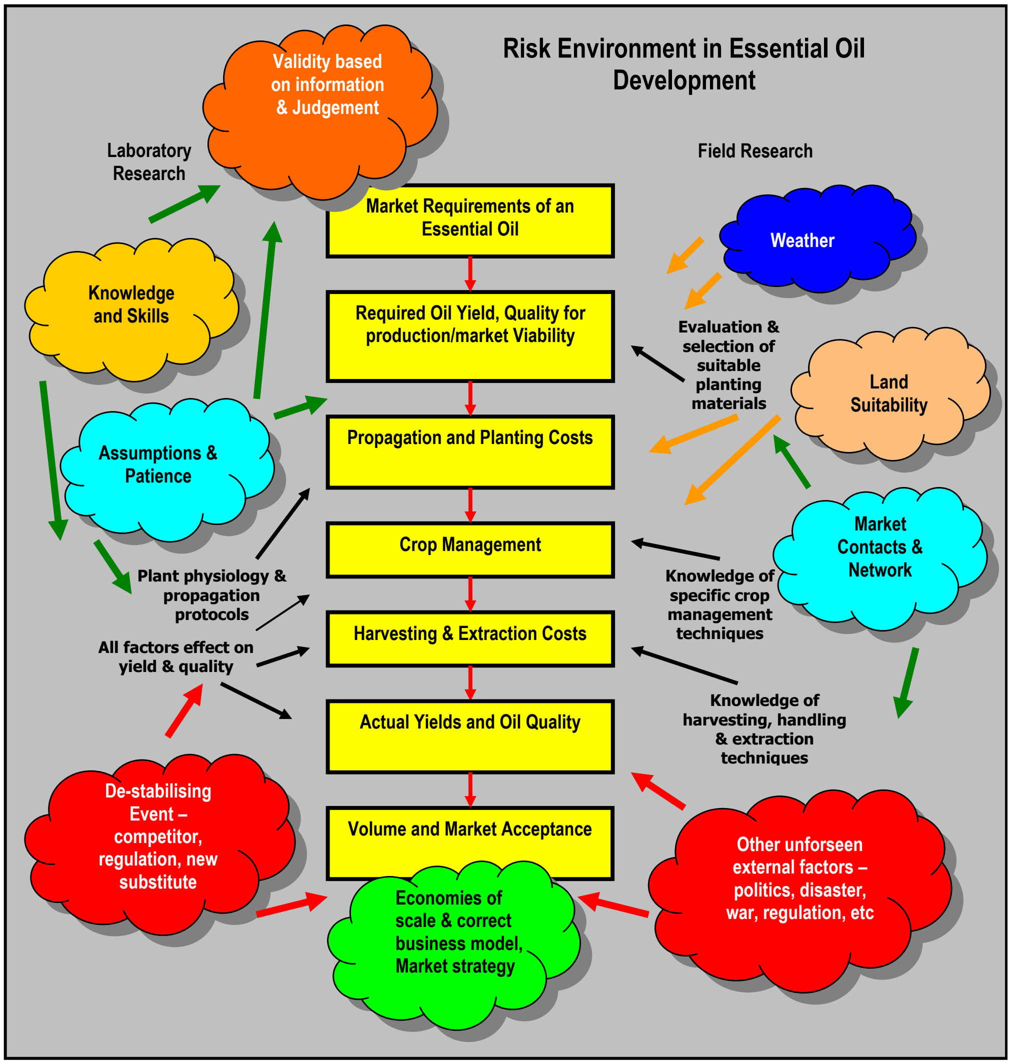

Figure 6.3. The risk environment in essential oil development.

The most powerful management tool in handling risk is wisdom based on hunches, intuition and experience in viewing a chaotic, but interrelated holistic system surrounding the new venture. By using reliable information and data as a starting point and systematically eliminating unknowns through sound reckoning based on research, certainty replaces uncertainty. This is in fact how managers make decisions in the everyday running of businesses and the actual way businesses plan strategically for the future [17]. Strategic models are a mere template for thought and enquiry, as a tool used heuristically in logical thinking, rather than a formal process, which will assist in coming to a conclusion that may have to be revised many times during the development process. This is not advocating "no planning" but flexibility and open mindedness without any cognitively biased conclusions, which are easy to develop early on in the development process.

Information is an important aspect in avoiding failure. Lack of information is a great impediment to new crop development [18]. Given that most knowledge can be self generated through good research and working closely with elements within the supply chain, risk is an issue that can in most cases be overcome with wisdom. Figure 6.3. illustrates the risk environment in essential oil development.

Some General Success Characteristics

Looking at why companies have success doesn't tell us as much about how to be successful as looking at and learning from other peoples failures [19]. However, knowing what the common success factors are will assist in approaching the development process in the correct manner. Based on a study of Ninety-Four Australian farmers developing new crops, Keith Hyde listed the following common characteristics of their successful ventures [20].

- There is someone who provides the vision, drive, passion and commitment and plan to turn that vision into reality,
- The venture is market focused, undertaking considerable market research which is crossed checked, competitors studied, consult with potential customers and key people in the market,
- Land selection was carefully undertaken to develop the best conditions (climate, humidity, topography, water, infrastructure and soil types, etc) for the new crop,
- Required technologies were clearly identified, either transferring, adapting or developing new technologies into the project,
- Adequate financial resources were available to the new venture to sustain it,
- A management ethos towards strong profit and quality focus, and value adding, where possible, use of research to develop best practices, and
- The Government played a positive role in the provision of infrastructure and right environment for new industry development.

Strategy

Early in the information gathering and thinking process, ideas will start being developed about what type of basic strategy should be pursued. A number of basic ideas about possible scenarios of development will arise. These ideas will lead to questions like *what essential oil should I produce, and why? What scale should I develop the venture? How should it be organised and who should be involved? What should be the core business? Where in the supply chain should I seek my customers?* All these questions require some strategic thinking about what outcome is desired. This in turn will heavily influence the way things are developed and the focus of the venture.

Strategy development must also take into account the interest of the promoter and accommodate his or her vision (see Figure 12.2., Chapter 12). This interest may be generated from thoughts and feelings about the industry, products and markets, originating from a desire to vertically integrate into agricultural production, an interest in a specific essential oil, a wish to develop products from a specific or group of essential oils or a desire to find an alternative crop. Whatever the inspiration for the promoter's vision is, it will most likely fit into the Essential Oil Strategic Matrix shown in Figure 6.4. This matrix identifies the basic characteristics of the contemplated essential oil as 1) an existing crop – product already traded, 2) an existing crop – leading to a new product, 3) a new crop to a new geographical area, where the product is already traded, and 4) a new crop and new product. Shown in the figure below are the specific important issues (or desired outcomes) that will become important objectives of the development project.

An Existing Crop – Product Already Traded *This can be seen as an improvement on existing production or setting up new production in an area already producing the crop.* • Improving cultivation and harvesting methods to improve productivity • Finding new customers and channels to increase sales	**An Existing Crop – Leading to a New Product** *This may involve moving along the value chain to a new market based on an essential oil already produced or producing an essential oil for some type of value added product.* • Improving cultivation and harvesting methods to improve productivity • Finding out what products potential customers want in a new product • Producing a new product according to identified consumer needs • Organising the supply chain for the new product to get to market • Making the product available to more consumers who are likely to want it
A New Crop to a New Geographic Area *This involves producing an essential oil already in trade in a new geographical area.* • Establishing the most efficient way to cultivate, harvest and process the essential oil • Matching the newly produced essential oil with customer expectations and requirements • Organising the supply chain so the essential oil reaches the market • Making the essential oil available to new customers who are likely to require it	**A New Crop and New Product** *This involves producing a product higher up the value chain, differentiating it and producing the essential oil.* • Making informed decisions about new crop choices • Establishing the most efficient way to cultivate, harvest and process the essential oil • Finding out from potential customers what they want in the new oil • Making sure the oil meets the customers needs as closely as possible • Organising the supply chain so the essential oil reaches the market

Figure 6.4. The Essential Oil Strategic Matrix

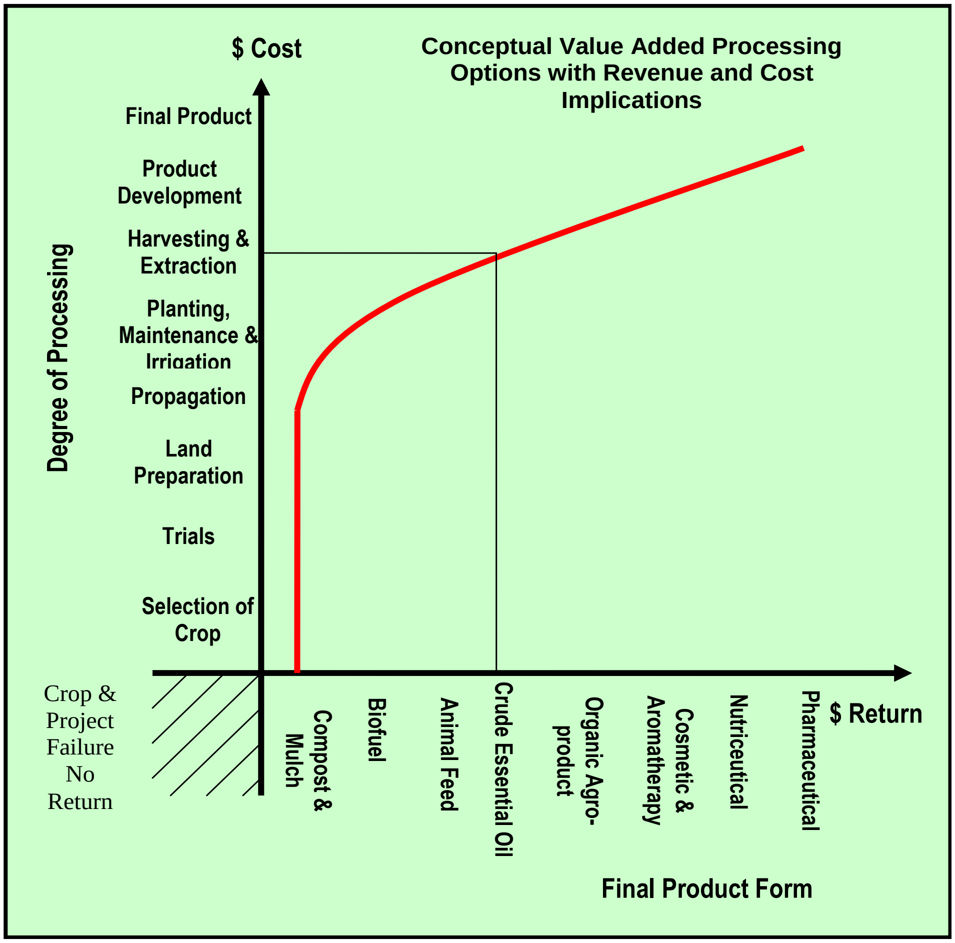

Figure 6.5. Conceptual Value Added Processing Options with Revenue and Cost Implications.

The promoter's vision may involve a want to produce value added products based on the essential oil as an input into a product further along the supply chain, utilising parts of the plant material for the production of other by-products, and/or utilising waste materials as much as possible to improve revenues and sustainability. In these cases the venture may market various products to different industries *(i.e., agro-products, alternative energy feed-stocks, animal feed, etc.)*, or in the case of value added essential oil products, focus on higher parts of the supply chain. These visions heavily influence the whole focus, capital, technology and processing, management and market development requirements of the venture. These value added and by-product diversifications also affect revenue. Figure 6.5. conceptually depicts the various value added processing options with cost and revenue implications.

After considering what type of product could be produced by the potential venture, which part of the supply chain will be focused upon to generate sales will be the next issue. The type of product and level of the supply chain the enterprise targets will require focus on different sets of issues. The production of an essential oil for the flavour and fragrance industry, especially an existing item of trade will require studies and information about current World demand and supply, future expectations, trends and the elasticity of supply from current producers. Once satisfied there is room for a new producer, the enterprise can target specific customers to work with or attempt to develop selling channels either directly or through traders on the open market. The development phase will be mostly concerned with technical aspects of producing an essential oil, which include meeting regulatory requirements, producing the desired olfactory profile required by customers, and meeting a cost that provides a positive return to the producer. This enterprise has an agro-orientation, where the important issues are demand, supply, competitive costs and quality.

Producing a new essential oil will require focus upon potential the specific industry applications that the oil will attempt to satisfy, *i.e., for a flavour, fragrance or cosmetic ingredient, etc.* Knowledge about final application of the oil in the intended industry use is important, so its potential value can be demonstrated. Some development of intellectual property, whether through patent or proprietary knowledge on process or product is likely, and can be used as a method to create barriers of entry to other potential producers. Within this focus, close work will most likely be undertaken with specific customers who may or may not exclusively purchase the product from the producer in the future. This type of enterprise has an industrial orientation, where the important issues are technical development, potential substitutes and complementary products.

Producing an essential oil or number of essential oils as intermediate products in the production of end products, such as aromatherapy, cosmetic, agro-chemicals, nutraceuticals or pharmaceuticals requires a focus upon the market. This means understanding consumer tastes, trends, product development and how to engage consumer markets. The enterprise is required to develop products that match and fulfil consumer wants, building up a theme or corporate and product brand images that differentiate the product from others already in the market. The enterprise will be concerned with ways to make the message about their products reach as many consumers as possible within the groups they target. Over the last decade new methods like the internet and direct marketing channels in South-East Asia have become very popular and allowed a number of companies to utilise these alternative supply chains, as has been successfully undertaken by Thursday Plantation Tea Tree Oil in Northern New South Wales, Australia [21]. This type of enterprise takes a consumer orientation, where emerging consumer trends, new product development and channels of distribution are their important issues. Figure 6.6. shows the various differences in venture focus along different parts of the supply chain.

The final consideration within the vision development for the potential project is the type of production structure, organisation and entry strategy. The structure and organisation will depend upon many factors. For example, issues like who are intended as the beneficiaries of the initiative, the selected crop, location, market size and potential market share target, required level of field and extraction technology and envisaged scale of the enterprise, will influence structure and oranisation. A number of options exist, which include a) wild collection, especially if the crop cannot be cultivated like sandalwood within a short to medium time frame, b) small scale production similar to a small holder if the project is a hobby, c) an extension crop of an existing farming enterprise, d) a small to medium sized plantation or e) a large plantation, if economies of scale are needed to develop the market based on cost competitiveness. These types enterprises can be controlled and managed by an individual, family or company, a cooperative or community group, or a company controlling processing facilities and a marketing organisation.

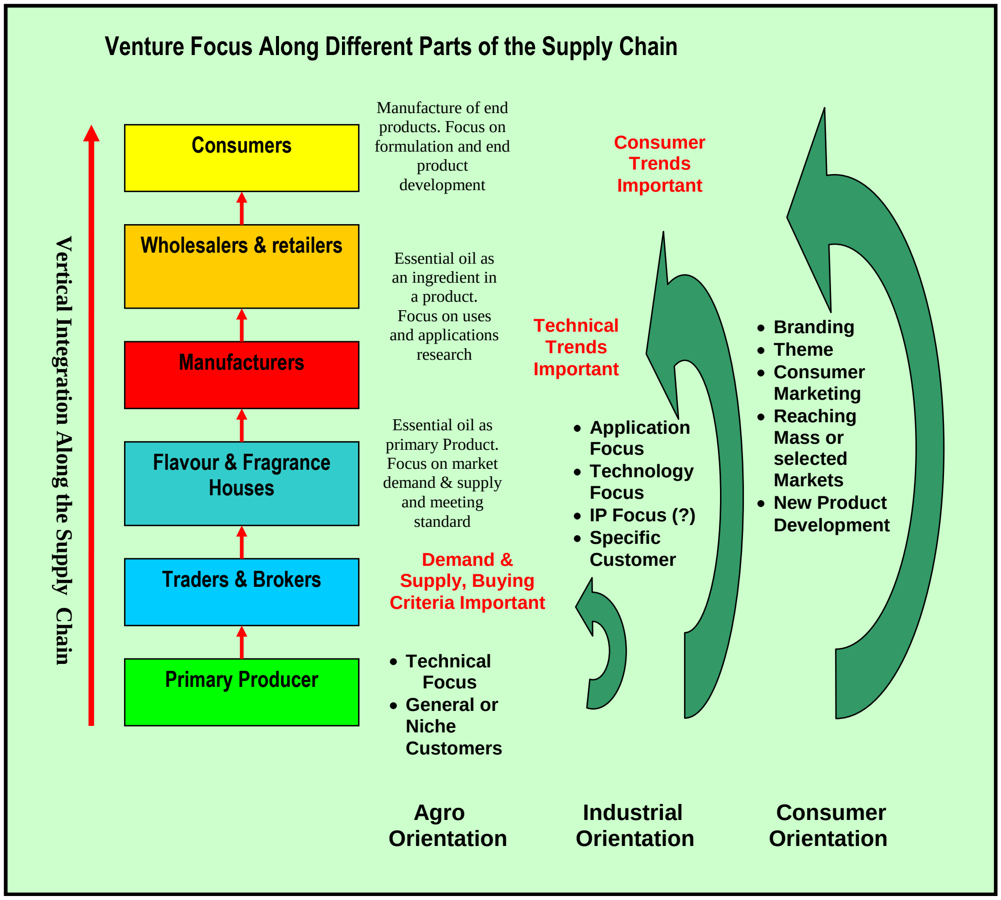

Figure 6.6. Venture Focus Along Different Parts of the Supply Chain.

A small, medium or large plantation venture may have complete individual, family or company control over seed, selection of growers and serving as sole buyer/processor of the crop. This approach is used in Australia and New Zealand with mixed results. Enterprises where farmers form a cooperative that controls processing and marketing, are effective in organising production levels, however as a group usually have little industry and business knowledge which inhibits growth because of an inability to make informed business decisions regarding production and marketing. Cooperatives have been generally poor in reacting to the changing business environment [22]. Some of these ventures have government involvement, achieve mixed success depending upon the commitment and support of individual officers and their understanding of the business environment.

One of the major challenges of organisation is the need to manage interpersonal relationships, group dynamics and ensure that each individual and group gains benefits from all decisions made [23]. Relationships between growers and processing companies can also become easily strained when growers perceive the processing company to be taking less risk than themselves [24]. This can lead to growers leaving the arrangement and cultivating alternative crops. Developing a new crop and managing it within a cooperative, contract or community framework requires as much concern about people as the product itself. The strategic issues involved in entering the essential oil industry are summarised in Table 6.2. below outlining some of the advantages and disadvantages each strategy.

The Essential Oil development Process

The next two chapters will present a framework for essential oil development, following the framework set out in Figure 6.7. [25]. The first part of the process is screening for appropriate essential oils to develop, which will be covered in chapter Seven, along with a summary about the regulatory process. Chapter Eight will then look at the enterprise planning and field development planning processes, while chapter Nine will look at the field development process.

Table 6.2. Potential Entry Strategies for Essential Oil Production

Strategy	Advantages	Disadvantages
Large scale cultivation for international market	• Low cost base in Indonesia, • Laos, Cambodia and Vietnam	• Low cost countries like Indonesia struggling to maintain competitive advantage • Most projects based on this strategy in both Australia and S. E. Asia failed to be sustainable • Competition based on price in buyers market
New Essential Oils	• No or little competition in early stages • Novelty has a marketing story behind it – cosmetics & aromatherapy	• Registration cost of new • products for F&F, cosmetic • and pharmaceutical • industries very high
Integrated Project as part of another business/ agro-tourism/ consumer products	• Adds synergy to the business • Costs distributed across whole business • Production becomes part of the marketing strategy • Develop own market for production	• Business complexity greatly increases
Community Empowerment project/small holder supply on buy back	• Low entry financial costs • Assist in providing sustainable income for communities in poverty • Becomes part of companies social responsibility activities • Marketing benefits	• High organizational resources required • Results of interpersonal relations great bearing on result.

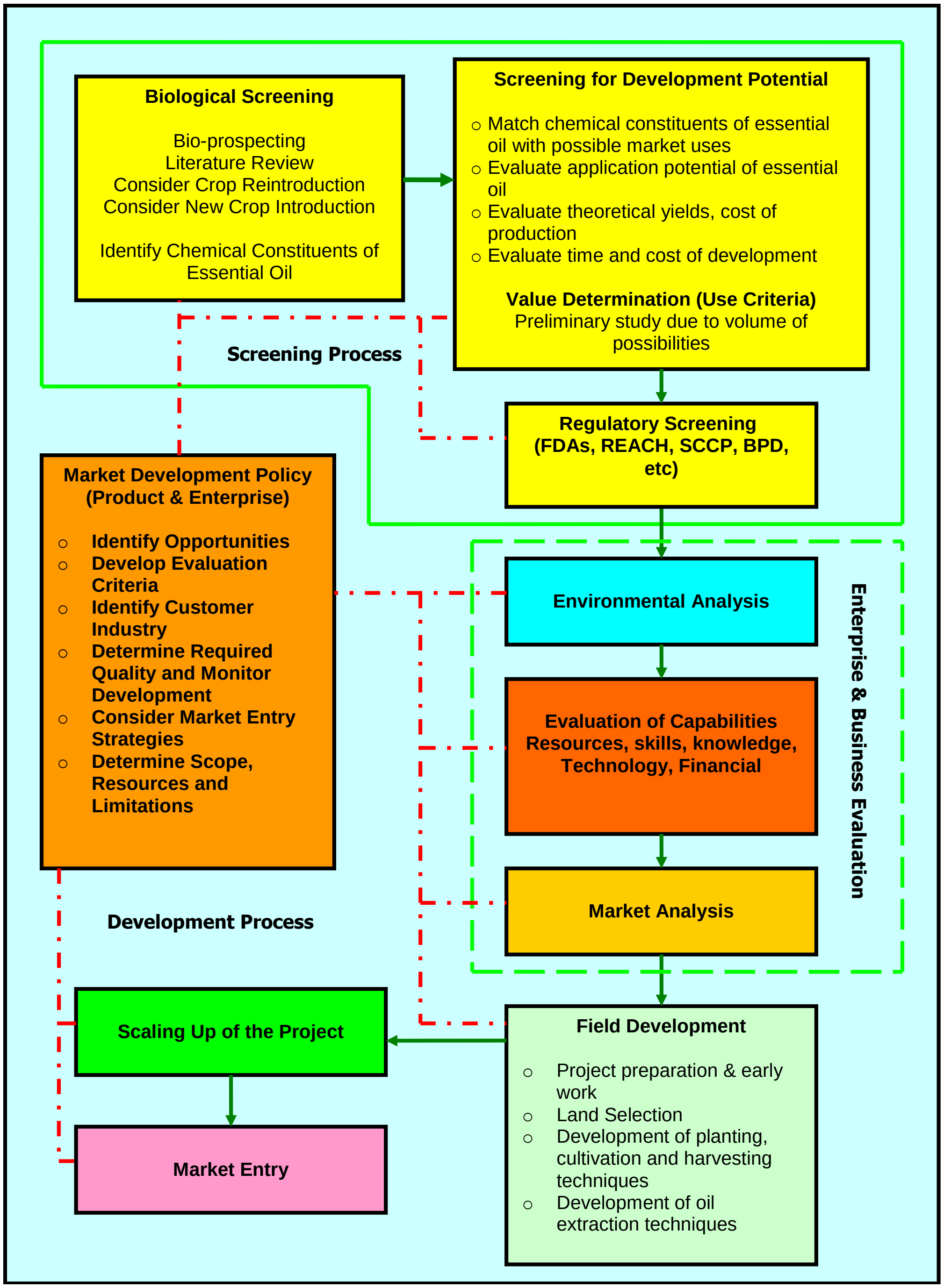

Figure 6.7. The Essential Oil Development Process.

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Chapter 7

THE SCREENING AND REGULATORY PROCESS

This chapter examines the screening and regulatory processes for new essential oils. The first part of this chapter provides and overview of a screening process that can be used to find potential new essential oils for commercialization. A framework with a set of evaluation criteria is presented for the evaluation of potential essential oils. In the second part of the chapter, the regulatory process is looked at in some detail due to its importance to the commercial potential of an essential oil. Regulation upon essential oils is one of the major factors deterring new developments.

INTRODUCTION

Essential oil development is expensive, time consuming, resource demanding and can in many cases be quite reward-less. Before any research and development can take place, the scope and limits of the project must be defined. The last chapter dealt with a number of issues involved in creating this vision, so development can be pursued within a focused framework within a product and market objective. This preliminary thinking process will form the basis of a vision statement which will carry three functions; 1. to create a clear and defined set of development objectives for the project, 2. to set a reference framework for continual referral during the project's progress, and 3. to set limits on the scope of the screening process. This vision statement must identify and take consideration of the resources required, those available and their limits and costs.

Before commencing with any physical development fieldwork, it is necessary to undertake a formal screening process, guided by the vision statement, to determine whether it is potentially feasible to spend time, effort and money developing a selected crop. The screening process as well as being a selection process, is a safeguarding process to minimize risk. The purpose is to make a preliminary assessment of physical variables (climatic, suitable to local land etc,), market potential and regulatory barriers. Once the influence of all these factors is established, potential crop feasibility can be evaluated, within the constraints or scope of the project vision.

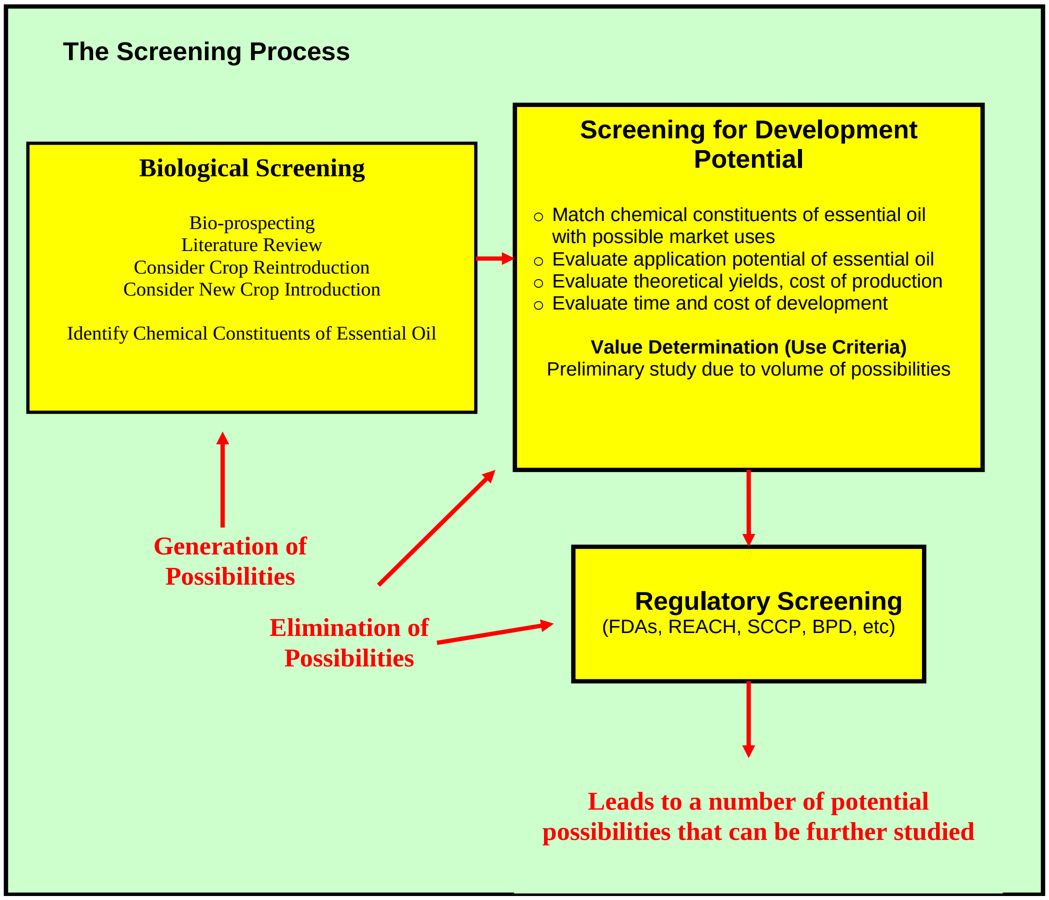

Figure 7.1. Overview of the Screening Process.

Opportunities for Essential Oil Development

There are a number of potential directions a development project can pursue. Opportunities for essential oil development fall into three major categories.

1. The introduction of existing commercially traded essential oil crops to new geographic regions.
2. The re-introduction of an essential oil once produced commercially, and
3. The introduction of a new and novel essential oil.

A potential producer can also choose to cultivate an existing essential oil already produced in the local area. This is simply a decision to follow other producers in the community, where the many issues in screening and development have already been settled by previous producers.

In this initial stage there should be an idea of which market and product functions are the most desirable to target in the screening process. There may be focus on developing the essential oil for the flavour and fragrance, cosmetic and aromatherapy industries, as an intermediate/industrial product, a pharmaceutical material or agro-chemical material. This enables the project to focus on developing the essential oil to those industry requirements. This will influence the type of chemical constituents that will be searched for, regulations and standards that need to be scrutinised, and define the supply chains the producer must operate within. The potential application also defines supply chain options and where in the supply chain the producer wishes to target as the market.

Essential oil production was very slow to diversify in the beginning of the last century because of the craft like culture of the flavour and fragrance industry. Only after world upheaval through wars and de-colonialisations, where shortages and rising costs of production occurred, did the conservative industry begin to accept essential oils produced out of non-traditional geographic regions. Greater challenges exist today with increasing competition for land use, where food crops and housing development potentially provide much higher returns.

The widening of essential oil opportunities in aromatherapy, cosmetics, pharmaceuticals and agro-chemicals has brought many new producers into the industry, seeking to take advantage of alternative supply chains. *'Origin'* is not considered as an important issue as before. Successful development of existing commercial essential oils depends upon individual and group efforts to overcome specific problems, such as the lack of research infrastructure [1], the capacity to develop and invest in development [2] and other structural problems, associated with the particular geographic location selected for development [3].

Some essential oils disappeared from the commercial market for various reasons over the years. However this has created the opportunity to reintroduce them into commercial production. Chempaka concrete is once again on offer from China and Frangipanni absolute is on offer again from India. With support from various sections of essential oil consuming industries, the production levels of these types of essential oils is on the increase [4].

The trend towards the greater use of natural ingredients in the food industry brought many hopes of much greater demand for natural materials in food flavours. However, these suggestions made by industry experts in the 1990s did not significantly materialise [5]. Yet, a number of new crops that provide more cost effective sources of specific natural aroma chemicals have led to shifts in demand for some oils, for example the decline of *lemongrass* and almost total disappearance of *verbena oil*, in favour of *Litsea cubeba oil* over the last few decades.

The market for natural cosmetics, personal care and household products is increasing however the majority of products are formulated with synthetic materials. Flavour and fragrance ingredients must be able to handle harsh technical conditions *(i.e., high acidity/alkalinity)* in products. Many natural fragrances are difficult to stabilise within formulations, particularly in the household functional area. This leads to very stringent criteria in functional fragrance evaluation, which limits the utilisation of natural materials due to the above reasons. Although the use of natural materials in fragrances has declined in recent years in product application, aggregate demand is still growing for natural materials, because of natural market growth and the growing *"natural"* trend and new applications in agro-chemicals.

THE SCREENING PROCESS

After formulating a vision statement and determining the direction of focus, the screening process can commence. Most research projects commence with some sort of screening process, either formal or informal. The aim of this process is to develop a short list of probable crop candidates for closer evaluation. Only plants that have some realistic commercial potential should be included on the short list. This process involves simultaneous biological evaluation and development potential evaluation. Adequate time should be allocated for the screening process.

Whether the screening process is restricted to desktop evaluation or involves some preliminary field work will depend upon available time, information and resources available. Without a proper screening process there is risk that any future field research will be *ad hoc* and lead to an unmarketable product due to technical, resource and/or market reasons. Still today, many projects commence without any formal technical or market studies about crop feasibility [6].

The screening process corresponds to the product ideation process used in industrial and consumer product development [7]. The manufactured product development process requires the generation of ideas through *lateral idea* generation, which is very different from the agro based product development process, where possibilities are eliminated.

The evaluation of essential oil market potential is only part of the total screening process. The screening process must also take into account the limits imposed by the physical environment (climate, rainfall, soil, sunlight hours, soil type and pH, water holding capacity, drainage, topography, etc.) and production economies. All these factors must be considered simultaneously. Lack of appreciation of the interdependence between production and market development has led to many failures by new producers [8].

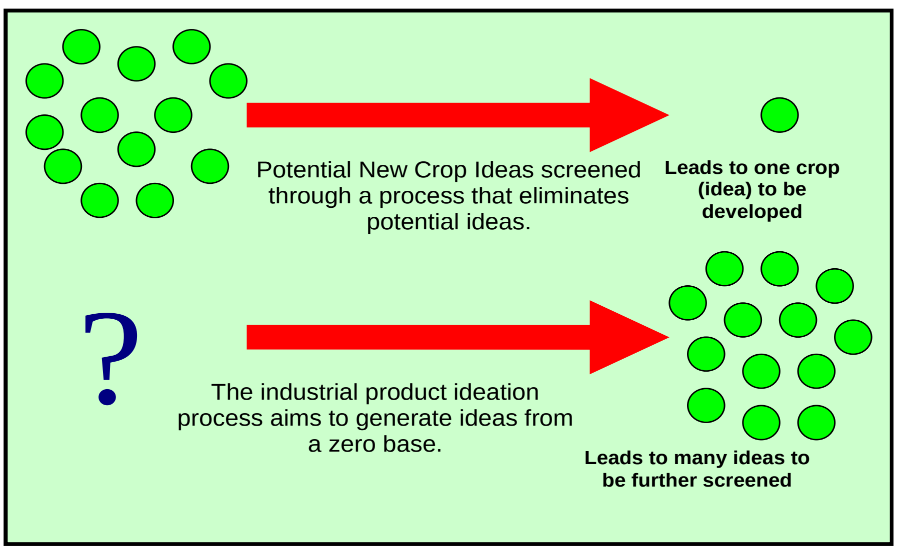

Figure 7.2. The differences in screening for essential oil development potential and the industrial new product development (Ideation) process.

Table 7.1. Comparison Factors between Potential Cultivation Site and Potential Crop

Actual Conditions	**Range of Possible Growing Conditions for Potential Crop**
• General climate	• Preferred climate(s)
• Range of micro-climates	• Preferred micro-climates
• Topography that influences micro-climates	• Preferred topography
• Rainfall range (access to irrigation)	• Preferred rainfall levels
• Temperature ranges	• Preferred temperature ranges
• Daylight hours	• Preferred daylight hours
• Soil types	• Preferred soil types
• Soil characteristics (pH, humus profile, soil layers, etc)	• Preferred soil characteristics

The process of screening aromatic plants for development potential is complex due to the multiplicity of issues – biological screening and development potential evaluation. All factors must be found to be compatible and potentially meet regulatory requirements, as the product must be able to achieve registration to be sold legally. Given that over 50 potential aromatic plants may be screened for potential, some system of handling the information in a manageable manner must be devised. The more ordered and systematic the system to handle the evaluation, the easier and more meaningful will be the process.

The first part of the screening process involves the creation of a list of crop possibilities that are both physically and market feasible. This infers converging knowledge in two areas; agronomic and market. This can be approached by generating a list of crops that can be commercially produced in the selected geographical area in question. A comparison between potential crops and the physical characteristics of the selected potential geographical area can be checked off using similar criteria listed in Table 7.1.

Direct comparisons between the physical conditions and potential plant suitability, will not always reveal all potential crops. Some crops cultivated in sub-tropical climates, may grow better in tropical climates, with more consistent weather and higher rainfall. There may be no data to support these possibilities and the exercise will rely upon experience, hunches and educated guesses. This was the case with Australian tea tree, originally cultivated in Central and Southern New South Wales, Australia. Trials in Northern Queensland, Australia, China and Malaysia found that the crop was not only adaptable to tropical climates, but produced more bio-mass leading to higher yields with a comparable oil quality to the original area of cultivation [9].

An alternative way to look for potential crops is to examine existing crops and plants already cultivated along similar latitudes, in the Southern and Northern Hemispheres. This way, possibilities can be looked at by region. This is also appropiate for specific geographic areas where the micro-climate may be similar to the climate at a different latitude, *i.e., at higher altitudes in tropical areas where temperatures are lower than the lowlands.* This is another good rough method of quickly creating a list of potential crops to examine. Figure 7.3. shows the 44° latitudes, North and South of the Equator. One we see that many essential oil crops currently cultivated in Tasmania and New Zealand are similar to those cultivated in Central Europe.

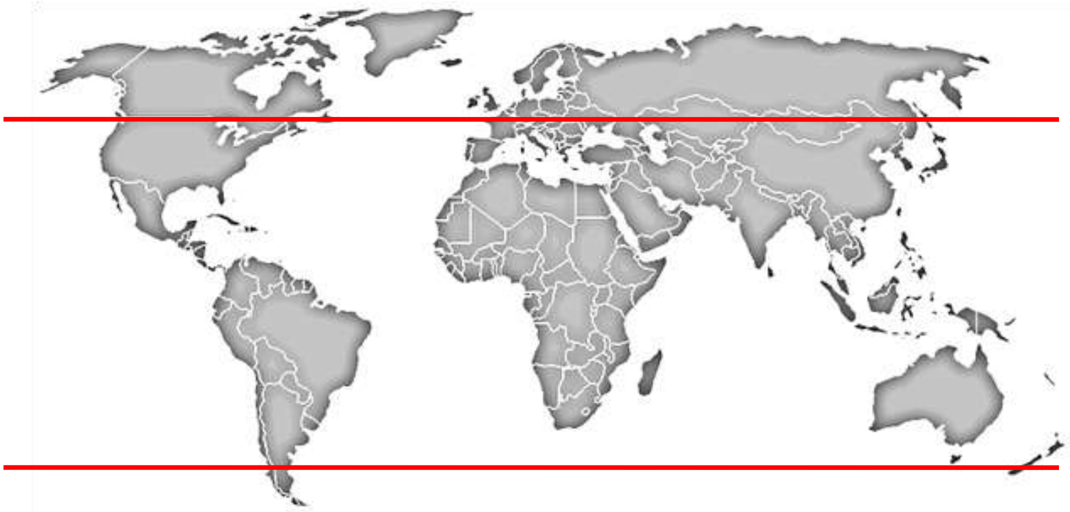

Figure 7.3. 44° Latitude lines North and South of the Equator.

Sources of Potential Plant Opportunity Identification

An active search for potential crops is the next step of the process. This can be achieved through field work (bio-prospecting) and/or a desktop search utilising existing published data.

Bio-Prospecting

The South-East Asia-Pacific region is abundant in flora where the majority of species are yet to be examined for their economic potential. In Malaysia alone, there are over 15,000 species of plants, of which only around 1,200 have been investigated [10]. On a global scale, of 350,000 known plant species, less than 0.5% of them have been chemically investigated [11]. Even with the flora that has already been investigated, much of the data recorded and reported lacks any economic evaluation. Many books containing flora references and catalogues may be out of print, which will require some time and effort in locating copies.

There are many approaches to bio-prospecting. Forest and jungle areas can be systematically and blanket searched, where all aromatic plants are investigated that the team comes across. This approach will be very time and resource consuming and may only lead to very long term results. Alternatively, plants with specific characteristics and properties identified in ethno-botanical literature are searched for in specific geographical locations in a bio-prospecting program.

Decisions have to be made about the scope of screening. Screening for multiple characteristics is very complex and will increase time and resources required. Potential screening protocols depending on the project focus. Some of these would include;

- The chemical constituents of the plant oil (leaves, flowers, roots, bark, fruits, seeds, etc.)
- Anti-microbial properties

- Anti-inflammatory properties
- Skin whitening properties
- UV absorbing properties
- Anti-age properties
- Flavour & fragrance application, and
- Aromatherapy application.

Desktop Studies

Potential new crops can be discovered through desktop studies. This requires a literature search through books, periodicals, journals and other monographs pertaining to essential oil crops. Studies would include studies of plants cultivated in similar latitudes. The aspects listed in Table 7.1. would be used to screen each potential possibility.

Through bio-prospecting and a desktop study a list of potential crops can be developed. The next step is to eliminate plants of little potential until a short list is obtained.

SCREENING FOR DEVELOPMENT POTENTIAL

The major question in screening for development potential is *"what value does the potential essential oil have for any industry?"* This question can be understood better, through evaluating each possibility with a series of sub-questions, answered with existing reported data on each essential oil. These questions would include; what are the chemical constituents? Are these chemical constituents similar to other oils? Is the odour profile of any value? Is this a similar odour profile to other oils?, etc. These questions and corresponding answers should provide some clue as to whether the essential oil is of interest and has any potential application in industry.

If there are some potential applications, the next set of questions would relate to potential yields and probable cost of development. If the reviewed essential oil is similar to something already existing commercially, then the questions will relate to relative yields, growth periods and percentage of valuable constituents in the oils. If the essential oil is novel and contains potentially valuable chemical constituents or interesting odour profile, what would be the potential yields? At this stage these estimates should be rough or very *'ball park'* based on what published data is available or through observation and sample distillations of the plant, extended out on a worksheet. A simple template can be used for manipulating very rough labour, operational and yield estimates. A sample template for this calculation is shown in Table 7.2.

Table 7.2. Worksheet for Rough Calculation of Financial Viability at Initial Screening Stage

1. Costs of Crop Domestication
○ Can they potential crop be domesticated into field production easily? • If not, will biomass be wild-collected? • What method would be most suitable for propagation, from seed, cuttings, tissue culture, other? • Does nursery propagation of the potential crop require any other special care? • What staffing will be required? • What would be the approximate costs of achieving the above?
2. Field Preparation and Infrastructure
• What overall infrastructure will be needed?, *i.e., nursery, road access, fencing, outbuildings, farming equipment, etc.* • What land preparation is needed, land levelling and contouring, drainage, etc. • Does the crop require large amounts of water to thrive during growth? • Is there adequate water available through rainfall to satisfy this? • Will irrigation be required? If so, what method? Will dams and catchment areas have to be constructed to ensure a plentiful water supply? • What will be the approximate costs of this? • Are there any other potential costs?
3. Planting and Maintenance
• Approximately how long will the crop take from field planting to harvest maturity? • How will the potential crop be planted?, manually/automated? What will be the costs involved? • What would the approximate planting density be? • Will nutrients have to be applied? If so, how regularly? How much? What method will be used to apply them? What will be the approximate costs of this? • How often are re-plantings required? After each harvest, after a number of seasons, after how many years, what are the costs involved to prepare for each re-planting?
4. Harvesting, Extraction and Post Extraction
• Is harvest timing crucial?, *i.e., a time of day, a very short window in a particular month, etc* • What are the costs involved in achieving this harvest window? • What method of harvest will be utilised? Manual, semi-mechanised, fully mechanised • What would be the approximate costs of building the harvest equipment? • What method of extraction will be required? Hydro-distillation, steam distillation, destructive distillation, vacuum distillation, solvent extraction, other • What power sources will be utilised? What are their costs? • How will spent biomass be dealt with? Does it have any economic value or can it be used back in the farming process? • Is the technology understood for the above processes? If not, what will be the costs of acquiring it? • What will be the fabrication costs to build the above?

• What regulations *(i.e., EPA)* are relevant to the processes? And how much will development and compliance cost? • Will specialist staff be required? • What would the approximate cost of energy to oil yield?
5. Estimated (guessed) Project Size and Yields
• How many hectares do you anticipate to cultivate? • How many years will it take to achieve this? • What (based on literature and other knowledge) would be the approximate biomass per hectare achievable? (min. and max. est.) • Does the biomass have to be wilted, stored or otherwise processed before extraction? • What would be the yield as a percentage of biomass after extraction?
6. Estimated Financial Viability
• 1. Research costs = • 2. Costs of crop domestication = • 3. Field preparation and infrastructure costs = • 4. Propagation, planting and maintenance costs = • 5. Harvesting, extraction & post extraction costs = • Total Capital Costs (1+3) = • Total operational costs (2+4+5) = • Total amount of oil yielded = • Total oil value = • Value – total operational costs = • Return/total capital costs x 100 = Return on investment

Notes: This is a rough estimate based on the whole project cost estimates. Alternatively this can be calculated on a hectare basis. Allowances must be made for varying yields on some crops (especially tree crops).

After u ndertaking the above exercise, some ideas on potential and critical issues should be understood and answered in some sort of preliminary manner. These issues are;

- Is there a match between chemical constituents and possible market uses?
- What is the application potential of the essential oil?
- What could be possible yields and cost of production?, and
- What would be the cost of development?

Issues pertaining to the screening process are shown in Figure 7.4. Determining the value of a potential essential oil is discussed in the next section.

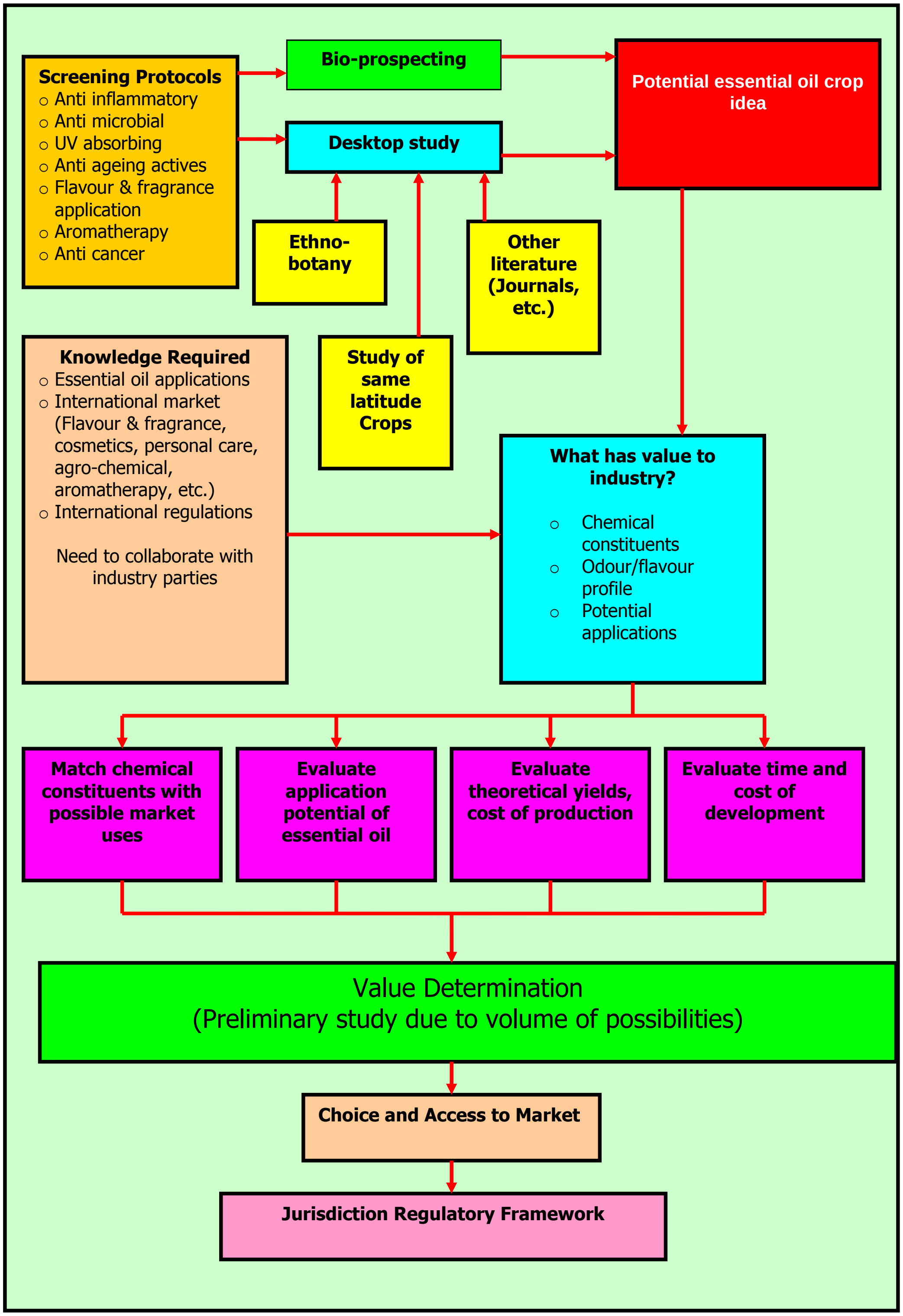

Figure 7.4. Issues Related to the Screening Process.

THE CHARACTERISTICS AND CLASSIFICATION OF ESSENTIAL OILS

Essential oils are considered commodities, but are by no means a homogeneous group of products. Trade statistics indicate the market size for many individual essential oils, but they may not be complete and thus of limited use in evaluating essential oil potential. To evaluate the commercial potential of new essential oils, a market orientation *(i.e., potential uses, characteristics, product strengths and weaknesses)* is required, rather than a commodity view of the essential oil trade. Some basic classification system is necessary to use as a tool for evaluating development potential and to indicate the types of business strategies required. A basic classification system is outlined in Table 7.3.

Group 1: The olfactory profiles of essential oils in this group are dominated by a single or few major constituents. The production of many essential oils in this group relies on high capital investment and mechanisation as the key to competitive advantage. The mint industry in the United States is a good example of this [12]. Other essential oil crops in this group are produced by small holders in developing countries. The small holder production sector has only survived because the cultivation of certain essential oils is not profitable in industrialised countries, full mechanisation is not possible, and cultivation of some plant species is only possible a few months each year [13]. The citronella industry in Indonesia is a good example of this [14]. Prices in this group of essential oils are kept relatively low due to the availability of substitutes (other essential oils and synthetic aroma chemicals) and competition between producers of the same crop in developing countries.

Group 2: Most essential oils in this group are produced by small holders in developing countries along the tropical latitudes. Some are produced on plantations, with low cost labour supply as a source of competitive advantage, but labour shortages due to rural/urban migration are beginning to erode many producers competitive positions [15]. Fluctuations in prices occur when there is a mismatch of supply and demand on the World market. Generally in times of supply shortages higher prices will encourage existing producers to increase production and marginal growers will be attracted back into production. High prices and shortages of essential oils in this group may not necessarily indicate potential opportunities to develop these essential oils in new geographical locations, as existing producer countries can easily increase production levels [16]. There are generally very low barriers to entry and exit to producers within this group. There are also few cost effective substitutes available to the flavour and fragrance industry in this group. This lack of close substitutes enables producers to gain slightly higher marginal returns for these oils compared to those in the first group [17]. However with rapid technology advances substitutes for these materials are becoming available.

Group 3: Essential oils in this group are primarily used in perfumery. These materials are valued for their depth, quality, complexity and richness in olfactory profile. Many of these materials are still traditionally cultivated [18]. However as production costs are rising in developed countries, the production of these materials is being encouraged in developing countries [19], often under the sponsorship and close working relationships with major European companies [20]. Generally these materials are becoming too expensive to use in functional perfumery, where reconstitutions and specialties have mostly replaced them [21]. Herbaceous oils are limited to minor use in flavour compounds [22]. Changing market trends have increased the application of some herbaceous oils in fragrance applications, but aggregate demand is not increasing above natural market growth.

Group 4: Essential oils in this group, like essential oils in group 3 are valued for their olfactory profile and are mainly traditionally produced, although some new ventures are utilising new technologies to enable competitive production. The availability of good reconstitutions of these materials has limited their use to fine perfumery applications.

Table 7.3. A Basic Essential Oil Classification Scheme

Group	Characteristics	Examples	Uses
1. Flavour/Odour profile due to one or few major constituents	• Usually high volume/low to medium value products. • Level of chemical constituents very important in trade • Synthetic aroma chemicals usually good substitutes	• Peppermint oil • Lemongrass oil • Some citrus oils • Eucalyptus oils • Clove oils	• Perfume and flavour compounds • Flavours where natural status is desired • Some citrus oils used for cleaning solvents • Isolation of natural aroma chemicals, eg. Eugenol from clove oil
2. Flavour/Odour profile due to one or a few major constituents and essential oil cannot be easily reconstituted	• -Usually medium to high volume, medium priced oils • Olfactory and flavour characteristics more important in purchase decisions • Difficult to reconstitute	• Vetiver oil • Sandalwood oil • Patchouli oil	• -Perfumery and flavour compounds (both functional and fine perfumery)
3. Character from main constituents, but richness and complexity from minor constituents	• Usually low volume/high priced oils • Olfactory characteristics important in	• Rose oil • Jasmine absolute • Many herb oils	• Fine perfumery, • Reconstitutions used for functional perfumes, • Limited flavour use,

	purchase decisions & pricing • In most cases these oils can be reconstituted efficiently		• Majority of herb oils used for flavours but beginning to be used for fragrances
4. None of the main constituents contribute decisively to the desired odour/flavour profile	• Usually low volume/high priced oils • Olfactory characteristics most important in purchase decisions • In most cases reconstitutions can be produced	• Mimosa absolute	• Fine perfumery (usually too expensive for functional products)

Essential oils in groups one and two tend to be traded like pseudo-commodities, but strong product differentiation, based on olfactory profiles is also an important purchasing criteria. Other industrial uses for many of these oils add to traded volumes. Essential oils in groups three and four are traded more like specialty and fine chemical products where olfactory quality plays a major role in price determination. Demand tends to be inelastic in the short term, as manufacturers are locked into using selected essential oils in the formulation of existing products. Past price trends and a poor supply history for some individual oils has encouraged the use of alternative materials in new products.

The above classification system can be used to generally identify essential oil use and trade characteristics. This establishes a structure from where further specific market analysis can be undertaken.

Evaluating the Characteristic Strengths and Weaknesses of Essential Oils

The market potential of a new essential oil for the flavour and fragrance industry depends upon potential flavour and fragrance applications. The scope of potential uses and applications directly corresponds to the characteristic strengths and weaknesses of the essential oil. After the objective identification of characteristic strengths and weaknesses, estimates of the essential oil's perceived value to potential end users can be made. The list in Table 7.4. provides a criterion to evaluate new essential oils.

Table 7.4. Characteristic Strength and Weakness Potential for an Essential Oil

Characteristic	Comments
The novelty of a new essential oil	The major factor determining the novelty is the perceived uniqueness of the essential oil's organoleptic profile. Thus, the degree of novelty is limited by the closeness of potential substitutes. The concept of novelty extends to essential oils that are more cost effective sources of natural aroma chemicals. New natural sources of aroma chemicals would also fit into this criteria of novelty.
The potential uses and applications of a new essential oil	Without perfumers and flavourists perceiving applications potential, a new essential oil will remain in the realm of curiosity. Time, effort and imagination on the part of perfumers and flavourists is required to discover useful applications for new essential oils. It is under this criteria that most new essential oils will struggle to find acceptance as a new aromatic material.
The closeness of any substitutes	It is difficult to find essential oils that cannot be duplicated by reconstitutions. New essential oils with close substitutes are of little value to the flavour and fragrance industry, unless they can offer a significant cost or stability advantage. The only exception is when a new essential oil is a source of a natural aroma material.
The stability of a new essential oil	One of the major problems associated with essential oils is stability in end products. Many processed food products undergo harsh cooking procedures during manufacture. Cosmetic bases often contain free fatty acids, even after neutralisation. Essential oils that contain high levels of terpenes, tend to polymerise on exposure to light and air, discolour end products or are not stable in alkaline or acidic media. Synthetic aroma chemicals and specialties are generally more stable than essential oils and used more extensively in functional perfumery.
The cost price/performance ratio	The cost price/performance ratio is important to the application potential of a new essential oil. If a new essential oil does not offer a perceptible odour/flavour at a low concentration, then its value to the flavour and fragrance industry is greatly diminished unless it is very cheap. Poor performance under this criteria will negate the potential of most new essential oils for application in functional perfumery.
The Toxicity	The cost of proving a new material is safe to use in flavours and fragrances is a major obstacle to the development of new aromatic materials. The industry has an impeccable reputation for self regulation and added EU regulations increases the cost of preparing dossiers on new materials even more. In markets outside the EU, most international flavour and fragrance houses would not consider using a new essential oil unless it meets IFRA safety and toxicity recommendations and is included on the GRAS list (mentioned in

	chapter two).
The general consistency of quality and supply	Natural material will vary in quality according to geographic origin, type of soil, level of nutrients in the soil, climate and weather, rainfall, time of harvest, season, method of extraction, altitude and the incidence of pests and diseases. Likewise there are risks with continual supply of natural materials because of adverse weather conditions, changes in climate, floods and other natural disasters, wars, political upheavals and the inexperience of new producers. Launching new consumer products require large investments on the part of the end product manufacturer. Flavour and fragrance houses do not want to be placed in a position of being unable to supply a manufacturer with a flavour or fragrance compound because of the unavailability of a raw material.
The prevailing market/product trends	Market and product trends slowly evolve. Changes in market trends are the result of complex forces, including technology, which makes new trends possible, advertising, and cultural influences upon consumer tastes and preferences. A particular essential oil may become more or less important to the flavour and fragrance industry, depending upon these trends.
The current level of technology	New technology advances influence the value of existing aromatic materials to the flavour and fragrance industry. The development of new essential oil reconstitutions are aimed at eliminating some of the potential toxicity and solubility problems of existing essential oils. Reconstitutions are generally more stable and cheaper than their more expensive natural counterparts. As better and more cost effective reconstitutions are developed in the future, the use of some essential oils will decline. Since the advent of more sophisticated analytical techniques, like GC-MS, headspace analysis, electronic noses, aroma chemical and specialty product manufacturers have been better able to isolate powerful aromatic molecules from essential oils and synthesise these compounds. The discovery of new aroma chemicals in essential oils due to increased equipment sensitivity is more likely to lead to synthesis rather than cultivation.

THE REGULATORY ENVIRONMENT

The third part of the screening process is concerned with evaluating the regulatory framework in potential markets to determine;

a) the limitations and restrictions on a product entering the marketplace,
b) the work and costs involved in meeting any required registrations or regulatory requirements, and

c) to determine whether the regulatory framework will be a barrier to deter development of a potential product.

The regulatory environment was introduced in chapter two. Each market is governed under different legal jurisdictions, which create differing levels of requirements (and costs) to satisfy in order for the product to be legally sold in the market. Generally regulatory frameworks cover three major aspects. These are, firstly the legal scenario for crude materials (chemicals), secondly the requirements for a finished (consumer or intermediate) product to be legally marketed in a market and third, the environment and related protocols a product must be manufactured under. The implications of all these issues will add time and cost to the development process, with respect to any targeted market. The development of an essential oil requires a lot of investigation as to what regulations must be met, what registrations must be sort and approved, what standards must be achieved and what certifications are important in trade. The required dossiers for product registration are considered one of the major deterrents to new essential oil development. This section will briefly outline relevant regulation and some of the important standards that needs consideration.

The European Market

Europe as a block represents almost 30% of total World consumption where the market is steadily growing around 8-10% per annum. The European Union is a major part of the European market and legally considered one market under one uniform jurisdiction. It has taken a number of years for the European Parliament and Council of Europe to develop a set of uniform codes and regulations. Each national authority carries out the work of the EU Authorities. All of these bodies are now fully operational and profoundly affect the legal status of products within the European Union market.

Food Additives and Flavour Materials

During the last few decades there have been a number of food scares in Europe – the safety of beef in the UK, dioxin contamination of food in Belgium and the debate on GM food – led to an undermining of public confidence in the food industry and enforcement authorities [23]. A white paper on food safety was commissioned by the European Council, which was released in June 2000, setting out a unified, coherent and proactive approach to food production, processing and supply chain management across the whole community.

This led to the enactment of the General Food Law and the setting up of the European Food Safety Authority (EFSA) to guide and administrate the law and recommend further directives and regulations in January 2002 [24]. The European Union laws were phased in, superseding all member state legislation and jurisdiction in January 2006. Now the whole European Union approaches food safety through three basic tenants; risk assessment, risk management and risk communication, in the concept known as the '*farm to folk'* approach. The effects of this approach is to provide a traceability framework throughout the whole supply chain, where any person supplied a food item or ingredient will be able to trace it back to its source of supply. This system is now mandatory for producers, manufacturers and importers. The three tenants of the General Food Law and the apparatus they employ in enforcement and operation is shown in Figure 7.5. From the point of view of an essential oil producer outside the EU, this implies the mandatory use of the *Hazard Analysis and Critical Control Points* (HACCP) framework, which will be discussed in more detail in chapter eleven.

The first directive on flavouring materials was enacted in 1988, which highlighted concerns about material purity criteria and procedures to be taken if a health risk was identified with any material. The directive also developed labelling requirements for natural and synthetic flavour substances, bringing rise to the term *'nature identical'* for synthetic flavour materials also found in nature [25]. Another important aspect of this directive arose out of a number of expressed opinions made by the Scientific Committee on Food on the toxicological consequences of natural materials from undesirable substances occurring in trace amounts, and their presence in food flavourings. This directive also created a positive list with restrictions on the dosage levels of certain materials to be observed in flavour manufacturing. Under the EU regulations flavouring substances are defined as chemical substances with flavouring properties [26]. The procedure for setting up the positive list began late last decade where each member state submitted a list of flavour materials used in their state, which would be compiled into a register of notified flavouring substances, where legal use in one state should be recognised in another member state [27]. Following on from this, an evaluation was to have been made of each material, based on priorities and be completed within five years. This positive list was supposed to become mandatory in 2005 [28], however delays and insufficient toxicity information according to the expert review panel delayed implementation [32]. Until the positive list is completed, existing member state regulations are still in force [29].

The European Chemicals Agency (EHCA)

On 18th December 2006 the European Council of Ministers adopted a new regulatory framework for the registrations, evaluation, authorisation and restriction of chemicals. This directive is known as REACH and was implemented to replace the separate regulatory systems of each respective member state [30]. The primary objective of REACH is to improve the protection of human health and the environment, while maintaining the competitiveness and enhancing the capability of the EU chemicals industry [31]. The REACH framework took many years to negotiate, develop and finally approve through the Council of Ministers and has been very heavily criticised by numerous groups. Some groups claim the new REACH regulations will actually stifle product innovation, rather than promote it [32].

Under the REACH regulation regime essential oils and other aromatic materials for fragrances, cosmetics, detergents and industrial cleaners are under its jurisdiction. Essential oils are only granted exemption under "naturals" in annex V if they are not classified and labelled under EU dangerous substances legislation. Essential oils for food and flavouring applications are exempted, as they are covered by European general food laws.

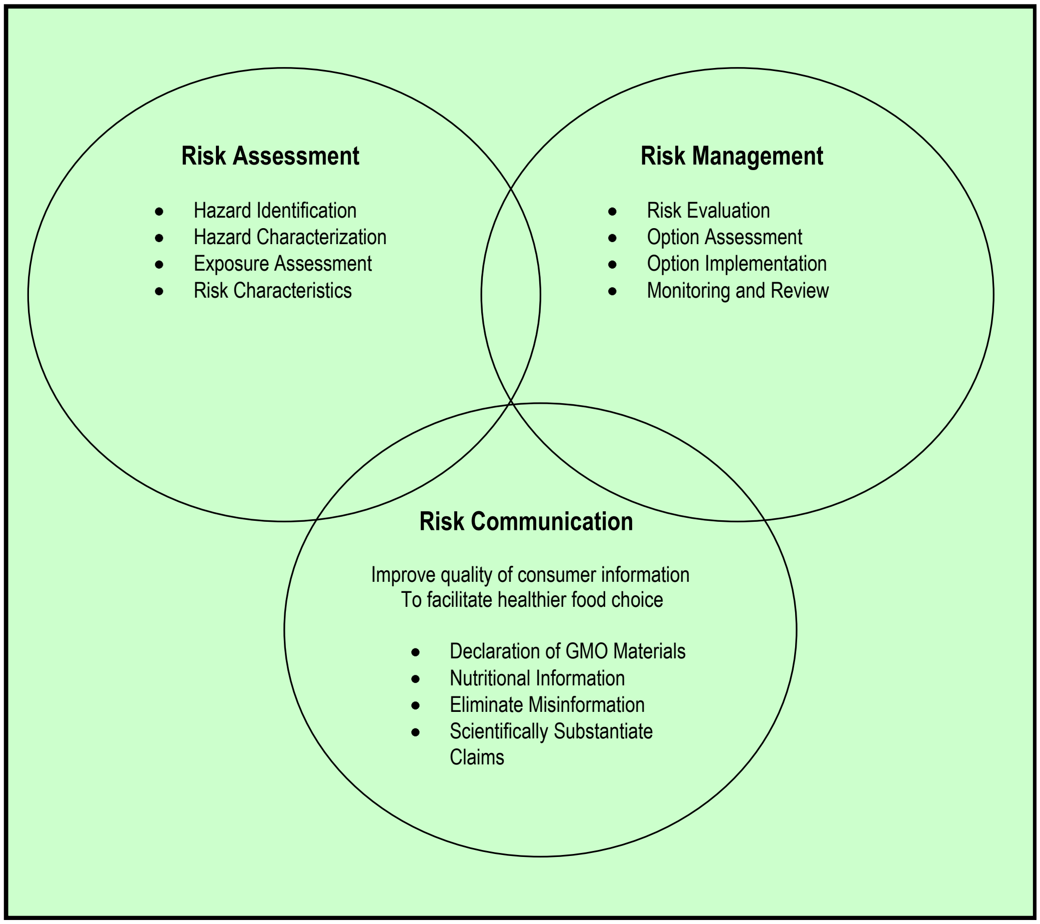

Figure 7.5. The Basic Tenants of the General Food Law.

On 1st June 2007 the European Chemical Agency (EHCA) was set up in Helsinki, Finland to administrate, recommend further improvements to the legislation, monitor and enforce the system. REACH requires the registration of chemicals that any EU enterprise manufactures or imports, in quantities over one tonne per annum. Firms are now responsible under a risk assessment and management framework approach to gather information on the properties of new substances, apply for use authorisation and act in accordance with the manufacturing and importing processes with the framework.

Under the agency's evaluation mandate, it is responsible for evaluating test protocol proposals made by industry and coordinating substance evaluation within the community. Risk concerning substances will be made the subject of agency authorisation for use by industry and subject to risk analysis, where it must be proved that the risks associated with use are adequately controlled or the socio-economic benefits of their use outweigh the risks. Certain materials which could be considered carcinogenic, mutagenic, toxic or adverse to the environment [33] need to be authorised for use. The agency will restrict the use of certain substances and require industry to develop specific risk management practices concerning the use of these substances and develop long term plans for the substitution of these materials with safer alternatives.

Table 7.5. Dossier Requirements for REACH Registration (from 1 Tonne to more than 100 tonnes per annum.)

Greater than 1 Tonne Per Annum	Greater than 10 Tonne Per Annum	Greater than 100 Tonne Per Annum
Melting/freezing point Boiling point Relative density Vapour pressure Surface tension Water solubility (or water extractivity for polymers) n-Octanol-water partition coefficient Flash point or flammability Explosivity Auto-flammability Oxidising properties Granulometry Skin irritation or corrosivity evaluation or *in vitro* tests Eye irritation evaluation or *in vitro* test Skin sensitisation evaluation or local lymph node assay Ames test *In vitro* chromosome aberration test Acute *Daphnia* toxicity Algal growth test Ready biodegradation	Light-stability for polymers Long-term extractivity for polymers Skin irritation (unless classified from Annex V data) Eye irritation (unless classified from Annex V data) *In vitro* gene mutation assay Acute oral toxicity Acute inhalation or dermal toxicity 28-day (or 90-day) repeat-dose study in the rat (normally oral exposure) Developmental toxicity screening study (OECD 421) Developmental toxicity study Toxicokinetics assessment (a prediction based on the available data) Acute fish toxicity Activated sludge respiration inhibition test Hydrolysis test Adsorption/desorption screening test	Stability in organic solvents and identification of degradants Dissociation constant Viscosity Reactivity to container material *In vitro* Mutagenicity studies 28-day or 90-day repeat-dose study in the rat (if not part of the Annex VI data) Developmental toxicity studies in two species (if not part of the Annex VI data) Two-generation fertility study in the rat (if there are adverse findings from the 28-day or 90-day studies) 21-day *Daphnia* reproduction study Chronic fish toxicity study Simulation test on the ultimate degradation in surface water Soil simulation test Sediment simulation test Fish bioaccumulation study (unless there is a low predicted bioaccumulation potential, e.g. from Log PoW < 3) Further adsorption/desorption study 14-day earthworm toxicity Study of the effects on soil micro-organisms Short-term toxicity to plants
	Plus requirements from left column (greater than 1 tonne)	Plus requirements from left columns (greater than one tonne plus greater than 10 tonnes)

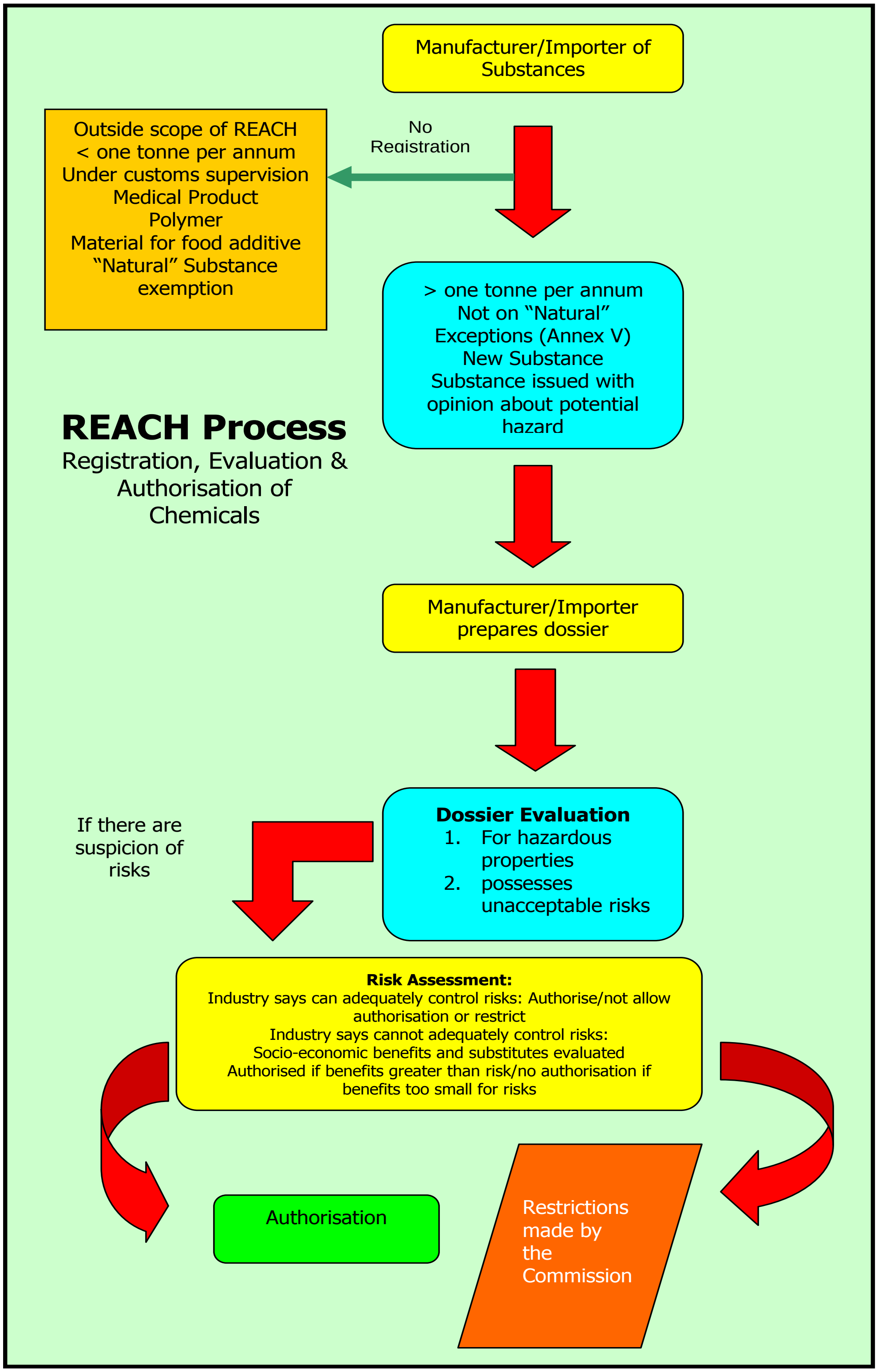

Figure 7.6. A summary of the REACH Registration Process.

Manufacturers and importers are required to submit a dossier of material information according to the level of use in the EU. Amounts under one tonne usage per annum are exempted, quantities between one and ten tonnes require sufficient information to assess the classification of the substance and guidance on usage (requirements listed in annex VI). Quantities above ten tonne per annum will require an additional dossier on chemical safety reports for substances produced or imported (requirements listed in annex VII). Quantities above One Hundred tonnes will require additional information (requirements in annex VII) and quantities above One Thousand tonnes more additional information (requirements in annex VIII). As a materials use grows above each threshold, additional information is required to be submitted to the agency, either as an individual firm or as an industry collaborative effort. The higher tonnage reporting requirements will be staggered in between 2007-2017 [34]. Tests undertaken for each dossier are required to be conducted under good laboratory practice (GLP) by nominated laboratories in the EU. The information required in each dossier is outlined in Table 7.5.

Failure to gain registration of essential oils by the set deadlines, *(all new essential oils require immediate registration through the system before entering the EU market, if quantities greater than one tonne),* will mean that the essential oil cannot be used within the EU. This has caused a lot of concern to individual producers over the issue of preparing the detailed information required before the commencement of enforcement dates. Costs for material tests and registration are in the majority of cases well above the ability of individual producers/importers to meet and there is much current discussion about how the industry can organise itself to share fairly these costs among all stakeholders. The costs for technical dossiers will cost anywhere up to USD 4.0 Million [35]. This in some cases makes costs of tests required for registration far in excess that the size of the market. A summary of the REACH registration process is shown in Figure 7.6.

Biocidal Products Directive

The Biocidal Products Directive (BPD) was first proposed in 1993 and approved by the European Parliament in 1998. It was enacted by the European Council a few months later and came into force in September 2000 [36]. The aim of the BPD is to remove trade barriers in biocides by developing a harmonised regulatory framework within the community and ensure a high level of health and environmental protection by controlling the supply and use of biocidal products. The legislation developed a risk assessment framework with a positive list of biocidal products that can be legally used within the community.

A biocidal product is defined as one or more active substances, itself or within a preparation of, one or more active substances in an aqueous solution, put into a form which they are supplied to the user. A biocidal product can be;

- one chemical compound with a well defined structure,
- a mixture by process of two or more chemical compounds,
- a UVCB-substance (substance with unknown or variable composition, complex reaction products or biological materials),
- micro-organisms, such as bacteria, fungi, or viruses, and

- extracts and oils of plants and micro-organisms, with a controlling effect on any harmful organism by chemical or biological means, intended to destroy, deter, render harmless, prevent the action of, or otherwise exert a controlling effect [37].

In effect biocides include all of the following types of products;

- human hygiene biocidal products,
- most types of disinfectants,
- veterinary hygiene biocidal products,
- preservatives,
- rodenticides,
- avicides,
- molluscicides,
- piscicides,
- insecticides and products to control arthropods,
- repellents and attractants,
- antifouling products, and
- embalming agents.

Excluded in the Biocidal Products Directive are plant protection products, medical devices, medicines, veterinary medicines, cosmetics and food additives.

The BPD is being brought in over a 10 year transition period which will end in mid 2010. This will enable each member state to work the BPD into their respective state regulations and establish an authority to carry out the directive. Each national authority will carry out the work of the directive;

- to evaluate applications for inclusion of active substances in the positive list in annex I,
- to evaluate applications for authorisation of biocidal products, and
- to enforce the biocidal products directive.

The development of a positive list of active substances is a high priority, so that substances of acceptable risk are available for use throughout the community, and substances of concern are identified and assessed [38]. Over this transition period substances will be assessed with priority for high volume and risk concern, so they can be confirmed on the positive list [39]. Member state authorities are presently able to authorise the use of substances on the positive list.

All new substances introduced into the EU market after 14th May 2000 must be registered and contain active ingredients listed in annex I of Directive 98/8/EC. A technical dossier is required to be submitted for each new substance to a national authority within the EU. A risk assessment will be carried out to determine human health and environment risk, where the substance and/or product will be categorised according to the following potential risk criteria;

1. The substance is of no immediate concern,
2. The substance is of concern, but further assessment will be deferred until the next tonnage threshold attainment,
3. The substance is of concern and further information is required immediately, and

4. The substance is of concern and recommended for risk reduction to be instituted immediately [40].

According to the European Chemical Agency (ECA) website, of over 1,000 applications for registration submitted, 52% were of no immediate concern, 37% required further information at the next tonnage threshold, 11% required further information, which were resolved satisfactorily, 10% unresolved and 11% were considered of concern and risk reduction measure required [41].

All data requirements for new substances are contained in annexes II, III and IV of Directive 98/8/EC. Annex part A is for individual active substances and part B for biocidal products containing them. A summary of the tests required for dossier submission are listed in Table 7.6. The approximate cost of preparing a dossier for registration is around USD 4.0 Million [42].

Table 7.6. List of Data Required for Biocidal Product Directive Registration

List of Data Required for Biocidal Product Directive Registration
1. General Information
• Substance identification (CAS, IUPAC, formula etc) • Substance information – colour, purity, physical properties • Spectra • Synonyms and trade names • Impurities • Additives • Quantity used in EU • Labelling • Hazard classification and labelling • Usage pattern – including application, types of use, volume per application, recovery, industry types • Manufacturing method • Existing exposure restriction and limits • Hazards • Degradation products
2. Physical and Chemical Properties
• MP • BP • VP • Viscosity • Density • Granulometry • Partition coefficient • Solubility in different media • Surface Tension • Flash point, flammability, explosivity • Oxidising properties • Dissociation constant

3. Environmental

Table 7.6. Continued

List of Data Required for Biocidal Product Directive Registration
• Photodegradation • Stability in water and soil • Monitoring data • Field studies • Transport between environmental compartments • Actual use degradation model • Biodegradation, BOD/COD • Bioaccumulation
4. Eco-Toxicity
• Acute toxicity to:- – Fish – Aquatic invertebrates – Aquatic plants (e.g. algae) – Micro-organisms • Chronic toxicity to:- – Fish – Aquatic invertebrates • Toxicity to:- – Sediment dwelling organisms – Terrestrial plants – Soil dwelling organisms – Other non mammalian terrestrial species • Biotransformation and Kinetics
5. Toxicity
• Acute oral • Acute inhalation • Acute dermal • Skin irritation • Eye irritation • Sensitisation • Repeat dose toxicity • Genetic toxicity in vitro • Genetic toxicity in vivo • Carcinogenicity • Toxicity to fertility • Developmental toxicity/teratogenicity • Exposure experience
6. Effect Against Target Organism
• Function • Effects on organisms to be controlled • Organisms to be protected • User

• Resistance

Scientific Committee on Consumer Products (SCCP)

The Scientific Committee on Consumer Products (SCCP), formally called the Scientific Committee on Consumer and Non Food Products (SCCNFP), is a committee made up of experts on toxicology from the medical profession, industry and institutes of higher learning, under the EU Health and Consumer Protection Directorate reporting to the EC Health and Consumer Products Scientific Steering Committee on matters relating to cosmetics and personal care products [43]. The SCCP was set up on EU Directive 76/768/EEC, amended with 93/65/EEC and 2003/15/EC, which deemed that cosmetic products must be safe for human health and the responsibility for this lies with the manufacturer or first importer.

The safety of cosmetics is taken through a risk assessment approach, where experts objectively quantify the probabilities and consequences of adverse health effects, based on assessing individual ingredient toxicity, allergenic and other risk probabilities to determine the impact and safety of a product on the consumer [44]. The SCCP/SCCNFP has provided a number of scientific opinions over a wide range of ingredients used in personal care, hair care and skincare products [45]. The onus and responsibility lies with manufacturers and importers to take consideration of general cosmetic material toxicity profiles, chemical structures and exposure risks in the products they manufacture or import.

There is no requirement for pre-registration of cosmetic products manufactured or imported into the EU. Article 7 of Directive 76/768/EEC requires only notification to the relevant member country authority at the place of manufacture or importation into the EU. The legislation restricts the ingredients that can be used in cosmetics through positive and negative lists under the directive;

- Annex II: lists substances that are prohibited for use in the composition of cosmetics,
- Annex III: lists substances which must be used according to the restrictions laid down in the list,
- Annex IV: is a positive list of cosmetic colourants permitted for use in cosmetics,
- Annex VI: is a positive list of preservatives that are permitted in cosmetics, and
- Annex VII: is a positive list of UV filters permitted in cosmetic products.

General cosmetic labelling requirements are listed in Article 6 of the directive and by any other directives provided in any of the other annexes. Products must be manufactured according to good manufacturing practice (GMP).

In order for a new cosmetic ingredient *(i.e., an essential oil)* to be legally used in the formulation of a cosmetic product in the EU, it must be on the positive list in annex III, IV, VI or VII. This requires a safety assessment process by one of the national enforcement bodies, under a similar process to REACH and BPD. A risk assessment dossier must be submitted with the following data obtained utilising specific test protocols specified in the directive as summarised in Table 7.7.

Table 7.7. Summary of Tests and Protocols Required under Directive 76/768/EEC

Data/Test Required	Protocol
1. General	
Nomenclature Purity Physical properties • MP • BP • Density • Rel. Vap. Dens • VP • **Log PoW** • **Solubility**	
2. Acute Toxicity	
Acute Oral Acute Dermal Acute Inhalation	OECD 425 OECD 402 OECD 403
3. Irritation/Corrosivity	
Skin Irritation Mucous Membrane Skin Sensitisation	Irritation: OECD 404 or OECD 431 (Episkin) Draize OECD 405 Murine Lymph assay OECD 429 or Guinea Pig OECD 406
4. Dermal/Percutaneous Absorption	
Dermal/Percutaneous Absorption	OECD 428
5. Repeat Dose Toxicity	
Repeat Dose oral/dermal/inhalation (28 day) Subchronic 90 day oral/dermal/inhalation Chronic (>12 months)	OECD 410 OECD 411 OECD 452
6. Toxicology and Carinogenicity	
Mutagenicity/Genotoxicity Carcinogenicity Reproductive Toxicity • Two Generation Reproduction Toxicity • Teratogenicity Toxicokinetics Photo induced Toxicity Phototoxicity Human Data	Ames OECD 453 OECD 416 OECD 414 3T3 NRU

The SCCP and Directive 76/768/EEC have been criticised on a number of issues. With risk assessment costs being around USD 2.5 Million per product [42], ingredients with very low aggregate demand will be eliminated from positive lists if challenged by opinion about risk by the expert committee. This has occurred with a number of essential oils including thirteen out of the top twenty essential oils produced worldwide today as listed in Table 7.8. Immense criticisms have been made by the industry about the scientific rationale of many committee decisions on natural materials that have been in use for hundreds of years without any apparent adverse human effects in the general population, which as a consequence may banish many long existing essential oils onto the negative list [46]. The cost of providing a technical dossier will deter essential oil producers introducing new essential oils in small quantities as cosmetic ingredients, thus inhibiting potential niche market opportunities in new essential oil development. Other concerns originate from members of the SCCP committee itself about alternatives to animal testing of new ingredients after 2009 when animal testing banned. With no suitable alternatives for certain test protocols, a ban on animal testing may compromise the assessment of human safety [47].

Table 7.8. Essential Oils within the top Twenty Produced Worldwide with Adverse Opinions made by the Expert Committee of the SCCP [48]

Essential Oil	**Botanical Name**	**Volume (Tonnes)**	**Under Threat from SCCP Opinion**
Orange	*Citrus sinensis*	26000	X
Cornmint	*Mentha Arvensis*	4300	
Eucalyptus	*Euc. globulus*	3728	X
Citronella	*Cym winterianus*	2830	X
Peppermint	*Mentha piperita*	2367	
Lemon	*Citrus limon*	2158	X
Euc. Citriodora	*Eucalyptus citriodora*	2092	X
Clove Leaf	*Syzygium aromaticum*	1915	X
Cedarwood (US)	*Juniperus virginiana*	1640	
Litsea cubeba	*Litsea cubeba*	1005	X
Sassafras (Brazil)	*Ocotea pretiosa*	1000	X
Lime	*Citrus aurantifolia*	973	X
Spearmint	*Mentha spicata*	851	
Cedarwood (China)	*Chamaecyparis funebris*	800	
Lavandin	*Lavandula intermedia*	768	X
Sassafras (China)	*Cinnamomum micranthum*	750	X
Camphor	*Cinnamomum camphora*	725	
Coriander	*Coriandrum sativum*	710	
Grapefruit	*Citrus paradis*	694	X
Patchouli	*Pogostemom cablin*	563	X

An EU commissioned report in 2004 [49] stated that the requirements of BPD registration is resulting in a rapid reduction of products on the market. The report also comments that increased costs in inputs due to the cost requirements of REACH registration will drive up material costs, lesson the choice of materials available for cosmetic product formulation and generally lower the level of innovation in the industry.

The EU legislative environment is still in a period of upheaval in the transition from individual member state jurisdiction to uniform EU jurisdiction. Until this is completed over the next decade, a number of anomalies will exist. Germany, Italy, Spain and the Netherlands still have their own specific positive lists for flavour materials, Spain and Belgium require pre-registration of cosmetic products before they enter the market and the UK requires pre-registration of laundry detergents [50]. Further restrictions in chemical use in biocides, flavours, food additives and cosmetics should be expected and some redefinitions of terms that will affect labeling requirements will no doubt be enacted with legislative amendments. The most profound impact of the EU regulatory framework are the requirements for handling of chemicals and goods through the supply chain. Other jurisdictions are also following and implementing these concepts. To comply with EU regulations, small producers have to implement procedures like HACCP.

The United States

The United States is the largest market in North America, representing approximately 26% of world trade. Canada and Mexico make up another 4%, making to North American market of comparable in size to the European market. The industry until the 1980s was almost completely self regulated. Cosmetic products did not require pre-registration and manufacture under Good Manufacturing Practice (GMP) before the 1980s.

Flavours and Food Additives

Flavour regulation in the United States is based on safety appreciation, history of prior use, manufacturer determination and voluntary notification. Flavours fall under the definition of food additives and are governed under the Federal Food, Drug and Cosmetic Act, through the food additives Amendment 1958. The act is administrated and enforced by the US Food and Drug Administration (FDA) with industry peak body cooperation.

In 1959, the FDA acknowledged that food additives with long prior use in food preparations had enough scientific evidence to deem them generally regarded as safe to use. These items were placed on a positive list of food additives which could be used in the manufacture of food items without pre-market evaluation or registration. The list known as the GRAS list [51] is supervised by the flavors expert panel (FEXPAN), comprising of scientific experts from various related disciplines. In 1969 a directive from then President Nixon required the FDA to work through the Gras list to reaffirm safety. This study reaffirmed most ingredients, with 6% given conditional use and around 8% judged to have insufficient data to make a determination [52]. In 1997 a notification scheme was proposed, which lead to a voluntary scheme of GRAS notification by manufacturers to the FDA.

The historical evolution of US food regulation has led to three methods of deeming a flavour additive safe to use;

1. The FDA states that not all food additives that are generally regarded as safe are on the GRAS list [53]. Consequently, any food additive that was in use before 6th September 1958 is deemed generally regarded as safe, unless otherwise proven not to be the case and has been omitted by specific regulation. This is affirmed by FDA Regulation 12 CFR 182.1 where it states a substance is still considered as generally regarded as safe if it is not on the list but widespread and long established community use has proven the substance to be safe.
2. A manufacturer makes its own determination and use a food additive without making any notification to the FDA, as the notification scheme is voluntary [54]. However industry self regulation through the Flavor Extract Manufacturers' Association (FEMA) [55] does not allow individual members to use materials outside the GRAS list. FEMA also issues an additional list with many more materials which is accepted by the US FDA as generally regarded as safe [56].
3. A manufacturer may inform the FDA of a self determination that the use of a substance is generally regarded as safe. This is submitted through what is termed a "GRAS Notice" which claims exception from the list. The "GRAS Notice" would contain a description of the substance, the intended use, the chemical properties and the reasons why it is GRAS through any scientific data [57]. Submitting the "GRAS Notice" does not prevent the product entering the market, as it is not subject to any legal requirement to await a ruling.

Ingredients used in food preparations for which producers and manufacturers wish to make claims (e.g. Dietary supplements) requires specific registration under section 21 (s) of the Federal Food, Drug and Cosmetic Act.

New substances require a safety evaluation through the expert committee supported by published and unpublished data. Listing is based on the opinions of the committee and no specific tests and data have been specified. Decisions in the past have been made on varying scope of toxicological data and it is the committee's decision on what specific data is required case by case [58]. The FEMA GRAS list, now in its 23rd update is the more active list, where addition to this list would allow US and many other international companies favourably consider the use of a new essential oil in the compounding of flavour materials. FEMA reviews of new materials are becoming more stringent, appearing to benchmark their reviews to the EU regulations, as there is ambition to develop this list as internationally acceptable in other jurisdictions [59].

Fragrance Ingredients and Cosmetics

The responsibility for regulating fragrance ingredients falls under the jurisdiction of the US Food and Drug Administration (FDA) under the Food, Drugs and Cosmetics Act. Fragrance ingredients are not regulated directly and defined as cosmetic ingredients, which do not require any formal safety testing or registration before entering the market. The only legal restriction is a small number of banned materials. The safety of fragrance ingredients lies with manufacturers, supported by surveillance from the FDA, which primarily relies on reports and complaints by consumers to open up investigations.

The fragrance industry in the United States has developed a system of self regulation administered by the Fragrance Materials Association of the United States (FMA). The FMA is linked with a number of other organizations and has adopted a similar system of placing fragrance materials which are regarded as safe on a positive list, known as the FMA Fragrance Ingredient Database (jointly with RIFM) [60]. Scientific contribution to the database comes from the Research Institute for Fragrance Materials (RIFM) set up in 1966 [61]. Most major fragrance manufacturers, through their national organizations are obligated to only use raw material deemed safe by RIFM and follow the code of industry practice developed by the International Fragrance Association (IFRA) [62].

The success of fragrance self regulation in the United States is claimed to be very effective by the Fragrance Manufacturers' Association (FMA), which on its website claims there are fewer complaints about fragrances to the FDA that many other FDA regulated ingredients [63]. However, other claims have been made that complaints about adverse effects from fragrance are on the increase [64] and some consumer groups are critical of the fragrance industry's self regulation citing that non compulsory disclosure is potentially compromising for health [65]. Commenting on the effect of regulation in the United States, Allen Osbiston in his article *"Living with Regulation"* used an example of an old chypre perfume, where today only 6 out of 22 ingredients would be able to be used without restrictions [66].

The FDA takes more direct responsibility for ingredients and materials that are used in products with claims attached. This is the case with aromatherapy products and essential oils where manufacturers would claim that they are soothing, relaxing, etc. If statements make any claims about diagnosis, treatment, mitigation, or prevention of disease, etc, they will be considered drugs under the legislation and require pre-registration before being put into the market. Judgments are made by the FDA on a case by case basis [67] and they will also have to meet requirement about claims governed by the Federal Trade Commission [68]. Consumer products incorporating essential oils will also have to meet US Consumer Product Safety Commission guidelines [69] and Environmental Protection Authority (EPA) guidelines [70]. Also under US EPA jurisdiction all ingredients in pesticide registration are revealed on a voluntary basis under an agreement between the FMA and EPA for the purpose of evaluating potential allergenic issues under the Pesticide Fragrance Notification Pilot Program which commenced in April 2007 [71].

The US cosmetic industry is also self regulated with the Cosmetic Toiletry and Fragrance Association (CTFA) representing manufacturers in the industry [72]. The CTFA also conducts material testing to determine safety and allergenic effects. There is no pre-market requirement to register a cosmetic product, but a voluntary cosmetic registration program (VCRP) exists as a post market reporting system by manufacturers, packers and distributors of cosmetic products [73]. The FDA specifies labeling requirements where ingredients are required to be disclosed in descending order of volume in the product [74]. The FDA investigates potential safety issues, primarily through consumer complaints, although it also has the power to inspect products and manufacturing premises without notice and the recall of products from the market.

Pesticides and Biocidal Products

The United States Environmental Protection Agency (US EPA) is responsible for the control of pesticides. Under US legislation the term pesticides include insecticides, fungicides, rodentcides, insect repellents, weed killers, antimicrobials and swimming pool chemicals which are designed to prevent, destroy, repel or reduce pests of any sort [75]. Bio-pesticides are divided into three groups;

1. Microbial pesticides consisting of microorganisms as the active ingredient,
2. Plant-Incorporated-Protectants (PIPs) derived from pesticidal substances that plants produce from genetic material that has been added to the plant, and
3. Biochemical pesticides that are derived from naturally occurring substances that control pests by non-toxic mechanisms.

Because of the difficulty in determining what product is a biopesticide, a committee makes case by case decisions [76].

The US EPA requires all pesticides before entering the market to be pre-registered with the authority. The US EPA will review the product to determine that it will not have a detrimental effect on human health and the environment. The US EPA will also set tolerances on products used in producing food in regards to allowed residuals [77]. This process requires a variety of studies related to toxicity, biodegradability, etc, as part of the risk assessment process. Some pesticides are exempt from this review to set tolerance limits within the registration process, where the exemption is found to be safe. Once the US EPA has made a determination, it will license or register the product for use in accordance with the schedule of labeling requirements.

FDA Globalization Act of 2008

In April 2008, the U.S. House of Representatives released a discussion draft of the Food and Drug Administration Globalization Act of 2008. The proposed legislation addresses the safety of food, drugs, devices and cosmetics. The draft proposes a number of proposals, which include;

- An annual subscription fee of USD 2000 for any food and cosmetic facilities within the US, or exporting food to the U.S,
- A voluntary FDA certification program
- A two yearly inspection of both domestic and foreign food establishments, if not certified,
- Labelling that identifies the country of origin of food, drugs and devices,
- Labelling that identifies food treated with carbon monoxide,
- A registration fee to cover drug and device inspections,
- An adverse event reporting requirement for cosmetics, and
- Some additional registration, re-inspection, certification, certifying agent accreditation, laboratory accreditation, export certification and importer registration.

The new registration fees are expected to collect more than USD 600 Million per annum and there are also substantial fines for violations of the new requirements. Although the proposed legislation may be modified and amended before being passed into law, there is widespread criticism of the bill on the grounds that the USD 2000 subscription fee does not discriminate between small and large companies and many home based, part time and hobby businesses will suffer badly under these proposals [78].

Japan

Japan represents approximately 10% of the world market and has the following regulatory framework for flavours, fragrances, cosmetics and pesticides.

Food Additives and Flavours

Japanese food regulations are based on the Food Sanitation Law which was enacted in 1947 and administrated by the Ministry of Health, Labour and Welfare [79]. Flavour materials are classified as food additives in article 4.4. The ministry regulates the use of flavour materials through a positive list which permits the use of materials in food products. A specific list exists for natural flavour materials [80] not deemed injurious to human health and an additional list provides broad chemical groupings from which chemical substances can be used in food production [81]. Article 10 states that no person shall use materials outside the list which is based on opinion of the Pharmaceutical Affairs and Food Sanitation Council. In 1994 the ministry formed a committee to develop and discuss food additive monographs and another committee to prepare and compile a specification of food additive standards. The 7th edition was published in 2000 [82]. Substances placed on the positive list have expanded greatly in recent years with the Ministry of Health, Labour and Welfares collaboration with US FDA, Enterprise Directorate of the European Union and Health Canada [83] to harmonize lists. Under article 27, those who wish to import food additives into Japan must obtain prior approval. This is done through an online system called the Food Automated Import Notification and Inspection Network System (FAINS) [84], set up in 2003.

Fragrance Ingredients and Cosmetics

Legal requirements for cosmetics and fragrance materials fall under the Pharmaceutical Affairs Law (PAL), administrated and enforced by the Ministry of Health, Labour and Welfare, which was first enacted in 1943 and subsequently amended in 1948, 1960 and in 1971 [85]. In 2001, the regulatory framework governing cosmetics and fragrance materials was totally overhauled. The Regulatory framework has changed from one of requiring pre-registration and a positive list of materials manufacturers and importers can use to abolition of the requirement to pre-register cosmetics and the use of prohibitive ingredient lists and a requirement to disclose ingredients on labeling.

The Pharmaceutical Affairs Law defines three classes of products;

- Cosmetics as *'products (other than quasi-drugs) designated to be applied to the body by rubbing, spraying or other similar applications with the aim of cleansing, beautifying or making it more attractive or modifying its appearance and of maintaining the skin and hair in good condition, to the extent that the action of the product on the human body remains moderate'*, which includes perfumes,
- Quasi-drugs as products defined with a fixed purpose of use and have a mild effect on the body but are intended for use in diagnosis, cure or prevention of disease or to affect the structure or function of the body. This would include deodorants, hair tonics, conditioners, mouthwashes, insect repellents, etc. and
- Drugs as items recognized in the Japanese Pharmacopoeia [86] and items not included in cosmetics and quasi drugs intend to affect the structure and function of the body of man or animals, which are not equipment or instruments [87].

For cosmetics, manufacturers and importers are only required to notify the Ministry of the brand name prior to market. Products must adhere to ingredients contained in a;

- List of prohibited ingredients,
- List of restricted ingredients,
- List of allowable UV ingredients,
- List of allowable preservatives, and
- List of allowable colour additives [88].

All manufacturers must be licensed under the Pharmaceutical and Food Safety Bureau (PFSB) [89] but good manufacturing practice (GMP) is not mandatory, although the Japanese Cosmetic Industry Association (JCIA) has a code of practice which has absorbed the major elements of GMP within it, where all members adhere [90].

Quasi-drugs and drugs are subject to pre-market registration and a review process under the Pharmaceutical and Medical Devices Agency (PMDA) [91]. This process evaluates all ingredients contained within the formulation which includes specified active ingredients, product usage and dosage levels, indications and effects required and a number of prescribed safety, toxicity and efficacy tests [92]. The Ministry has a prohibited list of substances but these are not fully published. However lists have been fully published for ingredients for use in certain categories like hair dyes. For quasi drugs only ingredients specified by the Ministry must be on the label with specific warning statements. When a fragrance compound contains a designated compound, it must be labelled.

Like the E.U. and the U.S., the objective of the regulation revamp is to put the responsibility for cosmetic and fragrance safety on the manufacturers and importers. It is a mandatory requirement that manufacturers and importers check the safety of their products before placing them in the market.

Table 7.9. Tests and Results Required for Registration of an Agricultural Chemical in Japan

Tests and Results Required for Registration of an Agricultural Chemical in Japan
1. Study Results of Efficacy
• Study results of efficacy on the indicated diseases and pests
2. Study Results of Phototoxicity
• Phytotoxicity of the applied crops • Phytotoxicity on the surrounding crops • Phytotoxicity on the succeeding crops
3. Study Results of Toxicity
a. Acute Toxicity Studies • Acute oral toxicity study • Acute dermal toxicity study • Acute inhalation toxicity study • Skin irritation study • Eye irritation study • Skin sensitization study • Acute neurotoxicity study • Acute delayed neurotoxicity study b. Study on mid-and-long-term effects • 90-day repeated oral toxicity study • 21-day repeated dermal toxicity test • 90-day repeated inhalation toxicity study • Repeated oral neurotoxicity study • 28-day repeated dose delayed neurotoxicity study • 1-year repeated oral toxicity study • Carcinogenicity study • Reproduction toxicity study • Teratogenicity study • Mutagenicity study c. Studies that are informative in considering the treatment of acute intoxication • Pharmacology study d. Studies that are informative in understanding agricultural chemical metabolic pathway in animals and plants and the structures of metabolites • T Studies of metabolic fate in animals • Study of plant metabolism e. Studies of Environmental Effects • Study of soil metabolism • Study of water metabolism • Study of effects on aquatic organisms • Study of effects on beneficial organisms other than aquatic organisms • Study of physical characteristics, stability, and degradability for active ingredients • Study of water pollution • Study of derivation of predicted environmental concentration
4. Residue Studies
• Study of residue in crops • Study of residue in soil

The Agricultural Chemicals Regulation Law

The Agricultural Chemicals Regulation Law was first enacted in 1948 and last amended in March 2007 [93]. The purpose of this law is to improve the quality of agricultural chemicals and to ensure their proper use. This law sets out a registration process administrated by the Ministry of Agriculture through the Agricultural Chemicals Inspection Station [94] for fungicides, insecticides, and other substances to control nematodes, mites, insects and rodents or other plants and animals or viruses that may damage crops. It also includes growth macerators and germination suppressants used to promote or suppress the physiological functions of crops [95].

Manufacturers and importers of agricultural chemicals are required to register agricultural chemicals under the law. Registrations must be accompanied by data and results to confirm the safety and efficacy of the products as outlined in Table 7.9 [96]. Tests must be carried out according to OECD-GLP standards. Under a risk evaluation and management framework, the Ministry will review the chemical according to a set of Nationally Accepted standards on crop and soil residues, food residues, and harm to humans, livestock and aquatic organism due to water pollution. These are called the “Standards for Withholding Registration”.

The Chemical Substances Control Law

The Chemical Substances Control Law was enacted in 1973 and further enhanced in 1986 and 2003. The objective of this law is to control the manufacture and import of chemical substances in Japan which may pose safety, toxicity and other hazardous risks. However at this point of time food additives, cleaning products under the Food Sanitation Laws, Agricultural chemicals under the Agricultural Chemicals Regulations Law, fertilizers and medical drugs and cosmetics under the Pharmaceutical Affairs Law are exempt and subject to their respective existing laws [97].

Australia and New Zealand

Australia and New Zealand make up a small percentage of total world market. Their regulatory systems have separately developed over the last 20 years, sharing some similarities with other systems.

Food Standards Australia New Zealand (FSANZ)

In the mid 1990s the Australian and the various state Governments with the New Zealand Government committed to developing a uniform food standards code. This was adopted in 2000, with a two year transition period and the commencement of operations of an independent statutory body called Food Standards Australia New Zealand on 1st July 2002 [98], replacing the Australia New Zealand Food Authority. The authority was mandated to develop the safer supply of food and ensure consumers become well informed about choices and nutrition, operate a joint code of practice in collaboration with industry, control the content of food labeling in Australia and New Zealand, determine maximum agricultural and veterinary drug residues in food through risk assessment and management, coordinate food surveillance and recall systems and support the Australian Quarantine and Inspection Service in the control of imported foods [99]. Australian and New Zealand companies are legally obligated to comply with the food standards regulations [100], which are under the Foods Standards Australia New Zealand Act 1991. Australia and New Zealand are not totally integrated as New Zealand operates its own Food Safety Standards [101].

Under the Australia New Zealand Food Standards Code flavours are covered under the general standard on food additives [102]. Standard 1.3.1. Schedule 5 defines a flavouring as *'intense preparations which are added to foods to impart taste and/or odour, which are used in small amounts and not intended to be consumed alone, but do not include herbs, spices and substances which have an exclusively sweet, sour or salt taste"* [103].The various types of materials defined by the technological functions they perform in food products are in three classes, flavouring, flavour enhancers and flavour modifiers. Permitted flavour materials in foods are on a positive list which includes any item listed in;

- *Food Technology*, a publication of the Institute of Food Technologists,
- Generally Regarded as Safe *(GRAS)* lists of flavouring substances published by the Flavour and Extract Manufacturers' Association of the United States from 1960 to 2005,
- *Chemically-defined flvouring substances* of the Council of Europe 2003,
- *United States Code of Federal Regulations*, 1962, 21 CFR Part 172.515 or
- A substance that is a single chemical entity obtained by physical, microbiological, enzymatic, synthetic or chemical processes, from material of vegetable or animal origin either in its raw state or after processing by traditional preparation process drying, roasting and fermentation [104].

The Flavour and Fragrance Association of Australia New Zealand (FFAANZ) has published a compiled list of artificial flavouring substances allowed to assist manufacturers comply.

Standard 1.3.1. further specifies the maximum allowable levels of food additives in schedule 1, item 0.1 [105]. Another list prescribes flavouring materials from plants and fungi which are prohibited, unless exempted under Standard 1.4.4. [106]. Under standard 1.3.4., specifications are provided for purity of food additives and maximum levels of contaminants and toxicants allowable [107]. Essential oils must also meet specified ISO/Australian standards set down, pharmacopoeia or with supplemental testing criteria. Under Clause 10 of Standard 1.3.3. [108], flavours sold to industry are generally treated as processing agents as they don't perform any technological function and usually present as a constituent in the final product in trace amounts and as such [109], individual ingredients don't have to be listed unless otherwise directed. GMP certification in food manufacturing and processing is mandatory in Australia and New Zealand.

The National Industrial Chemicals Assessment Scheme (NICNAS)

Cosmetic products and essential oils [110] for uses other than Food, medicines, veterinary chemicals and pesticides, fall under the jurisdiction of the National Industrial Chemicals Assessment Scheme (NICNAS). NICNAS operates under the Commonwealth Industrial Chemicals (Notification and Assessment) Act. 1989 and regulations 1990, to provide for the notification and assessment of chemicals for their potential effects on occupational health and safety, human health safety and environmental impact before their import or manufacture in Australia [111].

New chemicals require approval for use in cosmetics and a wide range of other applications. Any chemical not listed on the Australian Inventory of Chemical Substances (AICS) [112], which includes chemicals in use in Australia between 1st December 1977 and 16th July 1990, is deemed a new chemical and required to be assessed before it can be imported or manufactured in Australia and added to the list, after an interim period of five years. This includes chemicals forming part of a finished product such as a cosmetic, unless it is under 1% of the total formula and not considered hazardous. Varying levels of documentation are required depending on how much is sold and the perceived safety risk by NICNAS [113]. Risk assessment and testing costs could range between a couple of Thousand to Hundreds of Thousands of Australian Dollars [114]. NICNAS also continues to reassess chemicals on the AICS list on a priority basis from community, industry or agency concern. All importers and manufacturers of chemicals are required to register their company with NICNAS as an importer or manufacturer [115]. There is also a requirement on importers and manufacturers importing chemicals into Australia under exemptions [116], to submit an annual report to NICNAS.

At the time of writing, the Therapeutic Goods Administration (TGA) [117] currently regulates a number of cosmetics that are defined for therapeutic use;

- Anti-acne products
- Antibacterial skin products
- Antidandruff products
- Antiperspirants
- Moisturisers with secondary SPF 4-15 inclusive, and
- Sunscreen products SPF <4.

However under legislative changes, responsibility for regulation of these items will fall under NICNAS, with other changes to cosmetic regulations [118]. These also include taking over control of cosmetic claims guidelines from the TGA [119], although the Trade Practices (Consumer Product Information Standards) (Cosmetics) Regulations 1991 [120], requiring full cosmetic ingredient disclosure on labeling and labeling statements will remain in force. The Therapeutic Goods Agency will still maintain responsibility for medicinal products, including herbal medicines with essential oils, under complementary medicines requiring pre-registration [121]. On 18th July 2007, the New Zealand Government postponed its agreement to proceed with legislation to enable the establishment of a joint Australian New Zealand agency for the regulation of therapeutic products, due to inability to pass it through the parliament [122], thus Medsafe will continue to regulate cosmetics with secondary therapeutic uses and herbal remedies through a pre-registration process [132].

In New Zealand, chemical substances are assessed under the Hazardous Substances and New Organisms (HSNO) Act 1996, which carries out evaluation, assessment and registration of new chemicals [124]. This agency has grouped all substances together which were previously managed under separate legislation as toxic substances Act, Pesticides Act and Dangerous Goods Act.

The National Registration Scheme – Australian Pesticides and Veterinary Medicines Authority

The National Registration Scheme operates under the Agricultural and Veterinary Chemicals (Administration) Act 1992 and is administrated and enforced by the Australian Pesticides and Veterinary Medicines Authority (APVMA). Any chemical products or any substance or organism used to destroy, stupefy, repel, inhibit the feeding of, or prevent pests on plants or other things, destroy a plant or to modify its physiology, modify the effect of another agricultural chemical product or attract a pest for the purpose of destroying it, must be registered before entering the market [125]. This includes all herbicides, insecticides and fungicides. Insect repellents for use on humans, disinfectants, household insecticides, home garden products and rodenticides are also required to be registered under this authority. Before or at the same time, registration of the active ingredient must also be undertaken with safety and risk assessment information supplied to the authority [126]. A number of essential oils are exempt from active ingredient registration [127] and only product registration is required. A varying level of tests are required depending upon the nature of the product, the quality of scientific data and comments and consultations from manufacturers [128]. These ingredients must adhere to set down standards [129] and quality assurance scheme, which commenced 1st May 2007 [130].

Essential oils are also subject to a number of other legislative mechanisms in Australia. These include the National Poisons Schedules where any essential oil scheduled as a poison must be clearly labeled as such, according to the regulations [131]. Manufacturers and essential oil producers must comply with respective State Environment Protection Authorities guidelines on waste effluents. Essential oils must comply with hazardous goods regulations in transit [132] and storage under various State Occupational Health and Safety legislation [133].

New Zealand pesticide registration jurisdiction is currently in the process of transferring from the Pesticides Board to the Hazardous substances and New Organisms Authority, where procedures at the time of writing were only in draft form [134].

The ASEAN Region

The ASEAN region accounts for approximately 10% of the World market in its own right. Many domestic markets of member countries are rapidly growing in consumer sophistication and overall aggregate demand. They are in transition from less developed economies to developing economies or from developing economies to developed status. Viewing the regulatory framework from outside may give the impression that the region is beginning to act as a single block and developing harmonized and uniform frameworks as the

ASEAN Food Safety Network would suggest. However this body is only a consultative one focusing on sharing information, rather than attempting to create uniformity in member states regulations [135]. Developing uniform regulatory regime like the EU or Australia and New Zealand may be some time off as individual Governments are more focused on their own national issues. In addition, administrative structures are very different, markets are diverse and still have a large indigenous product profile, each member varies greatly in their stage of development and the overall confidence to develop and implement and enforce a uniform system is currently beyond existing operational competencies [136].

Indonesia

In Indonesia, all food, medicines, cosmetics and household products imported or manufactured in the country must be registered with the Agency for Drugs and Food (Badan Pengawas Obat dan Makanan: BPOM) [137], before entering the market. The agency requires extremely detailed information on product formula, manufacturing processes and material specifications. This has led many foreign manufacturers to by-pass the Indonesian market [138]. However, local companies are required to make applications for registration and are in most cases able to "*practically work through this barrier".* The agency also controls labeling and makes its own investigations of food, drug and cosmetic ingredients already used in the marketplace and from time to time issues prohibitive directives on these matters. According to Iwan Darmansjah in the Jakarta Post, the BPOM is not well organized and lacked enough qualified and experienced professionals to operate effectively [139]. There are pending directives to simplify many BPOM procedures, but at the time of writing these have not been approved.

Government decree No. 7/1973 was the original legislation which set up controls over the distribution, storage and use of pesticides in Indonesia. Under this and subsequent decrees, all pesticides for commercial distribution, sale and use must be registered with the Ministry of Agriculture. The registration review is undertaken by the Pesticides Committee, made up of representatives of relevant Government Ministries, who review applications on the basis of;

- Physical and chemical properties,
- Use,
- Environmental toxicity,
- Efficacy and phytotoxicity,
- Resistance and resurgence data,
- Residual data,
- Packaging and labeling,
- Disposal procedures,
- Existing foreign registrations, and
- Applicant biodata [140].

Applications will either be rejected or granted trial, temporary or permanent clearance for either restricted or general use. Active ingredients must not be on a Ministry prohibitive list. The Ministry also practices surveillance of pesticides through market compliance visits and analysis of residuals in soil, vegetables, rice and other foods to try and check the rampant use of unregistered pesticides in the country [141].

Malaysia

All pre-packaged foods on sale in Malaysia are subject to the control of the Food Act 1983 (Act 281 of the Laws of Malaysia) and the Food Regulations 1985. The main aim of these regulations is to ensure the safety of food on sale in Malaysia. This is administrated by the Food Safety Information System of Malaysia, operated by the Food Quality and Safety Division, under the Ministry of Health [142]. Under Part 5, Section 19 of the Food Regulation flavours are defined as food additives [143]. Schedule 8 of the regulations list prohibited flavouring substances and schedule 14 specifies the maximum permitted contaminant levels for flavouring substances. Good manufacturing practice (GMP) is mandatory and Hazard Analysis and Critical Control Point (HACCP) is being developed on a voluntary basis [144]. The Ministry practices vigorous market and manufacturing premises surveillance to monitor and enforce food safety.

All pharmaceutical, health and dietary supplements, traditional medicines and cosmetics are regulated by the National Pharmaceutical Control Bureau (NPCB) [145], under the Ministry of health. Under regulation 7 (1) (a) of the Control of Drugs and Cosmetics Regulations 1984 [146], all products must be registered with the Drug Control Authority (DCA), operating under the NPCB before being imported, manufactured, sold or supplied, unless they are exempted by specific provisions of the regulations [147]. A product is defined as a drug in a pharmaceutical dosage form, or a cosmetic, having a singular identity, composition, characteristics or origin. Dietary supplements fall under this definition rather than food because it is intended to prevent, cure, treat or reduce illness.

Assessment is made on the basis of safety to the public, quality and compliance with good manufacturing practices (GMP), conformity to standards and quality, claims and efficacy. The regulations also require the licensing of manufacturing forms. It is expected that in 2008, essential oils and aromatherapy products require notification to the authority under new regulations [148].

Pesticides are regulated under the Pesticides Act 1974 (Act 149 of the laws of Malaysia, amended 2004), administrated by the Department of Agriculture, which assesses and registers pesticides before they are marketed in Malaysia, under the Pesticides Control Division [149]. Active substances are also evaluated according an environmental, health and efficacy assessment. Presently, the pesticides Control Board is a small organization responsible for both agricultural and household pesticide registration and enforcement is limited with existing staffing. Like Indonesia, Malaysia also has many issues with high pesticide residuals in foods and has adopted a plan to improve the situation with the Ministry of Environment [150].

Thailand

The office of Food and Drug Administration under the Ministry of Public Health is responsible for regulatory control over food and drugs [151]. The FDA's role is to ensure that health products including food, drugs, cosmetics, medicines, narcotic substances and household hazardous substances in the market are safe, effective and of reliable quality. The FDA administrates and enforces the Drug Act 1987, the Food Act 1979, the Cosmetic Act 1992, the Narcotic Control Act 1987, the Psychotropic Substances Act 1992, the Volatile Substances Act 1990 and the Medical Devices Act 1988 through both pre and post market requirements on manufacturers and importers.

Food products are classified under four classes, a) specialty controlled foods, b) quality and standard controlled foods, c) labeling controlled foods, and d) general foods. The first three classifications require pre-market product registration and the fourth category does not require pre-registration but must conform to set quality standards and labeling requirements [152]. Flavours are considered specialty controlled food items and therefore require pre-registration. The Food Act also requires registration of food manufacturers and importers and good manufacturing practice (GMP). The National Bureau of Agricultural Commodity and Foods Standards (ACFS) is the body responsible for developing standards for agricultural commodities and food products, including food additives [153] and acts as an accrediting body for inspections and standard adherence certifications [154]. The food regulations although clear, are often criticized for inconsistent application in practice by different interpretations of bureaucrats and local officials. Close relationships between manufacturers and importers and officials seems to be able to take account and rectify these issues [155]. The Thai authorities are currently investing great amount of resources in capacity building in the area of safety assessment [156].

Cosmetics are administrated by the Cosmetics Control Group of the FDA. Cosmetics are classified into three categories, a) controlled cosmetics, b) specialty controlled cosmetics according to the ingredients used and c) general cosmetics. Controlled cosmetics require full registration whereas specialty controlled cosmetics utilizing controlled ingredients require notification to the FDA before entering the market. General cosmetics not utilizing any controlled substances on the list do not require registration or notification but are subject to market surveillance and monitoring [157]. Cosmetic ingredients are placed on one of five schedules which include a) prohibited substances, b) specialty controlled substances, c) controlled substances, d) permitted colourants and e) permitted preservatives. These lists form the basis of how a new cosmetic product will be treated for registration and control purposes [158].

Products which have pharmaceutical characteristics such as the ability to alter the functions and structure of the human body or is presented to the market as a pharmaceutical product is outside the scope of the cosmetics regulations and is subject to regulation as a drug. Under the Cosmetic Act, manufacturers and importers must be registered with the FDA and operate under good manufacturing practice (GMP) standards.

Pesticides, rodenticides, insecticides and household products are subject to the Toxic Substance Act 1867, amended in 1973 [159]. The Act was further widened to include a large number of hazardous industrial substances in 1992. Due to the wide scope of the classified hazardous chemicals three separate Ministries enforce the regulations in their respective areas, Ministry of Industry, Ministry of Agriculture and Cooperatives and the Ministry of Public Health. The type of product determines the control procedures as to whether a product should be either, notified to the authority, registered or licensed. Various levels of requirements for registration exist in assessing quality, efficacy and toxicity. General applications require details of active ingredient, chemical and physical properties, raw material quality, details of finished product, physical and chemical properties, efficacy, toxicity data, manufacturing processes and labeling information [160]. Licensing is also required in some cases of importers, manufacturing sites, storage sites to control potential health and environmental hazards [161]. The Department of Agriculture maintains a positive list of permissible pesticide active ingredients which have been recommended to the Ministry by the Pesticides Standards Committee [162]. GMP is required for hazardous chemical manufacture and codes of conduct for pest control operations. Continued surveillance is undertaken under an Adverse Product Reactions Program (APR) [163]. Thailand is perhaps leading the region in its extension efforts to reduce the use of pesticides in agriculture through the implementation of good agriculture practices (GAP) and sustainable farming methods.

Vietnam

The Vietnam Food Administration is responsible for regulating food in Vietnam [164], which operates under the Ordinance on Food and Hygiene and Safety, Order No. 20/2003/L-CTN of 7th August 2003 [165], coordinating a number of previous ordinances into a single code. The ordinance covers food hygiene, safety and quality, labeling and advertising, as well as the introduction of new food items into Vietnam. All companies producing, manufacturing or importing food into Vietnam are subject to the food ordinance. Under Article 3.7. food additives are not clearly defined, but Article 15 provides for a positive list of flavour materials that are permitted in the manufacture of food products. All food additives must be listed on food labels, but the term “flavour” can be used with words “natural” or “artificial”. New food additives must have prior approval by the Ministry of Health before they can be utilized in the manufacture of food. Prior to the new Food Ordinance in 2003, all food had to be pre-registered with the Ministry. However the new Food Ordinance puts the onus back on manufacturers and importers to comply with *‘industry’* or FAO standards [166] and are subject to inspections by the Ministry for compliance.

Cosmetics and beauty products are administrated under Order No. 35/2006/QD-BYT, 10th November 2006 [167], which specifies products must be pre-registered with the Ministry of Health for quality assurance and identification purposes. Cosmetics includes all substances and manufactured preparations used for direct application to external areas of the human body or to the teeth, gums or lining of the mouth for the purpose of cleaning, perfuming, changing appearance and body odour, or preserving or maintaining the body in good condition. This definition covers perfumes and fragrances [168]. Cosmetics must be manufactured from materials within the appendixes and annexes of standards complying with the ASEAN Harmonized Cosmetic Regulatory Scheme [169].

The Ordinance on Pesticide Management No. 58/2002ND-CP of 3rd June 2002 regulates the procedures of pesticide registration in Vietnam. Pesticides include herbicides, rodenticides, fungicides, plant growth regulators, insect attractants and repellents. This decree is administrated by the Ministry of Agriculture and Rural Development (MARD). Pesticides are registered according to active ingredients not being on a prohibited list, based on recommendations of an Advisory Committee for Pesticides. A technical dossier of safety, efficacy, environmental information is required with the application for registration. Under Decision No. 50/QD-BNN-BVTV all pesticides must be retested in Vietnam for residuals under local conditions [170]. Although the new ordinances seek to ‘deregulate’ and place more onus on manufacturers and importers, many companies talk of the cumbersome paperwork and bureaucratic systems involved with product registration in Vietnam, which requires the assistance of local personnel to navigate through successfully.

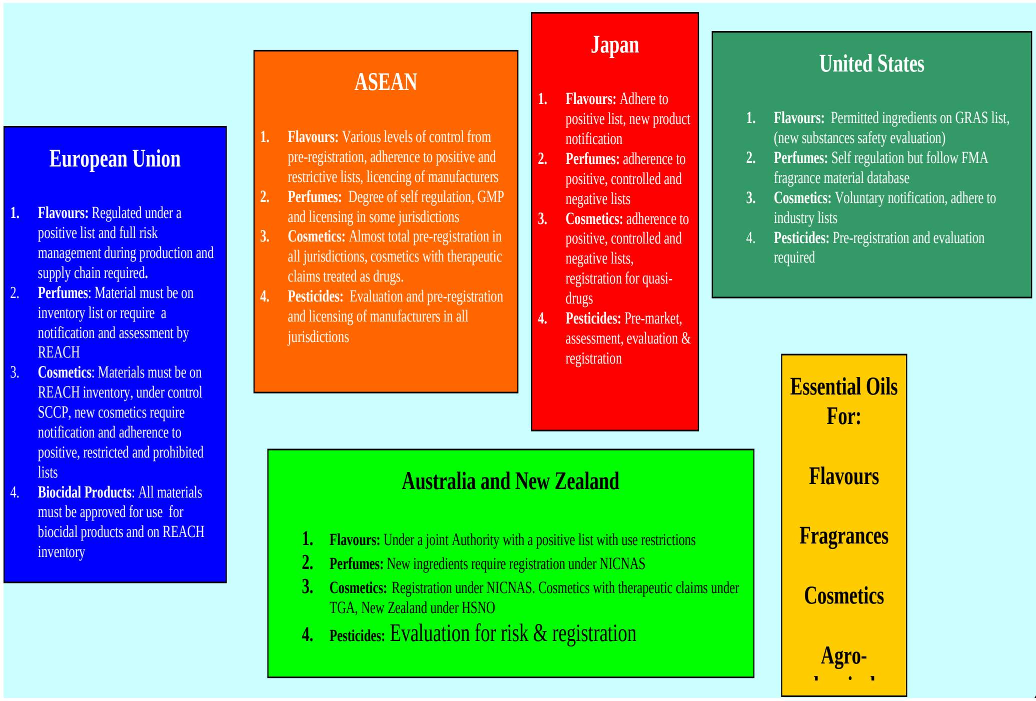

Figure 7.7. Summary of the International Regulatory Process.

The Philippines

The Bureau of Food and Drugs (BFAD) within the Ministry of Health is responsible for the administration of all locally produced, manufactured and imported food, cosmetics, drugs and hazardous substances. The Food, Drug and Cosmetic Act (Republic Act 3720), amended by Executive Order No. 175, with a number of Administrative orders lays down rules and regulations governing the above classes of products in the Philippines [171].

All food locally manufactured or imported into the Philippines must be registered with BFAD before it can enter the market. Under Section 10.2.b. of the Act, food additives are defined as *"any substance the intended use results or may reasonably be expected to result, directly or indirectly, in its becoming a component or otherwise affecting the characteristics of any food."* The section further states that any food additive should be generally recognized among qualified experts as safe, through accepted scientific procedures under the conditions of intended use. This includes flavour materials which must be on a positive list, specifying permissible materials and dosage levels, which must also conform to the CODEX Alimentarius [172] and/or the Philippine or the Pharmacopoeia standards, as specified under Executive Order 302, in 2004 [173].

All cosmetic products must be registered with BFAD before entering the market. Those cosmetics making claims must also provide efficacy information [174]. Cosmetics are defined under Section 10.h. of the Food, Drug and Cosmetic Act as any articles intended to be rubbed, poured, sprinkled, or sprayed on, introduced into, or otherwise applied to the human body or any part thereof for cleansing, beautifying, promoting attractiveness, or altering the appearance. All cosmetic products must be manufactured according to specified standards under good manufacturing practice (GMP). BFAD has issued a number of material lists which manufacturers and importers must ensure their products adhere to under Bureau Circular No. 19-A, of 1997 [175];

a. List of substances which cosmetics must not contain, except according to restrictions,
b. List of preservatives which cosmetics may contain subject to restrictions,
c. List of preservatives provisionally allowed,
d. Non-permissible colours in cosmetics,
e. Permissible colour additives, with specified restrictions,
f. List of provisionally allowed colours in cosmetics,
g. List of sunscreen agents which cosmetics may contain,
h. List of sunscreen agents which cosmetics may provisionally contain, and
i. List of substances which must not form part of the composition of cosmetic products.

The Bureau of Food and Drugs is also implementing the ASEAN Cosmetic Directive, which manufacturers and products must also conform [176].

Presidential Decree No. 881 puts responsibility for the management of hazardous substances under the Food, Drug and Cosmetic Act (Republic Act 3720), in relation to household goods [177]. Products requiring registration include, lighter fluids, paints, solvents, adhesives, polishes and waxes, cleaners and detergents, glues and inks, fertilizers, pesticides and air fresheners [178].

Pesticides are under the responsibility of the Fertilizer and Pesticide Authority (FPA) [179], which was established under Presidential Decree No. 1144 [180]. Manufacturers of pesticides must be registered with the FDA, which must be a Philippine incorporated company [181]. Pesticides include,

a. Agriculture, home and garden use,
b. Household use,
c. Other chemical pesticides,
d. Biochemical pesticides based on natural products, and
e. Microbial pest control agents.

Product licenses are granted as a full for conditional use [182]. The active ingredient must also be registered and not be on the prohibited list [183]. Applications for registration must include physical and chemical specifications, bio-efficacy, toxicological, human safety, environmental effect, residues in food data, along with the proposed label and manufacturing process flowcharts [184]. The Authority carries out post market surveillance and compliance activities.

The Philippine regulatory process is continually changing with new regulations concerning food, drug, cosmetics, hazardous household chemicals and pesticides and requires thorough checking of the latest changes before product registrations are made.

Consequences for Screening by the International Regulatory Framework

The international regulatory framework in the EU, the United States, Australia, New Zealand and South-East Asian countries has made the international regulation one of the prime considerations in essential oil screening. Not only are there consequences for potential new essential oils, but a number of existing essential oils are also potentially threatened, unless changes are made to the EU framework on existing items of trade, like the *'grandfather'* provisions of US FDA regulation. This is totally unforeseen at this stage. The international regulatory framework is a large barrier to any individual producer and producer associations around the world have not at this point of time been able to develop effective strategies to convey their points of view to the regulators. The effects of the international regulatory framework on existing and new producers include;

- A number of existing essential oils are currently under risk assessment threat, which will put restrictions upon cosmetic labeling unless risk assessment dossiers are submitted, and the data provided satisfies the committee on risk. Many essential oils with constituents named in EU Directive 2003/15/EC of 23rd February 2003 do not have a strong financially backed industry body to defend the concerns. If the SCCP issues an opinion detrimental to their status, this will decrease dramatically or even shut out access to approximately 30% of the world market. If the FMA and FEMA adopt similar scrutiny in their quest to follow European risk assessment standards, much more of the world market will become inaccessible to a number of essential oils. The effect of this could be in the worst case scenario, to put a number of existing essential oil producers out of business.
- The high cost of producing data to submit a risk assessment dossier will in many cases to too high to justify investing in the studies for potential new and emerging essential oils. Very few individual producers will have the financial backing to make such investment.
- Even if a producer makes the investment to undertake the tests to produce a risk assessment dossier, without some form of IP protection, other potential producers will be free to enter the market without having to make the investment in a risk assessment dossier. This is a large deterrent to individual producers or even small countries to develop new essential oils.
- The new international regulatory framework dramatically increases the costs of producing essential oils through the requirements to commission tests for risk assessment dossiers and the requirement to implement hazard management systems like HACCP.
- Essential oil users will be very hesitant or even totally uninterested to consider any new flavour and fragrance ingredients, cosmetic or biocidal materials knowing the costs involved in meeting regulatory requirements.
- Independent producers will have to either collaborate an EU based company to produce and submit risk assessment dossiers and register products under the BPD, which will limit freedom of choice by companies outside the EU as to which companies they deal with.

The effects arising from the developing international regulatory environment will force existing and potential essential oil producers to develop innovative ways to deal with the regulatory challenges outlined above;

- Producers and potential producers of essential oils and other natural products will have to be well aware of the international regulatory framework and allied risk and hazard assessment frameworks to survive and succeed.
- Existing essential oil production will have to implement risk and hazard assessment protocols and new essential oil producers must factor in these systems and costs from the outset.
- Essential oil producers will need to collaborate and possibly give monopoly distribution rights to major companies dealing in essential oils, in order to enter the market in any sizable manner with medium to large volumes.
- Producers can be highly selective about what essential oils, what volumes and what markets they supply, thus employing “niche market” strategies through boutique production, supplying quantities to the EU under the one tonne per annum threshold required for notification and/or supply very selectively small to medium customers in specific applications in other markets.
- Producers can opt to produce natural aroma chemicals as isolates of essential oils that already exist on positive lists from essential oils.

To this point, the book has outlined the background and dynamics of the essential oil industry and basic technical and scientific issues relating to essential oils. Chapter 6 laid a foundation as to where a potential producer may wish to position themselves within the industry and this chapter canvassed the issues involved in screening for potential essential oils to develop. The next two chapters will concern itself with the project planning and field development aspects.

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Chapter 8

THE DEVELOPMENT PLANNING PROCESS

An enterprise can develop a viable and promising product only to find through lack of planning and oversights, that some critical issues have been overlooked. This can lead to higher than expected production costs, longer development time and even failure to meet the original objectives. Planning is a necessary function in developing an essential oil production enterprise. It is necessary to understand all the issues involved before making any final commitments in the field. Planning also applies to the market and supply chain strategies proposed for the product when it is developed. This chapter will consider the pre-field planning process and the market and supply chain strategy development process.

INTRODUCTION

The screening process has enabled an examination of what flora it is biologically possible to develop, along with some indication of commercial potential and an understanding of the relevant regulatory jurisdictions surrounding the potential crop. The screening process flows onto the development planning process which acts as a further screening process to critically evaluate the technical and market feasibility of the essential oil. The process also examines the technical, market issues and challenges ahead that the physical development process at field level will need to contend with for successful development.

The screening process to date should have provided the following information and knowledge, which will act as the basis for further investigation and consideration;

1. A single or few potential crops that are potentially worth developing based on climatic and market suitability,
2. Some idea of what type or specific development work must be carried out to commercialise the crop,
3. Knowledge of the regulatory situation involving the potential crop, its requirements, timeframe and costs, and
4. An indication of what competencies are required to carry out the development project.

The above information and knowledge is the starting point of an environmental analysis, an evaluation of capabilities, resources, skills, knowledge and technology (competencies) required and a market analysis. This investigation should lead to;

a) A strategic business plan,
b) A physical and field development plan, and
c) Knowledge of what competencies are required and/or what disciplines will be most relied upon in the development and operational phases.

The above provides a complete framework for the commercialisation process along a path that becomes a project plan with milestones to monitor progress. Potential obstacles and challenges have been identified and planned for with some understanding of the risks involved.

ENVIRONMENTAL ANALYSIS

There are very few specifically designed strategic analysis and planning models for agricultural enterprises. Most are micro-economic models which have severe limitations in being applied to specific enterprises. Those involved in new and existing agricultural ventures usually utilise existing business analysis models in use by the general business community. Moreover, the use of strategic agro-business analysis and planning is really only a recent phenomenon in agricultural disciplines. Agricultural planning generally focused upon technical development issues, which was considered one of the major key success factors [1]. Further, existing strategic analysis models are limited in their application to SMEs. SMEs have specific start-up and growth problems, not well accommodated through existing strategic plan models [2]. A growing body of researchers have recognised the need to utilise different analytic tools in recognition of these differences [3].

The aim of any environmental analysis to create some understanding of the general competitive environment and in particular, the dynamics of the market where the venture intends to enter. Before we can identify any potential key success factors to build a strategy upon, the current market dynamics must be understood. Market dynamics are the current driving forces or factors that generate change and opportunities within a market [4]. The key is to identify these changes, value their importance and influence potential opportunity and then develop the enterprise in way that keeps others from successfully competing with you – competitive advantage [5].

Many models exist for examining industry structure, but Michael Porter's *Five Factor Competitive Forces Model* allows both separate examination of each competitive factor and combining them together to see their collective effect on a product/industry [6]. This is advantageous as different factors will vary in their relative importance according to the product, reflecting different sources of market dynamics. Utilising Porter's model takes the analysis of the market for the potential essential oil away from mere reliance on trade and market statistics and recognises that each essential oil is a separate market, as opposed to the whole industry, where industry market dynamics are too general.

The individual force factors in the model can be summarised as follows;

1. Rivalry Among Competitors

Rivalry among firms in the same product/market requires the utilisation of various techniques and tactics to gain customer loyalty and sales, which affects other businesses in the market. The main factors to consider in examining rivalry among competitors are price, customer approach, orientation and service, product quality attributes, delivery and credit and product innovation through specialised fractions, grades and certifications.

One must be aware that producers in countries like China have been historically very aggressive in promoting their products through state-owned or subsidised producers. Sometimes prices can drop for long periods of time where price bears little relationship to the cost of production, thereby driving out of the market producers in other countries [7]. In addition, some essential oils for aromatherapy or pharmaceutical application are being supplied by large producers to international retail chains in large volumes at prices well below market prices, which effectively puts downward pressure on the rest of the marketplace.

Many businesses have developed long term relationships with customers where new entrants to the market may find a very difficult barrier to overcome. Some companies have chosen to exclusively supply some customers or fulfil demand in particular 'niche' markets, which they understand well. They may have developed a very pro-active marketing network which causes a certain degree of closure of the supply chain to outside producers. This will vary in influence and effect according to the particular essential oil and type of customers. The supplier relationship coupled with specific odour or flavour attributes of the essential oil already being supplied will put the onus on the new producer to produce an almost perfect substitute to have any chance of being considered as an alternative supplier. With environmental factors like climate and soil having great influence upon final product quality attributes, it becomes very difficult for a new supplier to exactly match the odour/flavour profile of a competitor's oil.

Another trend in the market, particularly for high volume oils, is the supplying of bulk oil on consignment to major customers, where they pay for only what they use, usually on a monthly basis. This strategy greatly favours large and 'cashed up' producers. Over the last decade this method of consignment stock holding by customers is becoming widely accepted as something standard in the industry.

A number of essential oils are differentiated through specific certifications such as 'organic', 'wild collected', 'fairtrade', 'kosher', 'halal', 'pharmaceutical grade' (GMP), etc. Some oils are fractionated to produce valuable derivates like terpeneless oils, terpenes or natural aroma chemicals, like eugenol from clove oil, etc., to enable them to offer a specialty and differentiated product.

The importance of each factor will depend upon the market of the particular essential oil being studied. However generally speaking, essential oils that require large economies of scale in production, where the flavour/dour profile is either due to one or a few chemical constituents or a few major constituents *(i.e., group 1 & 2 of Table 7.3. in chapter 7),* will tend to be traded more like a commodity with certain buyer price sensitively, unless they cannot be easily reconstituted or there is a wide discrepancy of flavour/odour profiles in products on offer. Essential oils that get their character from the main constituents, but minor constituents influence their richness and complexity and where none of the main constituents contribute decisively to the desired flavour/odour profile *(i.e., group 3 & 4 of Table 7.3. in chapter 7),* will tend to be traded like specialty products and be less price sensitive. These generally tend to be produced on a small to medium scale with few producers being able to dominate the market.

2. The Threat of New Entrants

New entrants to the market have the effect of creating new production capacity and choice to customers. Given quality attribute considerations, this divides market shares into smaller segments and decreases existing producers outputs (or increases stock holdings), leading to lower revenues. The seriousness of this threat depends upon the barriers to entry and elasticity of supply, which is influenced by capital requirements, technology, knowledge and equipment availability, competitive production advantages due to geographic location, the relative returns of producing alternative crops and the fragmentation of producers in the market. Time lag effects are dependent upon how long a crop will take to reach maturity is another factor influencing how quickly increases in supply will influence the market. Tropical plant crops like citronella and patchouli can reach maturity within six months or can be collected from the wild by producers, whereas many tree crops may take years before they can be harvested for oil.

Where elasticity of supply is great, producers will quickly react to price fluctuations most often causing gluts where prices are high and shortages where prices are low, thus making markets very price volatile. Traders over the last few decades have used their stocks to smoothen peaks and troughs in supply by either, releasing stock when shortages occur or increasing their stocks when gluts occur. Pricing as a consequence may not necessarily be a result of producer supply and customer demand and this should be accessed before coming to any conclusions.

3. Bargaining Power over Suppliers

Generally the bargaining power of essential oil producers is extremely low. The only exception is if there are no or very few alternative sources of supply to users. Producer bargaining power thus depends on the number of alternative producers and the importance of the essential oil to the end users. In some cases where there is particular intellectual property or a high barrier to entry for other potential producers (i.e., specialty citrus fractions), where the material is of great usefulness to users, producers can exercise some degree of power over their customers. However this is more common with specialty aromatic materials than with natural products.

If producers rely on outside advice for technology through consultants and specialty equipment suppliers and are in relatively remote areas, supplier bargaining power over producers tends to be relatively high. This is particularly the case with analytical equipment where an agent will normally have exclusive sales territories, which makes the cost of equipment and after sales service relatively expensive. Suppliers of seed, especially those that supply relatively rare genetic material from very selective geographical areas and are able to offer certified specifications are able to obtain premium prices from producers. Transport contractors servicing remote areas are able to charge premium carriage rates to producers with lack of alternatives. Labour in many areas are hesitant to do many manual jobs like weeding and can exercise power over producers, who may be forced to pay premiums, especially during times of harvest.

4. Bargaining Power over Buyers

Essential oil traders supplying the flavour and fragrance industry are dominated by a small number of long established, often family owned businesses concentrated on the East Coast of the United States and the UK. With large financial resources these companies are able to yield substantial power over many producers in the World through their ability to hold inventory of many essential oils and buffer price fluctuations. Another cluster of newly emerging suppliers which are important to the industry are operating from China and India, supported by the dominant producing positions of those countries in essential oils. Most traders are influential in world essential oil producer and trade associations and thus are able to exercise certain control over the evolution of the essential oil industry.

The aromatherapy trade sector is much more fragmented than traders specialising in flavour and fragrance ingredients. Traders in this sector place different emphasis on issues of price and quality depending upon their respective end user bases. For example, those traders supplying cosmetic manufacturers may place more emphasis on price, while others may specialise in only organically certified oils for the upper market segments. Organic production, pesticide residuals, and community benefit from production revenue are growing in importance as buyer considerations. Purchasers in this sector tend to pick and choose their suppliers, sometimes based on non-financial and personal considerations. Personal relationships, experience and knowledge on the part of producers could be an important factor in business development.

In the cosmetic industry, channels of distribution tend to be very concentrated with both a small number of MNC manufacturers and retailers dominating the market place through the mainstream general market. Power is in the retail sector where buyers tend to set category directions and MNC cosmetic manufacturers try to influence retailer thinking through very professional submissions based upon market research. Manufacturers of 'niche' products have great trouble in penetrating the mainstream market and are often forced to either go to upper market segments through exclusivity agreements with department stores, specialty retailers, internet sales and/or direct marketing channels or to the lower end market segment through discount stores.

Bargaining power is less important in cottage essential oil and cosmetic production where the producer can market through selected channels such as specialty retail stores and stockists, direct marketing, Sunday specialty handcraft markets, internet web-based sales and/or agro-tourism outlets. Producers can develop product differentiation through developing different themes based on community empowerment, organic and sustainable production/products, indigenous products, etc. These specialised market segments according to the US based Natural Marketing Institute (NMI) are attracting great consumer interest and beginning to influence the theme directions of the mainstream cosmetic markets [8].

5. Substitutes

Table 8.1. Essential Oils that can be Replaced by Aroma Chemicals or Reconstitutions

Essential Oil	**Replacement**
Ho oil, Bois de Rose oil	Linalool
Litsea Cubeba Oil, Lemongrass oil, Lemon Myrtle oil	Citral
Aniseed oil	Anethol
Cassia oil	Cinnamic aldehyde, Cumminic Aldehyde
Wintergreen oil	Methyl Salicylate
Tonka Bean Absolute	Coumarin
Ambrette Seed Oil	Ambrettolide (proprietary specialty)
Eucalyptus oil	Cineole
Rose oil	Reconstitution made up of: Citronellol, geraniol, phenyl ethyl alcohol (base), aldehyde C9, alpha damascone, hydroxycitronellol, methyl ionone, nerol, phenyl acetaldehyde, (many more aroma chemicals can be utilised depending on quality and application desired)
Jasmine Absolute	Reconstitution made of: acetate C-8, Acetate C-10, Alcohol C-7-C-9, Aldehyde C-8, Aldehyde C-10, Aldehyde C-11, amyl cinnamic aldehyde, amyl alcohol, benzyl acetate, benzyl alcohol, benzyl butyrate, benzyl formate, benzyl isobutyrate, benzyl propionate, citral, dimethyl benzyl carbinol, diemtyl benzyl carbinyl acetate, methyl anthranilate, hexyl cinnamic aldehyde, hydroxycitronellol, indole (solution), isojasminate, linalool, linalyl acetate, methyl benzoate, methyl-p-cresol, phenoxy ethyl isobutyrate, phenyl ethyl alcohol, phenyl ethyl isobutyrate, phenyl ethyl phenyl acetate, phenyl propyl acetate, phenyl propyl alcohol, phenyl propyl aldehyde.
Tea Tree oil	Reconstitution made up of: Cineole, di-limonene, alpha-pinene, alpha-terpineol, alpha-terpinene, terpineoline.
Camphor oil	Synthetic camphor
Vanillin	Synthetic vanillin and/or ethyl vanillin
Neroli oil	Reconstitution made up of: Alcohol C12, alpha ionone, Amyl cinnamic alcohol, citronellol, di-limonene, indole solution, linalool, linayl acetate, methyl anthranilate, methyl naphthyl ketone, nerol, nonyl acetate, phenyl acetate, phenyl acetic acid, phenyl ethyl alcohol, terpineol.
Ylang Ylang oil	Reconstitution made up of: Benzyl alcohol, benzyl benzoate, heliotropine, alpha-ionone, vanillin, citral, phenyl ethyl alcohol, anisic aldehyde, geraniol, benzyl acetate, cinnamic acid, methyl benzoate, p-cresol methyl ether, p-cresol acetate, p-cresol phenyl acetate, phenyl acetic acid, terpineol, terpinyl acetate.

Many essential oils can be easily replaced with either aroma chemicals, especially those dominated by a single constituent, or reconstitutions of essential oils constructed from aroma chemicals. Specialty aroma chemicals under proprietary names have been produced to replace oils that are either very expensive and/or have very limited production. This is often done by the flavour and fragrance industry when cost and availability are major issues, especially in the area of functional perfumery for cosmetics and household products. Table 8.1. lists a number of essential oils that can be replaced with aroma chemicals and specialties and essential oils that are commonly reconstituted.

To some degree cosmetics and household products can all be considered substitutes for each other, particularly in the lower end of the market. Product attributes, branding, themes and promotion along with channel selection assist manufacturers develop consumer preferences and loyalty to their brands so they can develop a secure market share and differentiation of their products from competitors' products.

FACTORING IN THE DYNAMIC EVOLUTION OF THE INDUSTRY

Porter's Five Factor Model provides a framework to analyse the potential profitability and barriers to entry that must be overcome to make a successful entry into the industry. This assists in determining potential strategies for developing needed competitive advantage to compete against potential and existing competitors. However this analysis provides only a static view of the industry. According to Beinhocker industries are continually evolving through innovation, spurred more than ever by rapid increases in world per-capita incomes and new technologies [9]. In the essential oil and its downstream industries, this is certainly evidenced by changing technologies, changing business structures, relationships and organisation, changing products, and changing consumer preferences, tastes and trends. Thus to properly appraise opportunities in the industry, the impacts of the previously mentioned issues must also be factored in so that the complete scope of opportunities can be identified and planned for.

The precise relationship between new technologies and consumer trends is a very complex one. National markets are influenced by global trends to various degrees and visa versa. Consumers due to wider global exposure through media, travel and tourism are rapidly changing their tastes. Aided through rising incomes, generational consumers are able to purchase items they could have not purchased previously. Likewise regulation is changing to enhance food security systems, health and safety issues, partly reflecting and partly driving consumer and product trends. Both technology and consumer concerns and movements are creating industries and modifying existing industries *(i.e., mobile phones, organic foods)*. General opinion probably errs on the side that consumer aspirations are the main driver of technology acceptance, however many revolutionary advances in technology can only be weakly explained in this way. For example, *were organic cosmetics introduced to consumers by manufacturers or did consumers demand companies to produce them? Did consumers demand synthetic aroma materials in fragrances or did advances in technology allow the development of such materials which enabled companies to be more competitive?* What is important at this stage is that both technology advances *(technology being defined as the* *application of knowledge in new practical ways in industry*) and consumer trends be factored into the evaluation and planning process.

Two sets of industry trends can be identified, 1) those that are influencing the general nature of the industry and 2) those that are influencing the nature of future products, of which both are driven by technology and consumer trends. Some general trends influencing the nature of the industry are;

- Increasing per capita incomes in both developing and mature markets which is enabling rapid growth of consumer product markets, *this is enabling not just growth but changes in consumption patterns and changing the balance of the world market from a US/Euro centric world market to an Asian centric market,*
- Increasing knowledge by consumers and connection to the rest of the globe which is influencing the nature of markets, trends, tastes and preferences, *as consumers are more aware through education, not only products are changing but higher standards are expected. This is creating new markets for organic products in food, cosmetics and agro-chemicals, business ethic based product philosophies, naturals, etc., thus evolving the market to new centres not just geographically but in product type distribution schema,*
- The exponential growth of companies operating both regionally and globally, influencing products, supply chain structures and trends, *this is enabling much quicker transfer of consumer trends from one market to another, increasing supply chain concentration and expanding company business turnovers on an exponential basis, creating mega-mass markets, changing the balance of power in business both in terms of geography and supply chain points,*
- A rapidly changing regulatory, standard and certification environment which demands much higher company and product standards, *which is also increasing the barriers to entry into industries,* and
- A rapid increase in technologies, such as analytical technologies which is driving the ability of industry to use new methods of production, synthesis and extraction to create new products, the regulatory system to further control issues like pesticide residuals which previously couldn't be enforced due to lack of equipment sensitivity. *This is forcing producers to implement hazard and safety assessment procedures in production. As a consequence, this is probably a force that will assist in making large companies larger.*

These are some of the major trends of the global market, however counter trends exist where new paradigms are developing almost dialectically to mainstream trends, which include;

- Growing individualism demanding individualised products leading to consumer customisation and a rejection to mass consumerism,
- A greater willingness to try new products, want of diversity, lower brand loyalties and shorter product lifecycles, leading to the development of many 'niche product' companies and alternative channels of distribution,

- Growing consumer scrutiny and criticism of products and world wide consumer linkages through the internet,
- Consumers seeking self actualisation through products leading to the linking of product consumption to personal growth, and
- A yearn by consumers to maintain their cultural identity with familiar things indigenous to their cultures.

Taking account of the mass trends and counter trends enables one to see mass markets, potential niche markets and niche markets that have the potential to become future mass markets. Going down further to the products that the markets support, specific trends can provide some enlightenment on the types of essential oils that have future growth potential. Some specific product/market trends are summarised below;

- Cuisines are beginning to merge with experimentation of flavour ingredients from Asia and the Middle East. As well as the increasing popularity of Asian food generally, although it is as diverse from India to Japan, Asian ingredients are becoming regular flavours in what has been termed as 'fusion foods' [10]. Wasabi, ginger, galangal, sesame, green tea, cumin, coriander, shitake mushrooms, hibiscus, rose, cardamom, exotic nuts, lemongrass, Vietnamese mint (kesum), wild rice, soy as well as many new exotic fruits are more and more being utilised in foods.
- In the fragrance arena companies are more and more attaching their fragrances to themes [11], for example Tuscany leather and white sands musk to conjure up fantasy and escape [12]. The industry has very innovative in combining conventional scents with culinary scents with novel twists such as raspberry leaves, black rose, jasmine sambac, black violet, and more gourmand notes like caramel, chocolate, wild cherry, milky coconut, with more spicy oriental notes of green and black tea, and pepper. These scents are taking on regionalised *personas*, often identifying themselves with specific geographical areas. New fragrance themes are usually launched as fine fragrances and then eventually are developed as functional fragrances for cosmetics, personal care and household products [13]. Although a few 'exotic' essential oils are incorporated into these products, the majority of materials are still synthetic.

COLLATING THE INFORMATION INTO A PICTURE

All the information collected through the screening and planning process up to this point can now be schematically arranged to review potential, from a number of different points of view. Porter's Five Forces Model can be used as the base to the schematic. As current advances in technology, trends and regulatory show change and opportunity, these issues can be factored in over the base industry data. This point of this schematic is to provide an intuitive view of the industry situation, rather than a formal mathematic analysis, as the point of the exercise is to scan the data (which is actually a number of conclusions) for potential market viability, opportunities and strategies. The scale of demand relative to current and potential supply will determine the potential scale of the project. The analysis will be able to show potential areas where any other *value added* product production can take place.

This schematic should be prepared using the criteria set out in Table 7.4. of the last chapter. The objective of the analysis is to view all the issues relating to the potential essential oil to determine whether it has perceived value to end users. This will depend upon the oil's uniqueness in odour/flavour profile, its novelty which is limited by substitutes, its potential applications verses curiosity value of the oil, its ease of potential duplication through reconstitution, its cost/price performance ratio, its potential hazard and safety assessment, current technology, what effects promotion will have on end users, and finally what will potential competitors do [14].

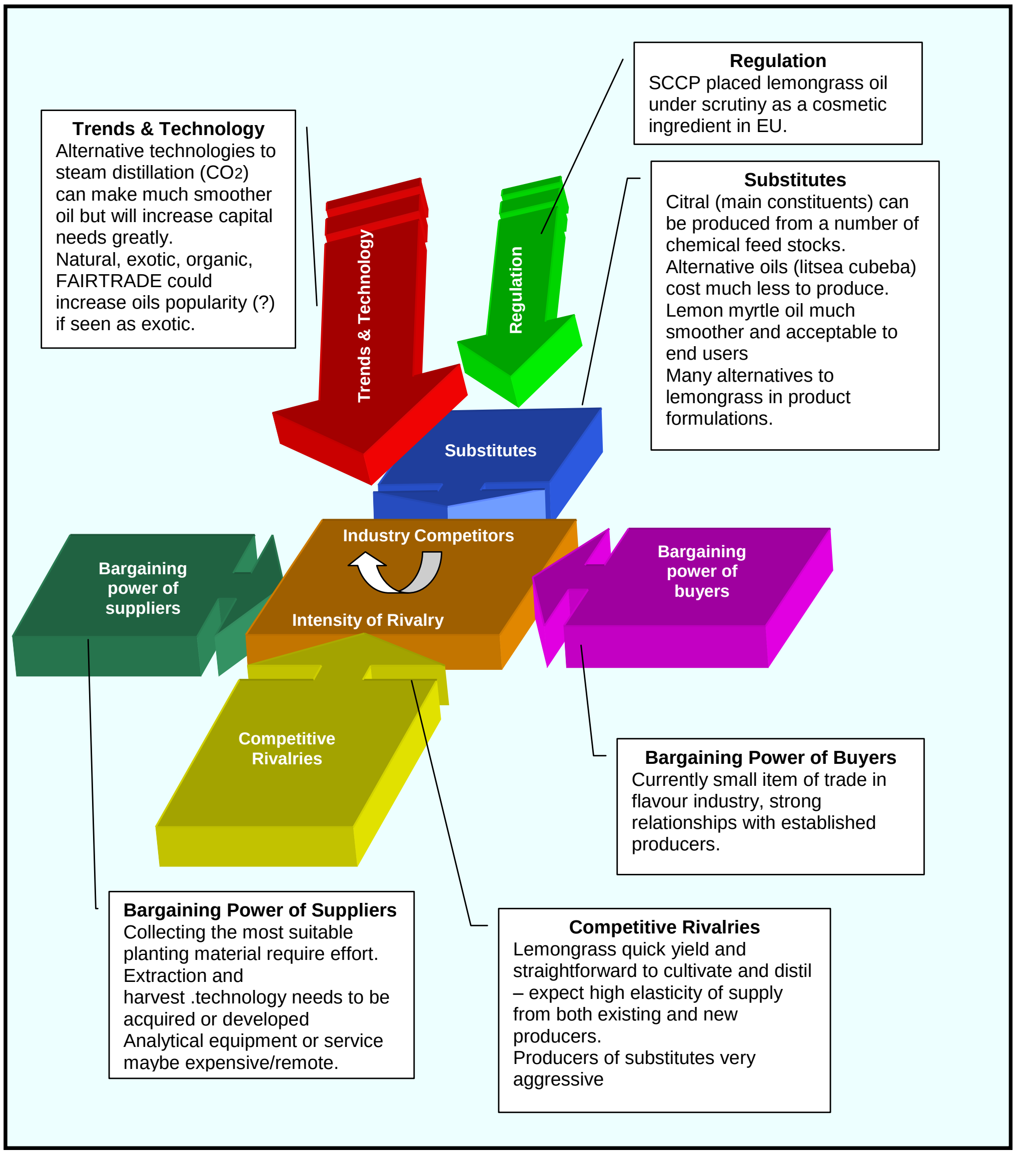

Figure 8.1. Example of an Industry Analysis for Lemongrass Oil.

In collating all the information collected into a strategic picture, one has to be very careful of the validity and value of certain aspects of the data. Anecdotal evidence and undocumented pricing should not hold too much validity and be recognised as such. One must be very cautious of price lists, which do not include quantity discounts. The price list must be scrutinised as to where in the supply chain it came from. The real market price (farm-gate) equates to bulk sales from large producers to traders, which has very little resemblance to quoted prices on any price list. Decisions about developing an essential oil should not be made from price lists that reflect only small quantity purchases. Such a misconception would just create totally unrealistic illusions about potential returns. Figure 8.1. shows a schematic analysis diagram for lemongrass oil*(Cymbopogon citrates/flexuosus*) as an example.

Based on the above assessment, some ideas about the viability of producing different essential oils within the vision formulated earlier can be made. This is still preliminary, as core competencies required, the supply chain and specific technical issues (discussed later in this chapter) need to be examined in more detail before final decisions are made. Assessments can be plotted on a matrix, similar to the Boston Consulting Group Matrix to visualise the assessment. The location on this matrix, where potential business activities are placed by different groups, will differ. This is because different groups have developed their own unique visions, see the industry differently based on different market knowledge, have different technical expertise and core competencies. In other words, different individuals will rate the potential of new products differently. Figure 8.2. shows a matrix for a hypothetical essential oil.

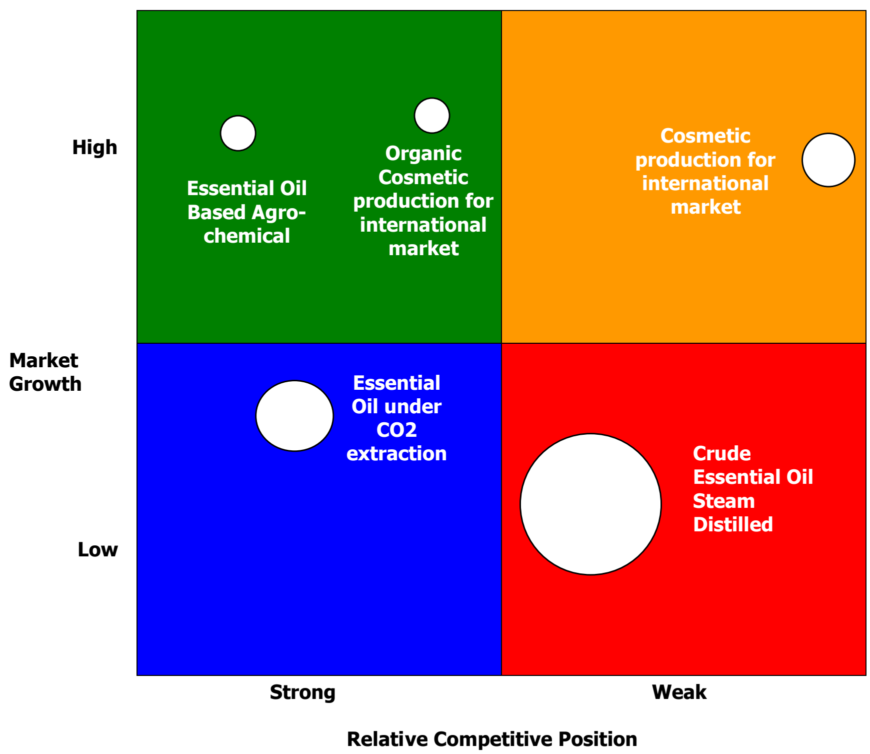

Figure 8.2. Industry Potential for a Hypothetical Essential Oil.

DEVELOPING A BASIC STRATEGY

Developing a basic strategy is the process of creating long term roadmap for the planned venture which has the objective of being competitive, sustainable and eventually profitable. Timeframes and financial resources have usually been decided and this puts the boundaries upon what can be done and how things can be developed.

Developing an essential oil based enterprise will involve a research aspect where successful outcomes will depend upon the technical know-how that evolves. New markets will be developed through new supply chains, so the venture is very similar to an entrepreneurial start-up. Traditionally most essential oil producers tend to be family or small groups of people sharing the same visions [15]. Only relatively recently large corporations began buying some of these enterprises up. Based on the historical development of the industry, it is likely that the owner/manager will be closely associated with all the activities of the business and as such will usually be a major provider of the initial general knowledge about the enterprise's vision.

The strategic planning process must recognise that all knowledge is not present at the time of developing the plan. Knowledge will be acquired gradually during the development process and after commercialisation has taken place. Much of the plan will reflect personal visions and ideas that the owner/manager believes can be achieved based on his or her personal competencies and limitations. The process must also recognise that over time the owner/manager will build upon his or her strengths to create a 'niche' market and develop some form of competitive advantage which will serve the enterprise well in the industry. Thus success will greatly rely upon the personal characteristics of the owner/manager and other key people around him or her [16]. The form of competitive advantage developed may be based on his or her own personal characteristics, skills and knowledge and be implicit rather an explicit form of competitive advantage [3]. This form of competitive advantage, whether based on radiating passion for the product in a way that can be transferred to potential customers, or the successful linking of a theme to the product, will be one of the most important factors in the success of the venture.

Essential oil enterprises over the last century have tended to evolve rather than been developed through rigorous strategic planning processes. Venture establishment and growth has come out of opportunities that were discovered during the early screening processes. This is why the planning process is extremely important, not as much for the plan it provides, but as a method to identify key issues that have to be addressed in order to initially develop, survive and grow. This closely resembles how SMEs actually run and operate in the real world [17]. Mintzberg and Waters found that strategic plans are only ever rarely realised and change dramatically during implementation [18]. Strategic plans are a way of shaping an overall view of the general direction in which the owner/manager/stakeholders wish to go, as plans should be modified when unforseen changes arise in the environment. Small deviations can be taken from the original roadmap when signs of change which influence the scope of an opportunity when seen from scanning the marketplace. This is a continual process [19].

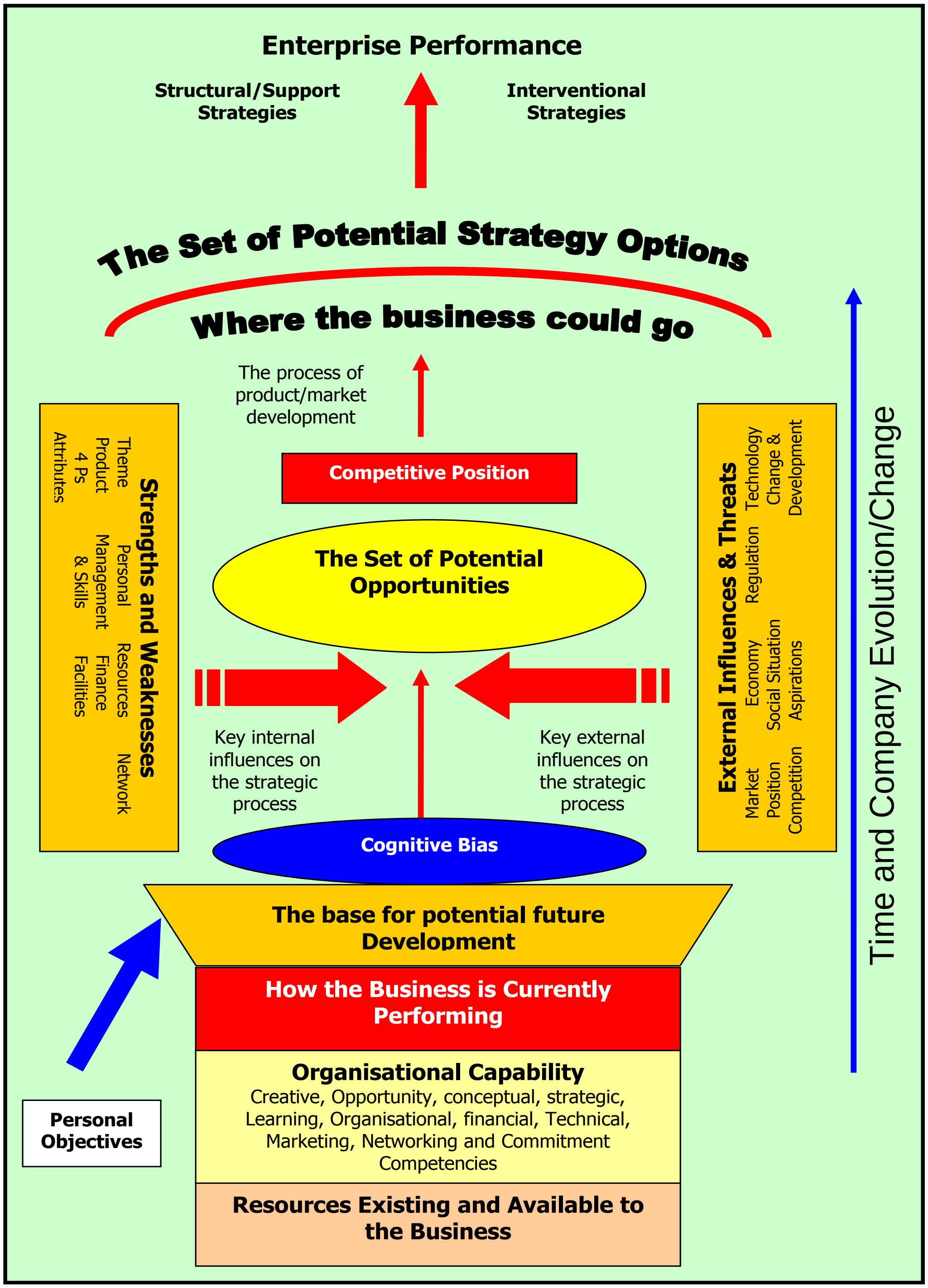

Figure 8.3. A Strategy Development Model.

The actual strategy that will be used in the enterprise will only develop as the owner/manager's experience increases and he or she learns from actually operating in the market [20]. Given the steep learning curve a new essential oil venture faces, this seems sound advice. During the early stages of development, strategy in an essential oil producing enterprise is more about the owner/manager's personal visions, personality based approaches, where he or she will be fundamental to its success. Success in the early years will be based on his or her own personal competencies [21].

The proposed venture should be modelled into a strategic plan. Gibb and Scott recognised that SMEs develop their strategy from change, anchored to the current environmental situation, threats, available resources, competencies and strengths [22]. The owner/manager/key stakeholder will be heavily influenced by the existing base (assuming a venture already exists) and core competencies in seeing opportunity and framing sound strategy. Framing strategy without the relevant competencies and strengths to support the activities and intervention into the market environment increases the risk of failure, unless efforts are made to develop or acquire the necessary competencies.

The base from where opportunity is seen is the current business situation, which is reflected in performance, resources and competencies. These factors are the components making up the overall strength of the business and the potential to grow and/or develop new strategies, *i.e., products and markets.* If a business does not already exist, then available resources and competencies available to the new venture make up this base. The potential resources and competencies would include;

1. The resource base of the enterprises financial resources and capabilities,
2. The resource base of the enterprises technology or access to technology, which would include research capability,
3. The resource base of the enterprise's land and infrastructure,
4. The resource base of the enterprise's human resources, experience, capabilities, skills and core competencies,
5. The enterprise's experience and network within the industry, market and (potential) customers, including its understanding,
6. The enterprise's experience, skills and capabilities in new product development,
7. The owner/manager's leadership and environment screening capabilities and personal vision and objectives, and
8. The idea's base of the business, which would consist of ideas for products, markets, development, technology, infrastructure development, and so on.

The resource base includes both all the individual and group competencies existing in the enterprise. The enterprise's competencies provide it with the ability to exploit opportunities in the environment. Thus competencies are the critical resources and skills needed to link the enterprise with the environment. Without these competencies opportunities cannot be exploited. Competencies are seen as a key to an enterprise gaining mastery in its activities so that it can gain some sort of competitive advantage in the industry [23]. Competencies should be seen as being something much wider than technical disciplinary proficiencies, they include the ability to recognise and develop market opportunities, the ability to gain cooperation communication and trust with outside individuals and groups, the ability to make decisions based on flowing information within certain risk parameters, the ability to organise research, production, human, physical and technological resources effectively, the ability evaluate, develop and implement strategy and the entrepreneurial drive to start and develop the business [24]. These abilities are not wide spread and rare in the community and need to be synergised with technical competencies to achieve overall venture success.

Table 8.2. A Simple Competency Audit Example

Competency	Present	Not Present	Comments
Technical			
1. Botany	Basic		Need guidance
2. Plant Physiology		Low	Need assistance
3. Chemistry/Analytical	Basic		Need guidance
4. Micro-propagation		Low	Assistance
5. Nursery Management	Experience		Available
	Experience		Can design
6. Environmental Engineering	Experience		Need appraisal
7. Chemical engineering/thermodynamics/etc			Use contractor
8. Soil Management		Low	Use institute
9. Agronomy/plant nutrition/field management	Basic	Low	Replicated experiments
10. Entomology		Low	With Environment
11. Irrigation engineering		Low	Use contractor
12. Agricultural Engineering		Low	Can develop
13. Regulation knowledge		Low	Need assistance
14. Cosmetic chemistry/food etc		Low	Learn from experience
15. Perfume/flavours			
16. Packaging & design	Basic		
17. Consumer product manufacturing	Basic		Use contractor
Opportunity/Entrepreneurial/Commitment			
1. Able to screen environment for opportunities	Yes		
2. Able to evaluate opportunities	Yes		Need to see realistically
3. Commitment level	Passionate		
Relationship			
1. Have relationships in target industries	A few		
2. Have relationships in research area	A few		
3. Have relationships in finance industry	Some		
Organising/Management			
1. Able to project manage	Yes		
2. Able to administrate	Yes		
3. Able to financially manage operation	Yes		
4. Able to undertake research	Yes		
5. Able to keep key people motivated	Yes		
Strategic			
1. Understand dynamics of market and industry environment	Yes		
2. Able to plan for a business within this environment	Yes		
3. Able to implement, evaluate and adjust plans in this environment	Yes		Believe so but not tested

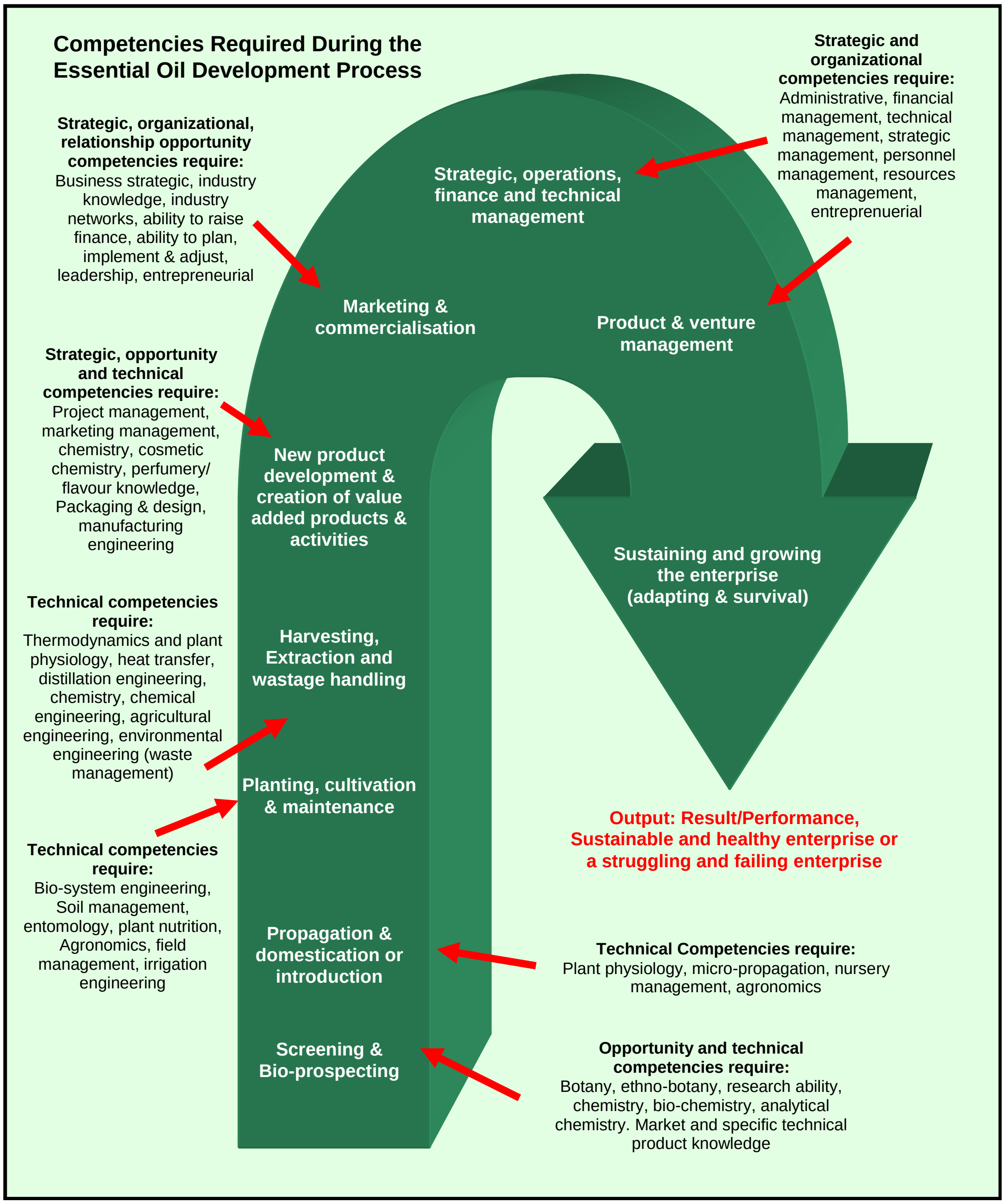

Figure 8.4. Competencies Required During the Essential Oil Development Process.

The collective competencies of the enterprise must be audited to determine any gaps *(i.e., where any expertise is lacking)*. Missing critical competencies could become a source of enterprise failure. Where competencies are deficient or lacking, ways must be sought to acquire or build them up. Experience is a great builder of competencies, but if required early in the venture it may not be good enough to build them internally and outside assistance will be required. Where competencies don't exist *'in-house'*, strategic alliances can be developed with local universities, research institutes or agricultural extension organisations (if they exist locally and have the expertise) to compensate. Total reliance on outside organisations can also be risky if key personnel from that organisation retire or move on for any reason in the future. This is a potential risk which may be critical. Some research institutions have a social responsibility to disseminate all technical information to those that want it in the community, so collaboration with a third party must ensure that a specific agreement is made on any potential intellectual property generated during any joint research undertaken. Some entrepreneurs see competency weaknesses as an intellectual challenge and spend lots of time and passion learning and developing new competencies. Competencies include new ways of doing things which may be very site specific and as such are very intrinsic to the enterprise, rather than something tangible. Table 8.2. shows a simple competency gap evaluation audit.

The base for potential future development makes up all the resources, technology and competencies that will go into making up the project. This is the current base where the project will be developed from.

The key internal and external influences on the development process equate to the strengths, weaknesses, opportunities and threats (SWOT) analysis used in strategic planning. Strengths and weaknesses refer to key internal influences on the development process. These would include issues that the firm perceives as strengths that can be capitalised upon and weaknesses that must improved so that they don't inhibit enterprise development. Weaknesses would also include issues exposed through the competency gap analysis discussed above. Threats relate to issues from the external environment, which are perceived to be critical to the activities and wellbeing of the enterprise. Strengths, weaknesses (internal) and threats (external) should be examined before opportunities are considered. This is because the set of potential opportunities will depend upon available strengths, or the development of strengths from identified weaknesses and the assessment of threats. Opportunities are greatly influenced by the cognitive bias of the owner/manage/stakeholders of the project. Figure 8.5. shows a modified SWOT matrix showing the types of issues that should be considered in this analysis.

The strengths, weaknesses and threats when viewed from the base potential for development, allows a scope of potential product/market strategy options for the enterprise to pursue in exploiting identified potential opportunities. There is usually more than one potential strategy option where the business can go, represented by the arch at the top of the figure. Two types of strategies need to be developed. Firstly, structural/support strategies to build and strengthen competencies and secondly, interventional strategies that are concerned about developing the product, market and organisation. Once selected, how well the outcomes are achieved will depend upon how well the external and internal influences on development were identified, whether relevant environmental factors changed much and how well the strategy was adjusted to changes in conditions. This reflects the point that ventures operate within a dynamic, rather than static environment. The enterprise performance will depend upon how relevant the strategies were to the defined problem, challenge (or opportunity) and the effectiveness of the implementation.

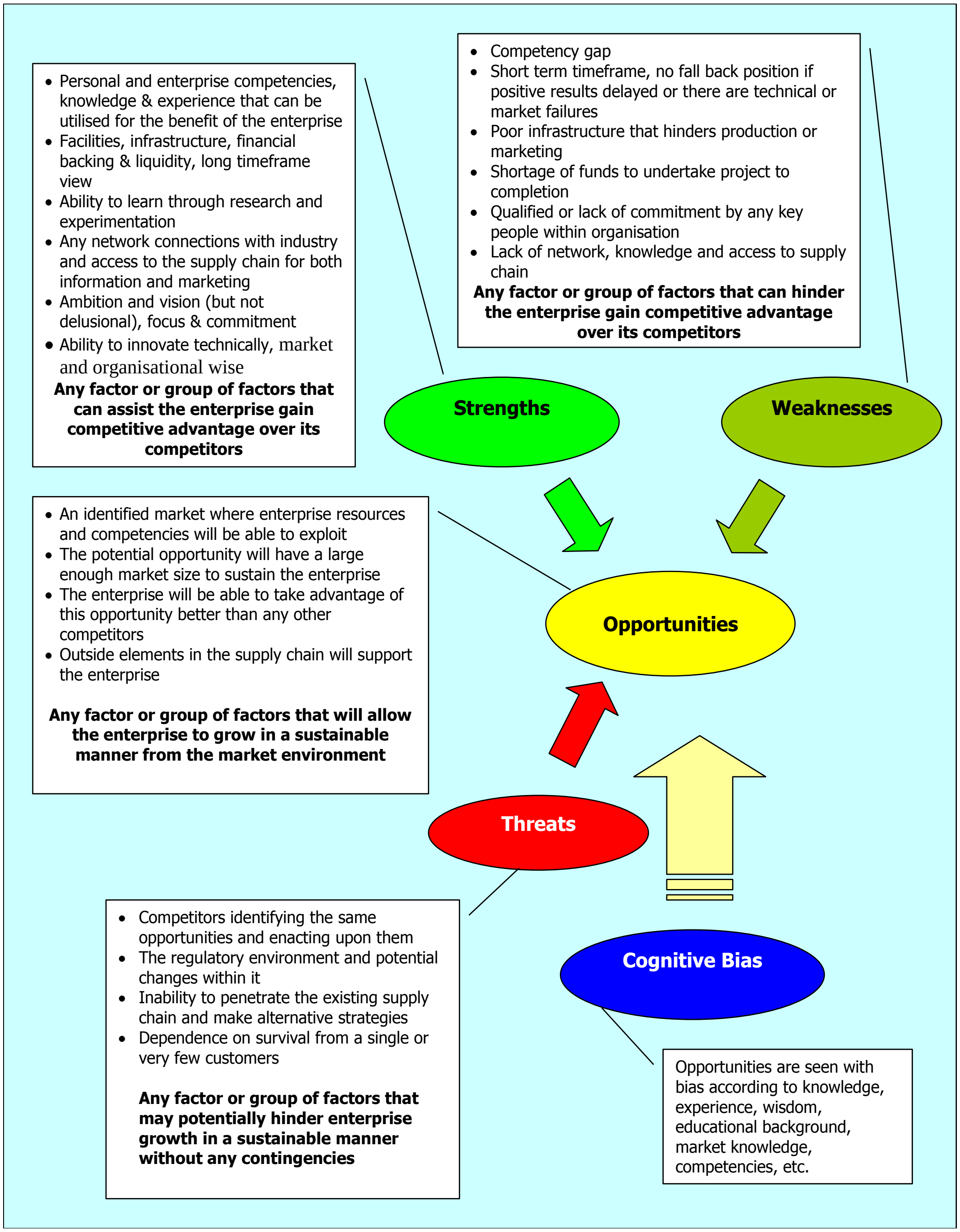

Figure 8.5. Issues a SWOT Analysis Should Cover.

ESSENTIAL OIL TRADE PRICE FLUCTUATIONS

Although the essential oil trade is very small relative to other agricultural commodities, essential oil trade characteristics resemble other agro-commodities [25]. Existing producers have been able to sustain essential oil markets through long term research and training with extension systems, developing specialled products and supply chains, and turning to the local market in times of economic downturns. Production is also partly protected by the specific climate and weather conditions in the region of production and the development of capital intensive mechanisation, *i.e., mint, lavender and citrus*. Countries with small local markets have protected themselves through favourable climates and the utilisation of low cost labour, particularly in crops that find difficulty in being mechanised like jasmine and rose. Their historical position in the industry has enabled oils originating from these countries to become the standard of trade, *i.e., basil oil Comoros.*

Many international agencies have initiated community essential oil development programs in Africa, South America and Asia, but not been too successful in sustaining them. In some industrialised countries entrepreneurs have also initiated a number of projects, also with limited success. Verlet argues that these projects have failed to obtain an optimal combination of several factors, including "*climate, quality of research, capacity to invest and innovate, the existence of economic structures ensuring low costs of production, established commercial relations with the downstream sector, and state politics"* [26].

Essential oil prices are influenced by both demand and supply patterns. The general factors that influence long term demand trends include issues like population growth and increasing consumer disposable incomes. This tends to promote a slow but gradual upward growth in demand. Consumer and product trends have much more immediate influences on the specific demand of an essential oil. This will correspond to the increase in demand for specific products, as consumers respond to advertising or other positive information about a product, and/or the launching of new products.

Demand for essential oils will change according to the sum of demand for all the end products where the essential oil is part of the formulation. This is called derived demand. A general increase in products that contain the same raw material will increase aggregate demand for that raw material. Likewise, a general decrease in demand for products that contain the same raw material will decrease aggregate demand for that raw material.

Another demand side factor is the influence of regulation. Regulation can restrict or ban a material, which will decrease demand of that material and result in increasing demand for any potential substitutes. Substitutes in turn also influence long term demand. For example, *litsea cubeba* oil is generally a cheaper source of citral than lemongrass oil. As a consequence, demand for lemongrass oil is slowly decreasing as litsea cubeba is substituted for lemongrass. Synthetic substitutes have played a role in keeping the prices of a number of essential oils low resulting in low returns to producers.

The supply side is much more volatile than the demand side. The major short-term factors influencing supply include the relative prices and net returns of other potential crops, like food crops, pressures on land use from urbanisation, and the availability of labour, *i.e., shortages can restrict supply*. Natural interventions like adverse weather, natural disasters, droughts and floods, etc, all influence supply and can cause sudden production decreases.

The effect of new producers entering the market is to increase supply. They will first supply any excess demand in the market, without any effect on the price, but extra supply in the competitive market will exert downward price pressure, resulting in competitive activities like discounting. The effect of intellectual property like a patent on a plant and/or extraction process is to create a monopolistic supply situation. If demand is strong enough, then the producer will have the ability to set prices.

Demand and supply is influenced by elasticity. Where alternative materials exist, an increase in price caused by a cut back in supply can trigger a switch by users to known substitute materials, thus decreasing demand for the essential oil. This demand elasticity could often be one-way if users lose confidence in the stable supply of the essential oil. Users may not necessarily switch back to the original material if the price reduces to former levels again. On the production side, if supply is very elastic, *i.e., very low barriers to entry and exit*, and the crop is a short-term annual or seasonal one, a rise in price will be responded to with an increase in production, thus bringing the price back down again very quickly within a few months. The elasticity of supply is greatly determined by the time lapse between planting and harvesting. If the time difference is very short, supply should be very elastic, given entry and exit barriers are low. If the time lapse is long in terms of a few years for tree crops, then supply would tend to be inelastic in the short term.

Over the last few years, most volatility came from the supply side. Users are usually hesitant to stop using an essential oil, unless something drastic occurs at the pricing or supply level. This is happening with the supply of a number of wild collected oils, which is causing users to switch to substitutes.

Essential oil prices are also influenced by production forecasts which create perceptions about future supply in the market place, usually creating either an upward or downward price trend according to the forecasts. In the short term, delays exist between price movements and supply due to time lags in production.

It could be argued that the pricing mechanism has not been a good regulator of natural resources and leads to poor business decisions, if the pricing mechanism is not fully understood. For example, price increases signal new producers to enter the market and existing producers to expand production. This will result in increased supply over demand sometime in the future, bringing prices downward again. How quickly this happens depends on the time lag between planting and harvesting, barriers to entry and capital costs. Thus short term crops with low entry barriers and low capital requirements tend to be the most volatile. Other crops with long time delays, effects supply only after a number of years. Thus prices will gradually increase due to inelastic production and gradually rising demand. This signals potential producers who see a long term rise in price that opportunities exist and a number of people may invest in developing new production. If a number of groups make this investment, then at some time in the future there will be a sudden increase in supply, which if in excess to demand will bring prices dramatically downward. This scenario could be occurring with the massive planting of *Aquilaria species*, now going on in South-East Asia.

Decreasing prices have the opposite effect and producers with the option to exit the industry will switch to alternative crops. This will decrease supply to the market and after excess inventories are soaked up by the market, begin and upward trends in prices again.

Unless essential oils prices are tied up in forward contracts, price fluctuation is common in the market. Some essential oils like mint are fixed from year to year contracts, but the majority of oil trade is governed by market prices. Traders with large inventory holdings, may have the power to negotiate with large producers for low fixed price contracts for large bulk supply. This has a depressing effect on prices. Several other long term factors influence supply such as the potentially higher value of land for other activities like industrial and housing development, prolonged water shortages in some countries, and potential higher returns for other industrial and food crops and increasing regulation. Figure 8.6. shows the general price behaviour of essential oils according to supply and demand, but each essential oil must be evaluated for specific factors that distort the market.

Due to the competitive pricing environment of the essential oil trade and generally relatively weak product differential attributes of bulk oils, the long term market effects will drive the price towards the most efficient producer’s costs of production. With price fluctuations, the prevailing market price may at times be under actual production costs. The only exceptions to this are where a particular essential oil olfactory/flavour profile or other factor, differentiates the oil from other producers in different geographical regions.

Low entry and exit barriers, low capital investment costs and low levels of technology used in the production of essential oils, generally provides an environment of low profitability to producers, where returns are marginal. Under such situations, producer commitment to the industry is very low, where they will quickly switch to alternative crops where opportunity costs to continue become too high.

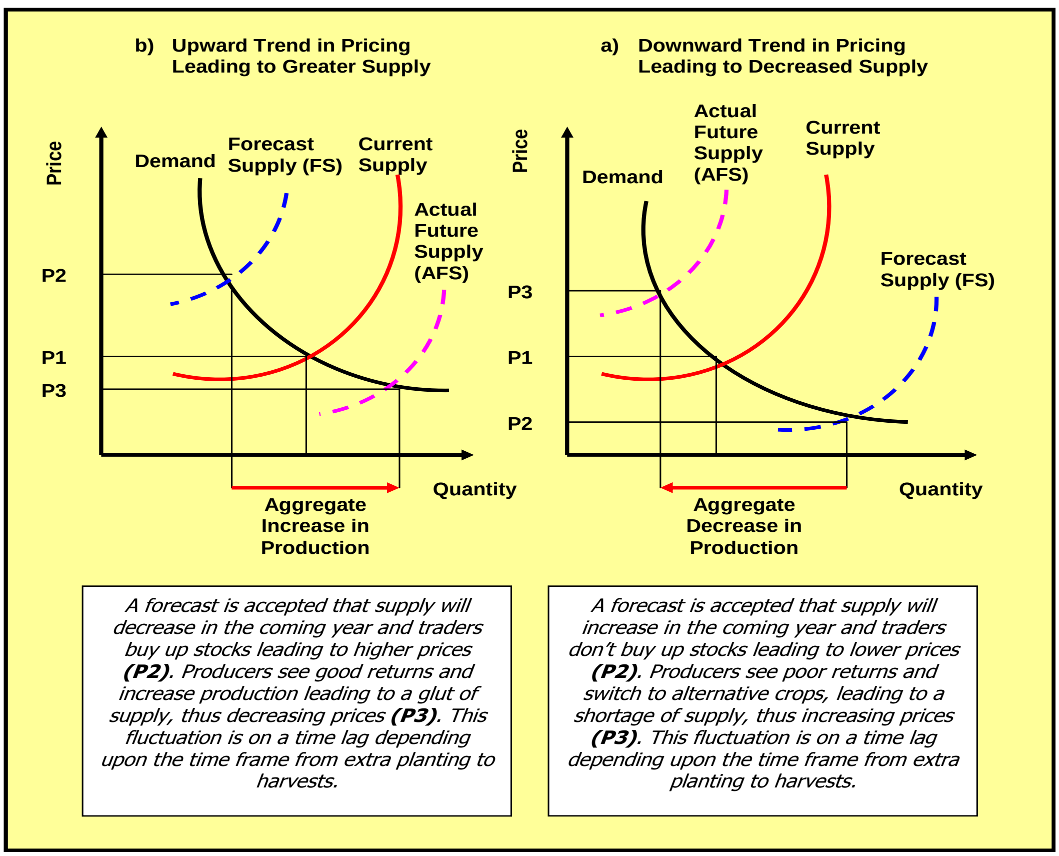

Figure 8.6. General Price Behaviour of Essential Oil Markets Leading to Price Fluctuations.

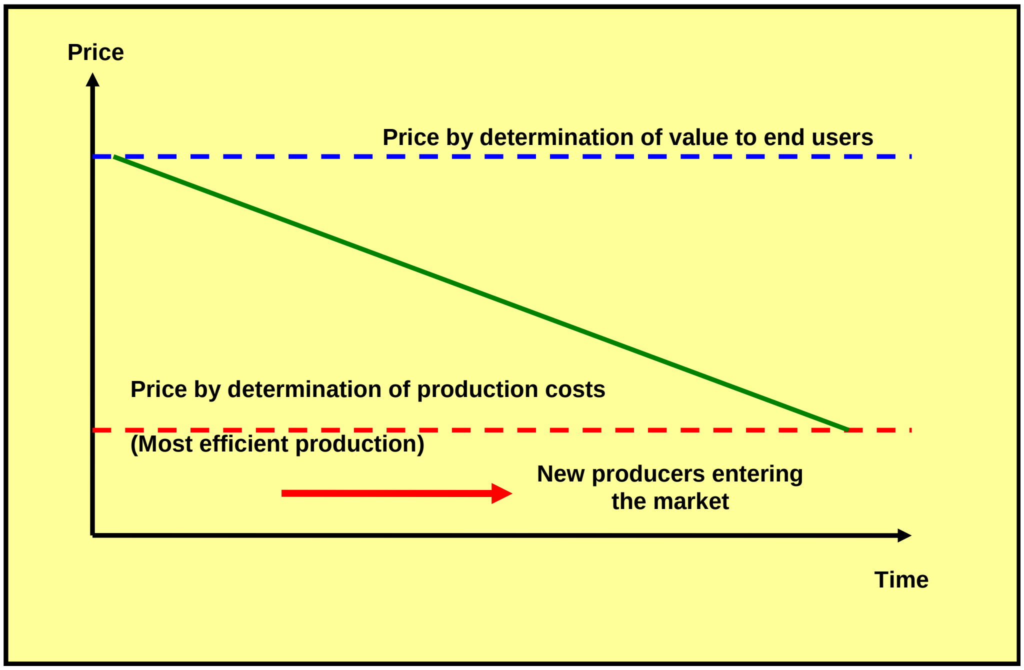

Figure 8.7. The effect of competition on the price of a new essential oil.

Certain factors like location, a unique climate, technology and mechanisation, restricted access to genetic materials and management abilities may enable a producer to obtain better than average returns for an essential oil crop, from either developing cheaper production costs or creating a barrier to entry for other producers. When producing an existing essential oil of trade, finding a way of developing some source of competitive advantage is a key factor in sustainability.

Totally New Essential Oils

A pioneer grower of a totally new essential oil which has some perceived industry value may be able to obtain a price based on its value to users rather than on its costs of production. Pricing will become an important factor in success. Too high a price will deter interest in the oil by potential users and limit the range of potential applications. Too low a price will lengthen the return on investment and recovery of research and development costs. It is important to take into consideration the list of characteristic strengths and weaknesses of an essential oil, i.e., *the possible range of applications, the application stability, and the cost price/performance ratio of the oil,* discussed in Table 7.4. of chapter 7 in framing a price. Valuation must objectively take into consideration the both the strengths and weaknesses of the new oil and the price level accordingly set.

Other potential producers will carefully examine the pricing of new essential oils and consider producing the oil should they see a good potential return. This factor must be taken into consideration by the pioneer producer when initially determining a price. A high price set for a new essential oil initially may encourage production inefficiencies on the part of the pioneer producer, because as a sole producer there will be little incentive to become more efficient. The pioneer producer will almost certainly face almost immediate competition unless some barriers to entry can be created though restriction of genetic material, patents or efficient production.

The price of a new essential oil will gradually decrease over time as competition from other producers increases. As the introductory price of the new essential oil was based on value to users, competitive forces will start pushing the price towards costs of production. If aggregate demand is equal to and not excessively higher than aggregate supply, other producers entering the market will push the price downward. This effect can be seen in Figure 8.7. Eventually the price of the essential oil will reach the point where the most efficient production cost exists. At this level only the most efficient producers will survive.

THE BASIC PRINCIPAL STRATEGIES OF ESSENTIAL OIL DEVELOPMENT

The successful operation of an essential oil enterprise requires the adoption of a strategy that will build some sort of strategic or competitive advantage over existing competitors. Ideally new essential oils should be developed with some sort of barrier to entry to other potential producers so that above average returns can be achieved. Porter in his book *Competitive Strategy* outlined three basic strategies. These can be applied to the development of an essential oil enterprise;

- Overall cost leadership (a low cost strategy),
- Differentiation, and
- Focus [27].

Overall Cost Leadership

Overall cost leadership is concerned with developing an extensive and mechanised system of production that produces an essential oil at the most efficient cost to compete with other producers. Research and investment in infrastructure and production facilities has focused on developing methods and production flows to maximise reductions in cost in all operational aspects in the nursery, field, harvesting, extraction and post extraction handling and storage. The enterprise is run in a professional manner.

The overall cost leadership approach is also extended to the supply chain where the enterprise is orientated towards selling large amounts of oil to large customers, trying to maximise its bargaining power over customers. This depends on the enterprise being able to control a sizable portion of world's production in that essential oil. Supplementary strategies are also used to enhance their position like supplying bulk stock to users where they can use it on a consignment basis, paying as they use. Many traditional forms of production have moved in this direction to survive [28].

This strategy usually employs the best technology available to the enterprise which has a high capital cost. Through low cost production strategies, the enterprise hopes to achieve above average margins and competitive advantage over other producers. Low production costs and high capital outlays produces a barrier to entry for other potential new competitors. This strategy is strengthened if there are other advantages like favourable site specific weather, where yields and quality are superior to less favourable areas. Also research and chemovar development assists in developing competitive advantage. For example, US cedarwood production where the industry had access to good chemo varieties which produce superior oil.

However utilising this strategy is risky. If absolute cost leadership is not obtained and other enterprises can produce competitively prices oils, the strategy has very limited effectiveness and has to fight on cost and any other product differentials for market share. If low cost strategies can be emulated with much lower capital expenditure by other producers, the original producer will be left with very little flexibility and high cost exit options. If capital expenditures have been highly financially geared or the enterprise lacks large financial reserves, sustained low prices can put immense strain upon the enterprise with its high fixed and financial costs. This offers very few contingencies it can employ to increase revenue.

Examples of low cost production strategies include the US mint industry and the citrus industries in Florida and Brazil. This strategy was used to develop the tea tree industry in Australia, but over production caused a glut of oil in the market which eventually led to the closing down of the major Australian plantations recently.

Differentiation

An essential oil enterprise may develop specific products or product attributes that may have special value to end users. These may be tangible or intangible and appeal to certain users, *i.e., organically certified essential oils, higher grades (BP grades under GMP) or different extraction method (CO_2), wild collected, etc*. This specialty, may or may not develop some user loyalty and attract a premium price in the market place. Where essential oils have very elastic demand due to a large number of producers, a price premium over other producers might be achieved with the producer marketing the benefits of the extra value, *i.e., organic, wild collected, etc*. Producers can also develop some specialities from the basic oils and promote them for specific applications to end users, like fractions, terpeneless oils, etc. Specialty products are differentiated from crude oils and other producers can be deterred from competing in this market through high capital costs and intellectual property protection from some proprietary technology.

Differentiation strategies often forgo competing in the main market segment and try to exploit specific markets with more value and higher return. This risks of this strategy are that in achieving a great enough volume, other producers may follow the lead, which would negate any competitive advantage.

Focus

A focus strategy is where a producer may specialise on specific products for particular market segments, where products may be tailored directly to specific user groups. Such markets can be either geographically or user specific. The focus strategy employs elements of the differentiation strategy, but is much more customised and service orientated. This strategy is effective higher up in the supply chain in market segments ignored by other producers and traders, because of lack of knowledge of the market and/or higher costs to service it. Image, reputation, knowledge and experience can develop barriers to entry to other competitors through the creation of image and branding to users. However if this market grows large enough new competitors will enter aggressively and compete for market share thus dividing sales amongst competitors. Some essential oil producers have focused small to medium scale operations around niche markets like aromatherapy and successfully been able to receive much higher than world prices by selling smaller quantities.

The above strategies are not mutually exclusive and a producer may develop their venture employing elements of all three and develop specific *hybrid* strategies that suit their location, build on strengths, make extra use of channels of distribution and/or diversify into allied downstream industries. This increases the value, revenue and reduces risk to the enterprise, which would be classed as diversification strategies;

- *Diversifying into Essential Oil Production from Existing Farm Base:* Essential oil production with little experience, industry knowledge and industry networks, makes the endeavour to develop a new enterprise very difficult. Even attracting any potential buyer interest from only a concept would be very difficult. Existing farmers have an advantage of operating an ongoing enterprise which can act as a base from which diversification can occur. This allows research and field trials to be undertaken and experience gained while other revenue earning activities are ongoing. This provides the opportunity to gain experience without financial pressure. A pilot project on an existing farm will greatly assist in learning about the various production variables of the crop and provide time to communicate with potential customers. This is a sound strategy for short to medium term crops with harvest intervals between 3 months and two years. Future commercial production will become part of a farm crop portfolio which would decrease risk due to the crop diversity on the farm, where one crop can subsidise the other in period of low market prices. Both the Tasmanian essential oil industry and the North-Eastern Victorian mint industry was developed in this way.
- *Diversifying into Agro-Tourism:* Nature, eco and agro-tourism is one of the fastest growing sub-sectors of the international tourism industry [29]. Agro-tourism has long been utilised as a strategy to generate revenue for a number of years in the essential oil industry. Integrated agro-tourism essential oil production ventures operate in France, UK, Australia, Indonesia and Thailand. Initially, essential oil enterprises ventured into agro-tourism to gain extra revenue to pay overheads, but now many ventures are specifically set up as agro-tourism ventures that produce essential oils. It would not be an understatement to say that many essential oil producers need agro-tourism to survive and for many producers agro-tourism is by far the largest revenue generator. Bridestow Estate in Tasmania, although renowned for its high quality lavender oil would almost certainly not survived until today if it was not for the agro-tourism side of the business. For some small scale passionate producers of essential oils, agro-tourism allows them to produce high quality oils without regard for the international market and dispose of their production mostly onsite and to select clientele in their local areas, either as an essential oil or as cottage industry products

like simple cosmetics. Agro-tourism is also becoming corporatised with the development of many up-market spas, ayurveda and aromatherapy centres being developed on resort farms.

- *Diversifying into General Essential Oil Trading:* Some essential oil producers develop strong customer networks and can obtain sales orders far beyond their own production. They begin purchasing other local producers stocks to fulfil orders. This trading becomes profitable with margins made through buying and selling and trading becomes their prime activity. This model exists in Indonesia where a number of the major exporters entered the industry as producers. Other essential oil producers in a number of countries have developed general essential oil trading both as exports and imports to supply their respective local markets as important aspects of their businesses.
- *Diversifying into the Production of Consumer Products:* (Cosmetics & Aromatherapy, Pharmaceuticals, etc): Some essential oil producers begin developing their own cosmetics, personal care, or pharmaceutical products based on the essential oils they are producing. Producers become consumer product companies marketing their brands through local supermarkets, overseas markets and through other means like direct marketing and e-sales. Examples of this diversification include Bosisto's Eucalyptus products [30] and Thursday Plantations Personal Care range from Australia [31]. Thursday Plantation's products are now the core part of the business with the plantation at Ballina remaining as a tourist attraction with little commercial production.
- *Other Agro-Businesses Producing Essential Oils as By-Products:* Various producers involved in primary production or agro-businesses produce essential oils as by-products of their core business. They usually become cost leadership operations with very efficient means of extraction of wastage through the production process of another product. A number of major essential oils are produced in this way including citrus oils from fruit juice processing, tall and turpentine oils *(sometimes called pine oil)* from wood pulp and cedarwood oil from woodchips and sawdust from the timber industry.

MARKET ANALYSIS

After general strategies and competencies have been reviewed it is necessary to have a closer look at the specific markets that the venture will pursue. This market analysis can vary from a full formal appraisal to a more informal review. This will depend upon the scope of the market (local, regional, national, international), the level in the supply chain (trader, direct to end product manufacturers, direct to consumers, manufacture own products, etc.) and the nature of the product (crude oil or a value added product). Which ever approach is taken, the following specific questions should now be able to be answered;

a. Is the essential oil in under or over supply?
b. What is the current supply situation?
c. Do prices fluctuate greatly?

d. What are the maximum and minimum prices over the last 10 years?
e. Are there any current use trends?
f. What are the potential markets for the essential oil?
g. What is the potential market size for the essential oil?
h. Who are the current producers of the essential oil?
i. What strategies do their enterprises pursue?
j. Is the oil a source of potentially valuable aroma chemicals?
k. Are there any substitutes for this oil?
l. Are there any other products that can be produced from the crop as a by-product?

Commercialising new crops, including essential oils without an established market should be based on a market development strategy [32]. With little or no market data, effort is required to develop potential uses and value to users. These users may not be the eventual customers of the venture as they may be very fragmented requiring distributors. The following specific questions must be satisfied for a new essential oil;

a. Does the essential oil have specific applications and have these uses been identified?
b. Does the essential oil fulfil and satisfy a particular need?
c. Are the identified applications important ones?
d. What material is currently used for these identified applications?
e. Will it be possible to get regulatory clearance and/or gain registration for the material?
f. What would be the appropriate pricing of the product?
g. What production volumes would be required? and
h. Are there now customers for the product?

Specific questions concerning end products would include:

a. What is the size of the market?
b. What are the market trends?
c. What are profitability levels?
d. What are the supply chain cost structures?
e. What would be the best distribution channels for the product?
f. Who are the customers?
g. Are the customers a uniform group?
h. Will the product satisfy their wants, wishes and needs?
i. What are the customers' motivation to buy the product?
j. Do they have any unmet needs, existing products have not met?
k. Who are the competitors?
l. What are the competitors characteristics and profiles?
m. What are the important forces in the market?

Any unsatisfactory conclusions should halt any further progression in development until a positive conclusion can be made. Opinions of experts from the flavour and fragrance industry would be invaluable at this point of time if the main market for this oil is as a flavour or fragrance ingredient. Good and informed opinions could save many months of research.

Communication with end users will provide further knowledge on potential applications and the overall usefulness of the oil to them. Communication and positive feedback from potential customers at this point can provide encouragement and motivation during the long research and development phase.

Table 8.3. Various Secondary Uses for Some Selected Essential Oil Crops

Common Name	**Botanical Name**	**Parts Used**	**Product**	**Industry**
Anise	*Pimpinella anisum*	Seed	Oil or tincture	Medicinal, Flavour, Cosmetic, Fragrance, beverage
Calendula	*Calendula officinallas*	Flowers, seeds, leaves	Dried flowers, Absolute, oil, animal feed (deepen egg yoke colour)	Medicinal, Flavour, Cosmetic, Fragrance, Stock feed
Caraway	*Carum Carvi*	Seed, leaves	Oil and spice	Medicinal, Flavour, Cosmetic, Fragrance, Food
Clary sage	*Salvia sclarea*	Whole plant	Fresh, dried, tincture, oil	Medicinal, flavour, cosmetic, perfume
Coriander	*Coriandrum sativum*	Fresh leaves, seed	Leaves, seeds, powder, oil	Medicinal, flavour and fragrance, spice
Sage	*Salvia offcinalis*	Whole plant	Fresh and dried leaves, tea and oil	Medicinal, flavours, fragrance, food and beverages
Sweet Basil	*Ocimum basilicum*	Whole plant	Fresh and dried leaves, oil	Medicinal, flavours and fragrances, spices, food
Fennel	*Foeniculum vulgare*	Seeds, leaves, roots	Oil, water, seeds, stems	Medicinal, flavours and fragrances, spices, food
Thyme	*Thymus vulgaris*	Whole plant	Fresh and dried leaves, oil	Medicinal, flavours and fragrances, spices, food
Lavender	*Various species of Lavandula*	Leaves and flowers	Dried flowers, balms and oil, hydrosol	Medicinal, fragrances, cosmetics
Valerian	*Valeriana offcinallis*	roots	Tincture, juice, tea	Medicinal and tea

During the market analysis the potential markets for by-products and alternative products to the essential oil should be investigated. By-products can provide additional incomes to assist in covering overheads and create new markets, independent of the essential oil industry. Alternative products can provide a contingency product if supply gluts the market and prices drop. Potential by-products and alternative products include;

- Mulches and Waste Products
- Uses for other parts of the plant or tree (leaves, flowers, etc.)
- Hydrosols
- Aromatic Isolates

Finally in the market analysis phase preliminary marketing strategies should be mapped out and the supply chain examined to determine at which level the enterprise will operate.

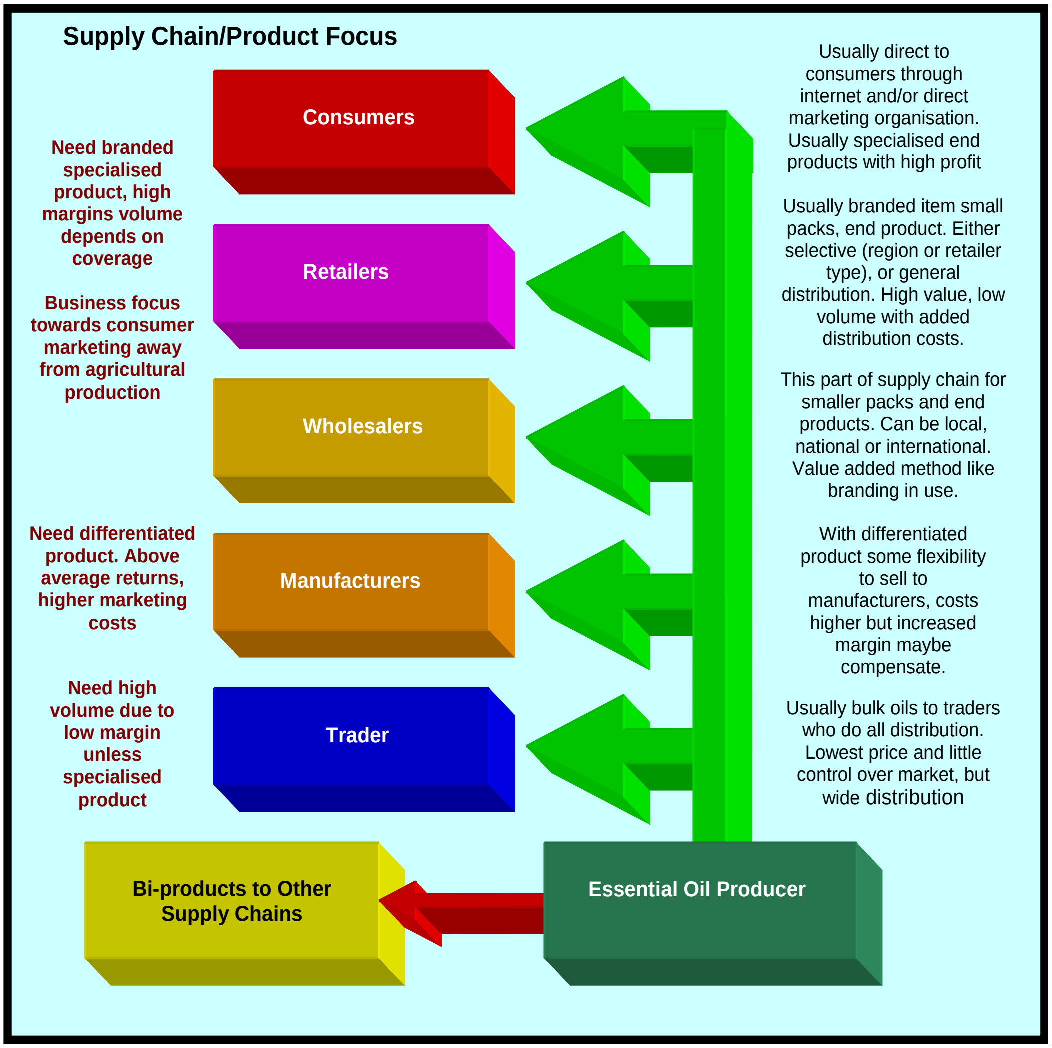

Figure 8.8. The Supply Chain and Various Potential Levels of Entry.

SUPPLY CHAIN

One of the major challenges facing a new enterprise is selecting the optimum part of the supply chain to develop the business within. This should be where the business could develop maximum revenues and profitability, with the greatest management ease and within its limited resources. The part of the supply chain the enterprise is best suited to operate within will depend upon the type of product *(essential oil for the flavour and fragrance industry, for cosmetics, food and beverage industry or aromatherapy, etc.)*, how differentiated the product is from its competitors, the geographical distribution of customers, and volume. The personal preferences of the owner/manager will heavily influence this decision.

Linkages between primary producers of raw materials and end users of the supply chain have been traditionally very weak or non-existent until the last decade. The closer to the end user an enterprise markets its products the higher will be the margins, but at the same time costs will also increase dramatically. Focusing closer to the end users will also require a greater market orientation than would be the case if supplying traders at the bottom of the supply chain. Supplying directly to manufacturers requires an understanding of manufacturers business operations and the nature of the products they produce to enable communication on technical matters concerning the products. Developing the correct infrastructure to service the part of the supply chain the enterprise wishes to focus upon will take time to develop.

It will take a number of years to establish a market for a new essential oil. This will initially involve working with small and specialised distributors on projects centred around potential new essential oil applications and obtaining the necessary registration and certifications in the initial years. New producers will also be scrutinised, where customers will carefully look at service levels and reliability of supply. Producers will quickly develop a poor reputation if they cannot fulfil customer demand. In essential oil development, sales and production development must be developed in tandem. Figure 8.8. shows the supply chain and various potential levels of entry.

SELECTION OF BASIC MARKET STRATEGIES

After undertaking a market analysis, basic market strategies can be formulated. One of the early major decisions that will have to be made is whether focus will be on the domestic or international market. Generally the domestic market will provide very limited opportunities for a new essential oil, so an international market focus will most likely be necessary. In the case of cosmetic and pharmaceutical products, where sales are made higher up the supply chain, the domestic market or even a region within the domestic market may be of adequate size to focus market efforts upon, by launching a single product or range. Figure 8.9. shows the general strategy choices open to the enterprise to pursue.

Figure 8.9. General Strategy Choices.

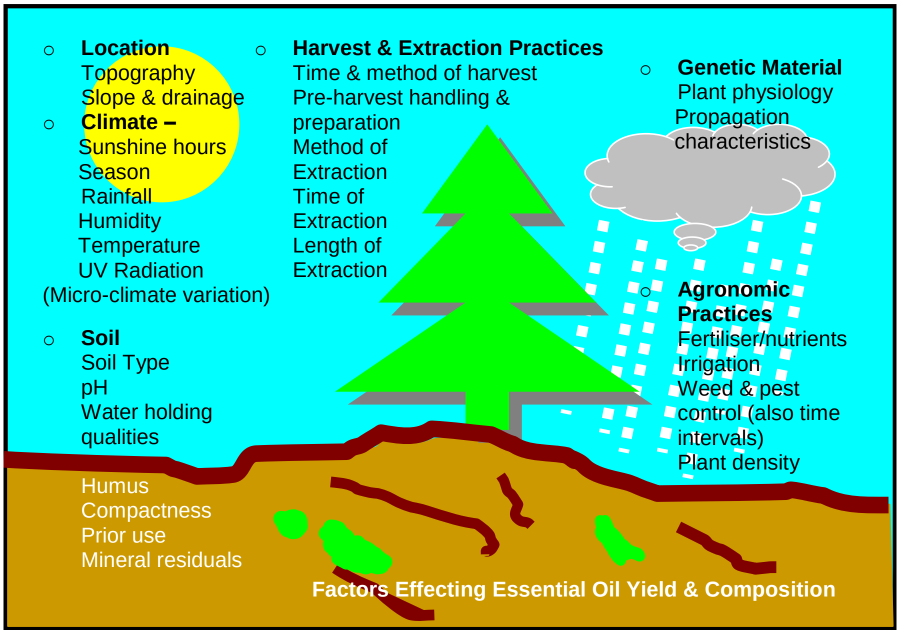

Figure 8.10. Factors Effecting Essential Oil Yield and Composition.

PLANNING FIELD AND TECHNICAL DEVELOPMENT

The objective of planning technical and field development is to set up a project roadmap, where agronomic research and development will follow. This will require identifying the most important factors that influence the quality and yield of the essential oil and economic sustainability of the project. The field development planning process will also assist in calculating the costs, time and resources required to develop the new essential oil and create a viable production enterprise.

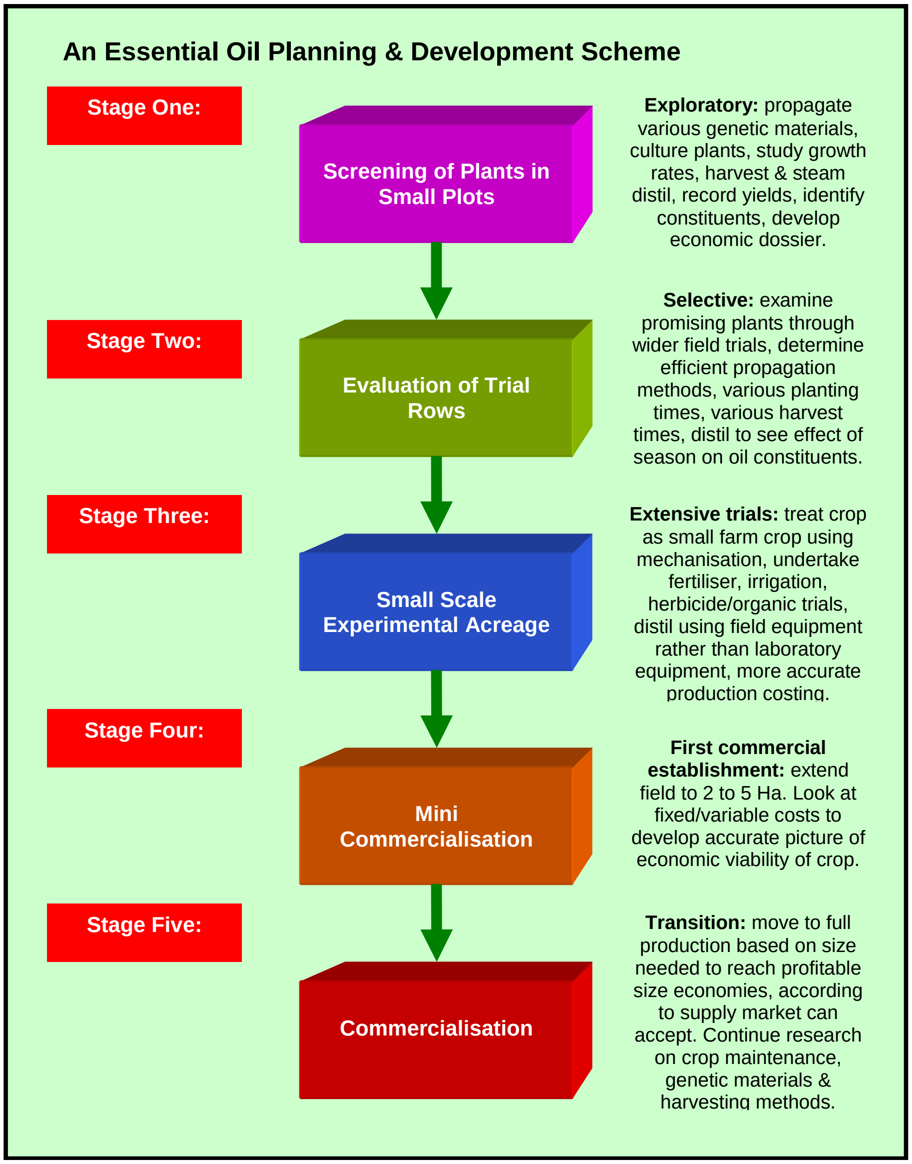

Figure 8.11. An Essential Oil Planning & Development Scheme.

The yield and chemical composition of an essential oil will be influenced by both intrinsic and extrinsic factors [33]. Some of these factors are shown in Figure 8.10. Some factors can be controlled, while other factor influences can be minimised or maximised through deliberate actions within the farm eco-system to negate or enhance their influence, while other factors are totally outside any field management control. To fully understand these variables would take a research cycle of between two to five years and over, depending upon the crop cycle. However, some factors, like disease incidence *(rust in mint)*, if left unchecked may not create critical issues until certain thresholds are reached, some months or even years after planting [34].

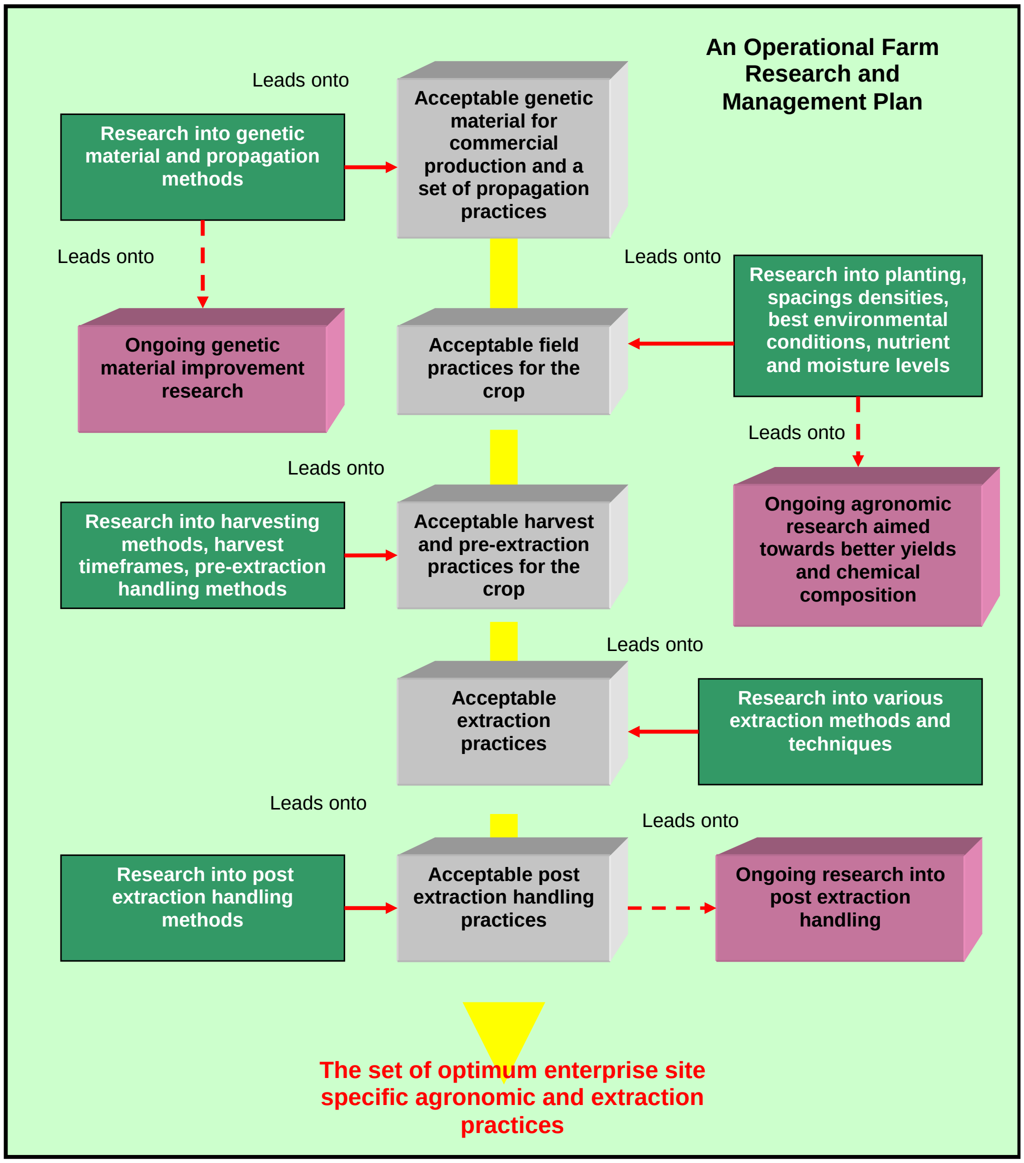

Figure 8.12. An Operational Farm Research and Management Plan.

Lawrence outlined a specific essential oil development scheme that leads to increased commitment only after the previous stage has been satisfactory completed with positive outcomes [35]. The advantage of this approach is that resources and costs are only allocated to the project with promising agronomic and extraction results. Lawrence's scheme also allows for multiple investigations of a number of crops in stage one. The scheme also allows specific learning about the selected crops in question along a progressive path. Lawrence strongly recommends trials and pilot stage production before committing totally to full scale commercial production and advises continuing research after commercialisation has taken place. A pictorial description of this type of approach is shown in figure 8.11.

A conceptual framework is needed to focus all research towards developing a set of practices and protocols at field level that will assist in producing an essential oil with a yield and chemical composition that is acceptable in the market place and allows creation of a financially viable enterprise. Farming for maximum yield does not always correlate with achieving a desired chemical composition of an essential oil. Agronomic techniques, harvesting, pre-extraction and extraction practices must be determined in a manner that provides both an acceptable yield and quality within the realm of production possibilities. The results from research at the field level will lead to a set of operational farm procedures that guide the management of propagation, planting and maintenance, harvesting, extraction and post harvest handling. An operational farm research management framework is shown in Figure 8.12.

After examining and researching the factors that affect yields and oil composition, a procedure manual of 'best practices' at farm level for the production of the essential oil should be written. The set of procedures should include propagation guidelines, preparation of land, the desired soil conditions, methods of planting and densities, growth cycle parameters like pest and weed control, nutrient and water management, determining optimal harvest times, harvesting methods, pre-extraction treatment of foliage, extraction procedures and post extraction handling and oil storage [36].

Before any research commences, one of the keys of planning and achieving a successful outcome is to identify the specific causes and effects on yield and quality, so focus can be put upon researching specific levels. Decisions will have to be made between a number of research priorities due to the multiplicity of factors, varying degrees each factor influences yield and quality, resource limits, time, available competencies and cost. The variables that most influence oil quality and yield should be selected for investigation. Potential factors influencing yield and quality can be mapped out on the Ishikawa (fishbone) diagram approach as shown in Figure 8.13.

Usually specific crop information is difficult to obtain, especially information relevant to site specific development. Focus should be put on manipulating factors that will improve yield and achieve a desired oil constituent profile. Thus research should be focused on two facets of development;

1. Adapting the crop to current conditions to maximise site specific yields and constituent profile, through varying nutrients and application levels, and
2. Improve efficiency through upgrading methods which can influence decrease operational costs, such as moving from manual labour to mechanisation, from lab to field propagation or from traditional ways of cultivation to more efficient ways of cultivation.

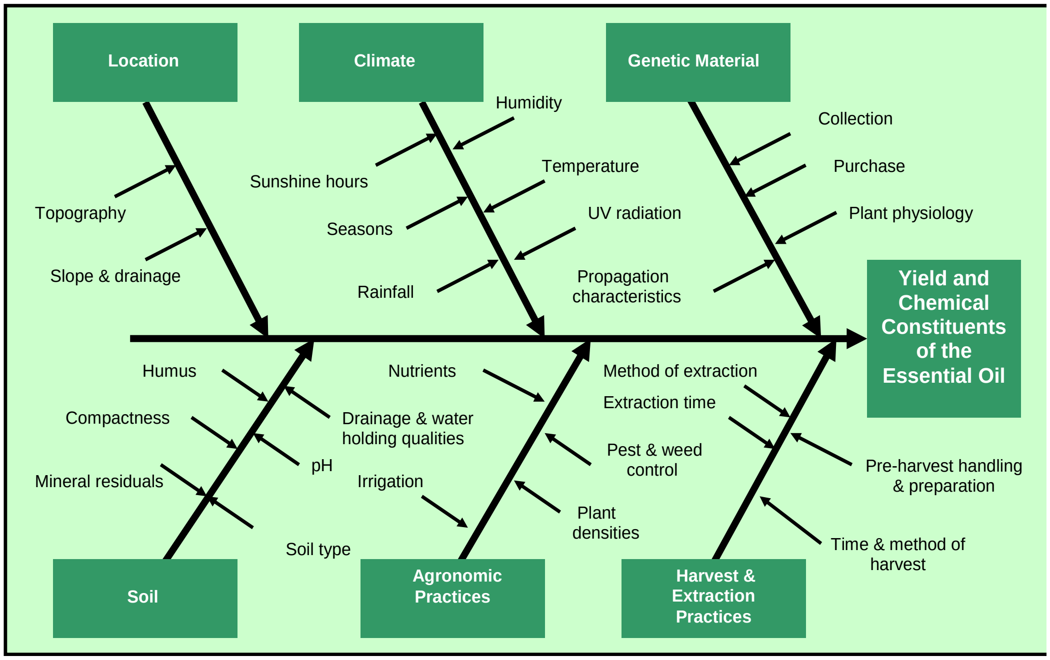

Figure 8.13. Factors Influencing Essential Oil Yield and Constituents on a Ishikawa (fishbone) Diagram.

The following basic questions can assist in prioritising research;

1. What are the specific technical goals and objectives?
2. What are the major technology, infrastructure and climatic constraints (boundaries)?
3. What are the areas where innovations will develop quick improvements?
4. What is the probability of successful outcomes?, and
5. How do we choose between successful outcomes?

Setting priorities will involve comparing the benefits expected from each focus area against the expected costs of undertaking the research and probability of success. Priority can be focused on achieving various parameters, such as;

a. overall high yield and specified oil constituents (which represents the 'quality' desired),
b. emphasis on high yields above other factors, or
c. emphasis on oil quality above other factors.

If possible, a potential hypothesis that can produce multiple solutions *(i.e., yield and quality),* should be constructed before any fieldwork is undertaken, as a means to keep research and development costs within reasonable limits.

Modifying *'off the shelf solutions'* and knowledge can solve many problems and should be considered first. An *'off the shelf solution'* is a research result that has proved positive, but not tested in the site specific project that is intended. This will save project time and reduce cost. Importing ideas, practices and equipment may not always suit local conditions and will be expensive. Similar crops within the region may have methods and equipment that may be easily modified to lead to a more effective solution. High improvements in yield and gaining the desired oil constituents can often be achieved through low cost methods, for example high yield responses to fertiliser application, finding the point where greater application gives only marginal returns [37]. Unexpected costs should also be identified, such as the time to clean out vats between processing multiple crops.

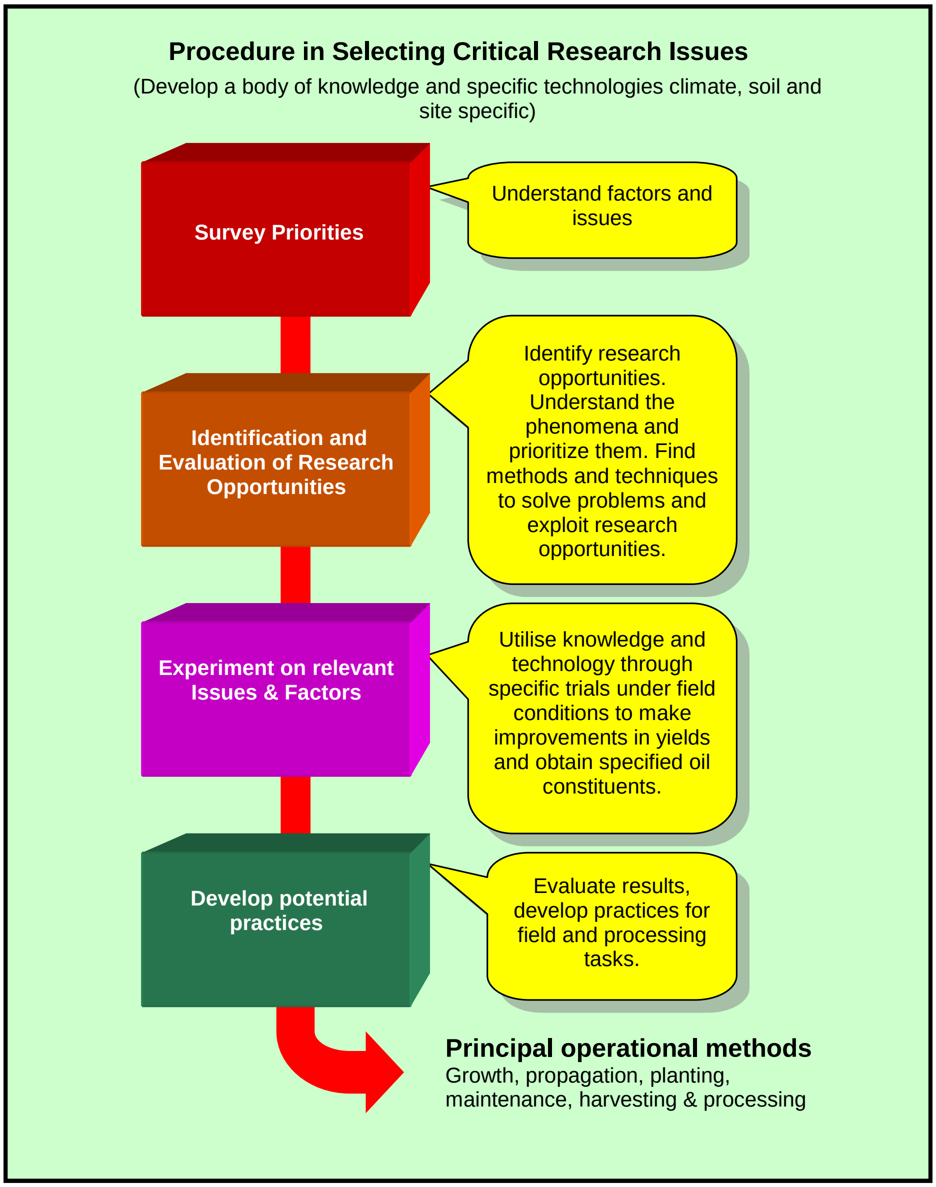

Figure 8.14. A Procedure in Selecting Critical Research Issues.

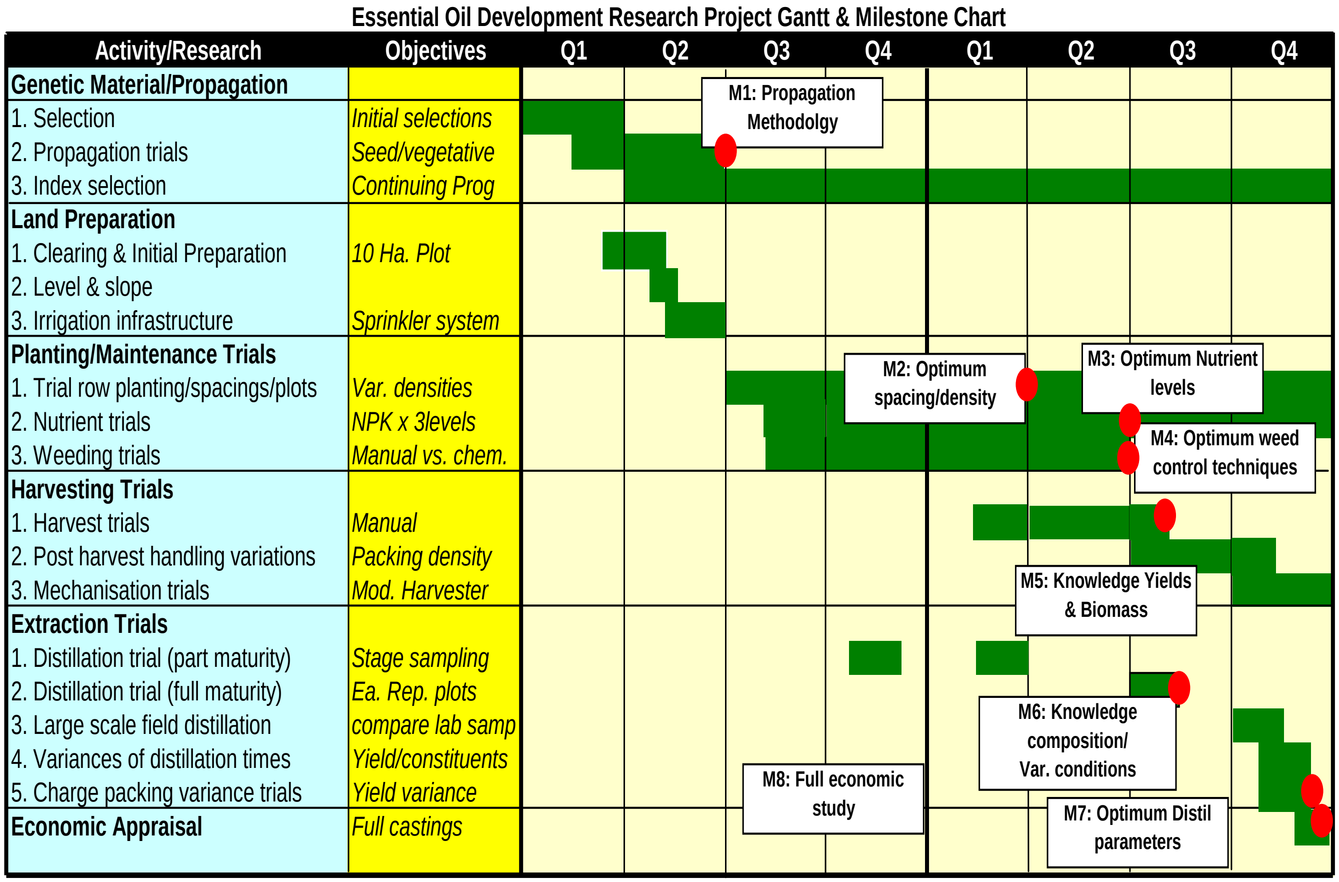

Figure 8.15. Research Project Gantt Chart.

Table 8.4. Budget Items for an Essential Oil Research Project

Budget Items for an Essential Oil Research Project
1. Capital Equipment and Infrastructure Development a) Land Preparation • Field preparation • Fencing • Buildings (equipment storage, office, processing equipment, etc) • Access roads and internal roads • Dams and irrigation equipment b) Farming Equipment • Tractors and accessories • Ploughs, etc • Basic farming implements c) Harvesting Equipment • Harvester and foliage bins • Cart and/or field trays d) Processing Equipment • Field and/or commercial distillery • Source for steam generation e) Laboratory Equipment • Laboratory distillation equipment • Glassware • Scales • GC (optional) f) Regulatory Compliance • Any licenses relevant to rural operations
2. Project Costs a) Seed and/or other genetic materials • Cost from seed supplier/merchant • Travel and costs of field procurement b) Nursery • Seed germination housing (pest, sun and weather proof) • Potting transfer facility (weather protected) • Tissue culture facility (if required) • Nursery materials c) Farm Chemicals and Supplies • Fertilisers • Pesticides/Herbicides • Other agricultural materials d) General Overhead Costs • Electricity, rates and other expenses • Insurance & sundries • Repairs and maintenance
3. Project Operational Costs • Wages & salaries (general workers) • Administration costs • Consultation, researcher costs and allowances

- Travel and accommodation
- Other operating expenses

Other factors may require capital intensive solutions, where cost competitive production is a factor in success and sustainability. For many agricultural activities the use of mechanisation has been proved to be more efficient than manual labour, even in very low labour cost countries [38]. However small scale decentralised mechanised production units may not always necessarily lead to lower production costs and there are often some advantages in flexibility, at early project stages [39]. The selection of appropriate farming, harvesting and processing equipment will depend on the technology available, the potential to adapt the equipment to the site and crop, and the finance available. Not much equipment will be available *'off the shelf'* and in most cases existing equipment will need to be modified. Practical experience during trials is needed to understand exactly what changes are necessary. Good metal and machine fabricators need to be identified.

On the whole, most essential oil enterprises trying to access the international market tend to fail from fundamental mistakes in the planning process, rather than complex technical and agronomic issues. Examples of these planning mistakes was the failure of rose oil development in New Zealand [40] due to poor exploration of the economics involved [41], and lack of success of many Australian lavender growers to gain international customers for their oils due to planting unacceptable genetic varieties [42].

The following procedure in figure 8.14. can be used for selecting the most critical issues to research.

All the conclusions made about the areas of research required and specific objectives can be collated into a research project plan. The desired outcomes can be marked as milestones within the plan. The required research competencies can be clearly identified and a budget developed. A sample essential oil development research project Gantt and milestone chart is shown in Figure 8.15.

All potential project costs can now be identified and a budget created for the project. At this stage a budget can be created to cover just the research phase or complete estimate until the commercialisation stage. Allowance must be made in the budget for unforseen blowouts in costs. These factors would include;

- Poor weather and unusual climate requiring extension of the project time,
- Inconclusive results requiring more time and resources to investigate due to weather, pests, etc.,
- General under-estimation of land development costs,
- Requirements for outside technical assistance on specific issues,
- General under-estimation of fabrication costs, and
- Equipment breakdowns and repairs.

Table 8.4. shows a list of items that should be budgeted for in a research and development project.

This chapter has outlined the planning process and recommended some conceptual thinking tools to create a development plan for the early research phase of the project. This process should provide some overall evaluation of project viability in regards to a selected crop(s) and identified both the opportunities and challenges involved. The planning process so far has focused on the questions of '*what to produce?*' and '*how to market?*' Chapter nine will be primarily concerned with the question of *how to produce?* and cover the relevant field development issues for an essential oil crop.

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Chapter 9

THE FIELD DEVELOPMENT PROCESS

This chapter covers some of the important technical aspects of the field development process. The chapter begins with a discussion about the concept of agriculture as a system. The implications of climate change on agriculture are discussed. Plant metabolic pathways are reconsidered in reference to their importance to influencing field practices before the chapter commences a discussion on the field development phase proper. This chapter continues to describe each step of the development process, including land selection, propagation materials collection, the nursery, land preparation, planting and maintenance, harvesting and distillation. Good Agricultural Practice (GAP) is discussed before the methods of budgeting to determine financial feasibility of a project at the conclusion of the chapter.

INTRODUCTION

The fieldwork related to developing an essential oil as a commercial crop requires an interdisciplinary approach. This requires the integration of botany, plant physiology, agronomy, engineering, chemistry and new product development skills, all within a business orientated framework [1]. The last three chapters were concerned with *what to produce* and *how to market* the potential end product. This chapter concerns itself with *Where and how to produce*, while keeping economic viability in mind. Figure 9.1. shows the various stages of the field development process that must be considered [2].

AN AGRICULTURAL ENTERPRISE AS A SYSTEM

Sustainable agriculture is now a major issue among academics, government, business, community groups and consumers around the world. This is reflected in the growth of sustainable farming practices, the growth of organic markets, growing community interest in where products come from and changing government policies. Emerging markets based on the *'natural paradigm'* should embrace sustainability as a major objective.

An agricultural enterprise is part of a complex ecological and sociological system, which is influenced by interrelated sub-systems including, physical, environmental, biological and social systems. We have managed these systems through the current state of our collective knowledge to exploit economic opportunities within a competitive environment. Through the *'green revolution'* of the 1960s improved genetic materials, mono-cropping, synthetic fertilisers, herbicides and pesticides, provided great improvements in productivity. However this dramatic increase in output led to a number of negative externalities which included soil erosion, loss of soil fertility, reduced biodiversity, pollution of ground water and rivers, which led to long term environmental consequences and unsustainable production [3]. The development of sustainable agriculture practices became popular in the 1970s as a passionate response to the above mentioned problems [4]. A new systems paradigm based on the two following principals emerged;

- Crops are developed with respect to nutrient and water cycles, energy flows, and the relationship between the target species and pests and competitors, and
- The system is managed through strategic and tactical planning, resource allocation and financial and economic considerations, governed by goals, attitudes, knowledge and values of the manager, working within the eco-system [5].

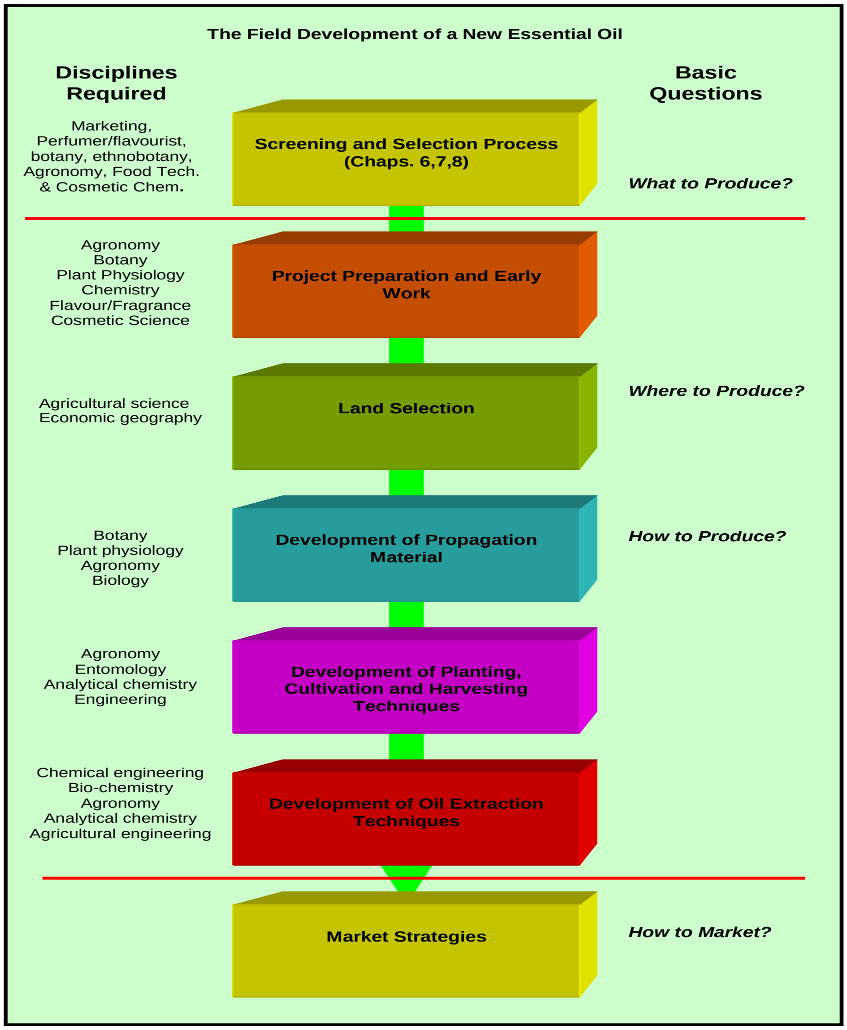


Figure 9.1. The Field Development of a New Essential Oil.

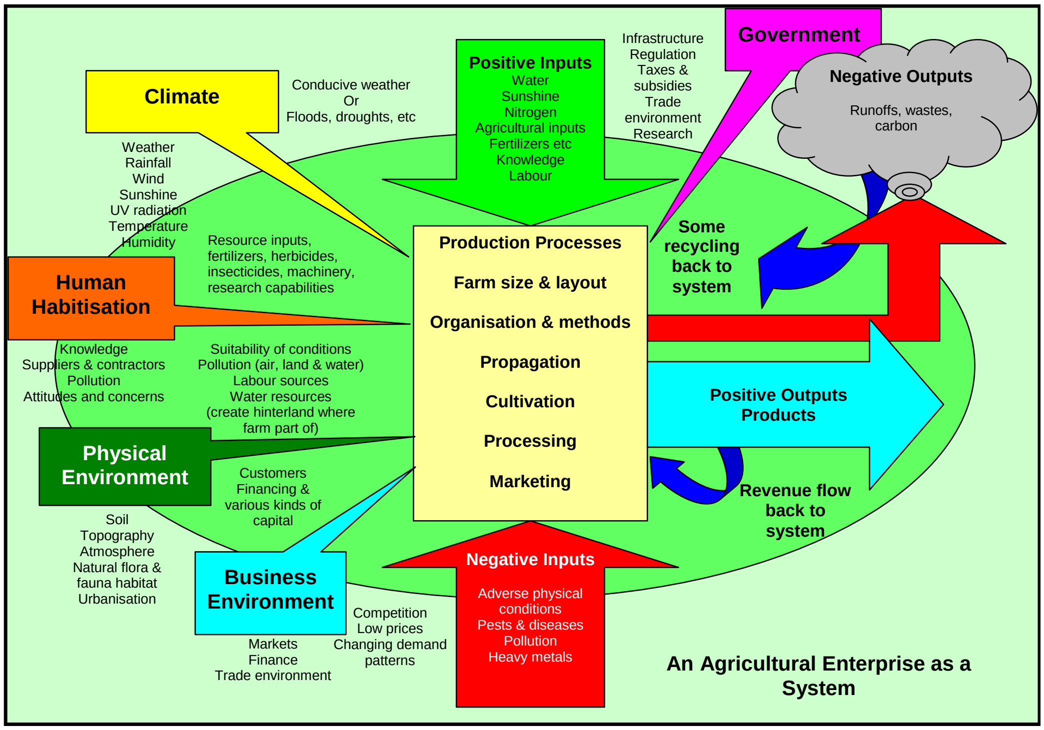


Figure 9.2. An Agricultural Enterprise as a System.

An illustration of the farm within an entire eco and human system is shown in Figure 9.2.

This farming paradigm shifted from just trying to treat the symptoms through alleviation or suppression to treating and curing the actual sources of problems in agriculture. Thus under a systems context [6] the major tools of management became;

7. Enhancing the re-cycle potential of biomasses to optimise nutrient availability and balance,
8. Securing favourable soil conditions for crop growth through managing organic materials and biotic activity,
9. Minimising losses due to solar radiation, air and water through microclimate management, water harvesting and soil management,
10. Developing genetic and species diversification, and
11. Enhancing beneficial biological interactions through maximising agro-biodiversity to promote beneficial ecological processes [7].

These principals and strategies have to be tactically applied in different ways to various farming models, differentiated due to climate, geographic, social and organisational diversity, as Table 9.1. demonstrates [8]. However the aim of each type of system is the same; to reduce the dependency on nitrogen fertilisers, reduce the levels of residual phosphorous fertilisers, reduce dependency on herbicides, find ways to manage weeds, break pest and disease cycles, increase total system water use and protect against soil erosion, in a way that maintains good crop yields and quality [9].

Table 9.1. Major Eco-Systems, Production Systems and Organisation

Major Eco-System Type	Production Systems	Organisational Form(s)
1. Arid Agro-Ecosystem	Agro-Horticulture-pastoral activities	a) small subsistence b) semi-subsistence, partly commercial farms c) Large family commercial farms along estate lines d) Commercial estates, mono-crop with hired management
2. Coastal Agro-Ecosystem	Livestock, fish, agriculture and horticulture	a) small subsistence b) semi-subsistence, partly commercial farms c) small commercial specialised family farms c) Large family commercial farms along estate lines d) Commercial estates, mono-crop with hired management
3. Hill and Mountain	Agriculture, horticulture and livestock	a) small subsistence b) semi-subsistence, partly commercial farms c) small commercial specialised family farms
4. Irrigated Agro-Ecosystem	Rice-wheat, sugar cane, cotton, soy, dairy and fish	a) small subsistence b) semi-subsistence, partly commercial farms c) small commercial specialised family farms c) Large family commercial farms along estate lines d) Commercial estates, mono-crop with hired management
5. Rainfed Agro-Ecosystem	Arable farming, agro-forestry and livestock	a) small subsistence b)semi-subsistence, partly commercial farms c) small commercial specialised family farms c) Large family commercial farms along estate lines d) Commercial estates, mono-crop with hired management

The concepts contained within systems agriculture provide an appreciation of the interrelationships between crops and farming variables. The objective of experimentation and research is to correlate productivity and sustainability during the field development process. In effect, the result of the field development process is to create a set of theories (or operational practices) that will develop a sustainable farming system. Sustainability in the agricultural production process has commercial implications. It is becoming an important issue on the minds of users, especially in regards to pesticide residuals [10], and is being used by some producers as a point of product differentiation.

CLIMATE CHANGE

Global warming and climate change is full of academic and political controversy, where fact and conjecture is fiercely debated [11]. Although evidence exists and is sometimes dramatically portrayed as signs of an impending global disaster, there are still scientists who are disputing that the current temperature trends are within the bounds of natural change based on historical data [12]. Conservative US politicians also dispute the issue where the US Government with Australia (until the election of a Labor Government in November 2007) failed to sign the Kyoto Protocol, claiming the economic costs of achieving 1990 CO_2 emissions are too high.

At the end of 2006, a film featuring the former Vice President of the United States Mr. Al Gore, *An Inconvenient Truth* dramatically and graphically showed a string of natural occurrences which were attributed to climate change, caused primary by carbon dioxide emissions [13]. Mr. Gore in his documentary showed that 10 of the hottest years in history had occurred during the last 14 years, the occurrence of much stronger hurricanes/cyclones and typhoons than ever before, more flooding and droughts across the globe, the permafrost in Siberia and Alaska melting, as well as the melting of the polar ice caps. Mr. Gore also showed evidence that the white house (under the Bush administration) had arbitrarily changed some of the conclusions of the EPA climate reports [14]. *An Inconvenient Truth* was released at a time which spurred on the arguments for action, but was also not without its criticism and found to be flawed in some of its factualism [15]. Ironically just 24 hours after the British court ruling that there were nine factual inaccuracies in *An Inconvenient Truth,* Mr. Gore was jointly awarded the Nobel Prize for peace jointly with the United Nations Intergovernmental Panel on Climate Control (IPCC).

It is not disputed that methane and carbon dioxide concentrations are continuing to rise in the atmosphere and the Earth is currently undergoing a period of high temperatures. There are many stories in the media about farming regions struggling with their traditional industries like the vineyards in Australia, South Africa and California, while at the same time, new regions are quickly developing new agricultural industries, like the wine industry in Nova Scotia, due to the decline in frosts [16]. Wide evidence exists of loss of soil moisture due to dehydration, rising land salinity levels in many dry land regions, increasing carbolic acid in the rain changing pH levels in the soil, increased growth of algae, and the increasing incidence and threat of bush or wildfires around the world.

An Australian CSIRO report put the above concerns to the Australian Government stating that *"…Australia is one of many global regions experiencing significant climate changes as a result of global emissions of greenhouse gases (GHGs) from human activities"* [17]. The report confirms that average temperatures have globally risen over the last 100 years and there are marked declines in precipitation in some regional areas, while increases in others. The report concludes that even though initially there are some benefits of longer day period and shorter winters, with increasing crop yields; rising temperatures, droughts and adverse weather conditions will negate these benefits and become a factor threatening the vitality of agriculture in the future. A more recent report released by the IPCC based on actual measurements rather than projections, establishes that greenhouse gases in the atmosphere are increasing much faster than previously estimated and are already over the threshold that could be potentially dangerous to climate change [18].

At the time of writing there are signs that political figures are slowly bringing the issue up more seriously, as is the case of China [19] and the US. However with the global financial crisis taking most attention of World Governments, it is doubtful that any serious international agreements can be made over the next couple of years.

Some of the challenges that climate change may bring to agriculture and should be considered are;

- *Habitat Change:* The habitat is already undergoing some changes [20], which is improving environmental conditions for some species, while at the same time denigrating the environment for others. Some pests will become more evasive to crops, while others will disappear. There will be increased geographical scope for planting some crops, but a narrower the scope for others. The viability of some existing growing areas will be threatened [21]. For example, a 1.0 C. degree rise in average temperatures will chance core conditions for 25% of eucalypts in Australia. The consequences of this, is not currently known as to whether they will adapt new conditions or become threatened with area extinction [22].

- *Loss of Arable Agricultural Land:* Decreasing precipitation, increasing salinity and long droughts in areas adjacent to drylands is leading to a loss of arable farming lands in many continents [23].
- *Increase in Adverse Weather Conditions:* Weather conditions can be expected to be more abnormal in the future bringing floods and droughts to different geographical regions. The decrease of snow in alpine areas will create water management concerns in respect to drought and flood management, and
- *Increase of External "Natural" Threats:* Bush or wild fires will increase bringing threats to farms and crops and require consideration in farm layout planning and management.

At the field level crop stress will become a prime agronomic issue. Atmospheric warming will expose crops to higher temperatures, which will lead to changes in plant physiology at the cellular level. Once optimal temperature ranges pass for specific plants, heat stress will develop, causing various plant metabolism changes that will slow down cell growth dramatically [24]. The effects of climate change on crops will be profound, not at least upon the basic plant processes within the plant metabolism [25]. Plants have metabolite and growth responses to salinity, heat stress, evaluated CO_2 and drought (Table 9.2.), which would most likely lead to changes in whole plant carbon and nutrient budgeting, leading to changing growth patterns.

Table 9.2. Summary of Plant Responses to Environmental Change

	Salinity	Heat Stress	Elevated CO_2	Drought
Primary Metabolites	Slight relationship	Varying relationships	Unknown	Strong relationship
Secondary Metabolites	Positive relationship	Positive relationship	Unknown	Strong relationship
Growth	Strong relationship	Strong relationship	Unknown	Strong relationship

PROJECT PREPARATION AND EARLY WORK

Project preparation and early work involves the determination of the major factors that influence yield and oil quality. The analysis of the factors that lead to optimum plant productivity is important in the field development stage. It is important to know how each factor interacts. The key to optimum productivity may rest on a single influencing factor.

Thus efforts to uplift yield and quality may have little effect until this single factor is addressed. In other cases, two of more factors may be either co-limiting or co-synergists. The first step in this investigation involves matching the climate, weather, moisture needs of the proposed crop to the locality available.

There is a need to understand the basic paths through which aromatic materials develop within the plant metabolism. This will assist in the development of nutrient and moisture regimes and the timing of harvest. Paramount to good yields and quality is the quality of the genetic planting material. The selection of the correct material for cultivation is important.

CLIMATE AND MOISTURE

Temperature and moisture are two of the most important factors regulating plant growth. Plant adaptability to temperature is the parameter that has most influence upon its growth rate in a new location. Moisture is a factor that greatly influences the vigour and vitality of the plant.

Plants originating from various indigenous environments exist with particular sets of growth and behaviour characteristics. The basic plant climatic zones can be describes as;

- Tropical Zone where all mean air temperatures are above 18-20°C, where no frosts exist. This area covers the Earth between the Tropic of Capricorn and Tropic of Cancer (23.5°S & 23.5°N).
- Tropical Monsoonal Zone where part of the tropical zone which has a distinct dry season of 3-5 months, where the dry seasons usually increase mean temperature two or three degrees above the wet seasons. Dry seasons are usually cloudless or spasmodically clouded days and these zones are coastal along the equatorial region.
- Sub-tropical Zone where the coldest month of the year would have a mean temperature above 16°C, where only occasional frosts would occur. This zone occurs between 23.5-30°+ latitudes.
- Arid-Dryland Zones where mean temperatures are above 18°C and there is very little precipitation. Arid-dryland zones are sometimes accompanied with soil salinity, which together with high temperatures and salinity make the land marginal for agriculture.
- Temperate Zones where temperatures are high enough for around 6-7 months each year for active plant growth. These zones occur above the mid 30°s latitudes and in the mountainous areas of sub-tropical and tropical zones.
- Boreal Zones where mean temperatures are around 10°C and may warm up enough only for plants to grow two to three months a year. Boreal zones also exist in high altitude areas of the other zones.

Examples of some types of crops that grow in these zones are indicated in Table 9.3.

Plants introduced into new areas will exhibit different phyto-synthetic responses (the process of bonding CO_2 with H_2O to make basic sugars and oxygen). This is directly related to biomass yields in the field [26]. Plants that have difficulty adapting will become stressed, so temperature is a major factor in adaptability. Plant adaptation to higher temperatures is related to photosynthesis efficiency. Four basic photosynthesis systems exist in plants [27];

Table 9.3. Examples of Crops Grown in Different Climate Zones

Zone	Crops	Aromatics	Comments
Tropical	Palm oil, rubber, cocoa, banana,	Citronella, Ylang Ylang, Vetiver, lemongrass, ginger, vanilla	The main zone for chill-sensitive evergreen perennials. Crops that benefit from chills like apples are not commercially successful in this region. Warm season annuls successful, whereas cool-season annuls not commercially successful.
Monsoonal	Rubber, rice, some citrus fruits, mango	Patchouli	With irrigation this region is similar to the tropical zone, although crops that need flowering to fruit like mangoes grow successfully in this region.
Sub-tropical	Sugar, maize, sunflower, oranges	Citrus, petitgrain, neroli, tea tree	Areas around the Mediterranean Sea are sub-tropical as well as most of the Eastern Seaboard of Australia, above Sydney until the Tropic of Capricorn. A broad range of species grow successfully; evergreens, deciduous trees and warm season annuls. Some tropical and temperate crops are successful, near their respective temperature ranges, i.e, cool season annuls.
Arid-Dryland	Some citrus fruits in irrigated areas. *Hoodia* cacti species in Southern Africa.	Eucalyptus species	High temperatures and salinity make the land marginal for agriculture, unless areas are irrigated.
Temperate	Potatoes, lettuce, carrots, apples, pears	Most herbaceous oils, peppermint, Lavender, etc	Cool season annuls from spring to autumn. Winter can cause dormancy. Some warm season annuls can be successful if temperatures are high enough for a sufficient period of time. Deciduous trees that require chills like apples and pears very successful, as well as frost resistant perennials and conifers.

Table 9.4. Temperature, Rainfall and General Habitat Parameters for Some Aromatic Plants

Plant	Botanical Name	Habitat	Temperature Range Optimal Max.				Rainfall Lat. Range (mm)			Altitude	Diurnal Radiation
Lavender	*Lavendula*	Mediterran	15°C	28°C	7°C	24°C	500mm	1000m	35-	<1700m	Direct Sunlight
Angelica	*Angelica*	Temperate	5°C	19°C	-	-	600mm	1300m	30-	700-	-
Ylang Ylang	*Cananga odorata*	Tropical	-	-	21°C	32°C	1500m	2000m	10-	<400m	Direct after maturity
Lemon	*Citrus limon*	Mediterran	15°C	18°C	-	-	250mm	1250m	40°S-	-	Direct exposure
Coriander	*Coriandrum sativum*	Versatile	6°C	17°C	4°C	28°C+	1500m	2500m	40°S-	<2200m	Direct exposure
Lime	*Citrus aurantifolia*	Tropical	22°C	28°C	18°C	32°C	1250m	2500m	30°S-	<2200m	Direct Sunlight
Cumin	*Cuminum cyminum*	Sub-	17°C	26°C	9°C	26°C	800mm	2700m	Along	lowlands	Direct exposure
Galanga	*Alpinia galanga*	Tropical	24°C	30°C	18°C	34◦C	1500m	3000m	20° N&S	lowlands	Partial Shade
Lemon Balm	*Melissa officinalis*	Temperate	14°C	25°C	6°C	30°C	500mm	1300m	30-	<1700m	Direct exposure
Sandalwood	*Santalum album*	Arid-	22°C	30°C	10°C	38°C	450mm	3000m	20° N&S	<2500m	Direct exposure
Aloe	*Aquilaria*	Tropical	20°C	22°C	18°C	32°C	-	-	0-	<1000m	Direct sunlight
Dill	*Anethum graveolens*	Temperate	15°C	18°C	6°C	26°C	500mm	1700m	28-	-	Direct sunlight
Cardamom	*Elettaria*	Temp/Trop	-	-	10°C	35°C	1500m	1700m	5-	<1400m	Shaded areas
Hyssop	*Hyssopus officinalis*	Mediterran	10°C	24°C	7°C	36°C	600mm	1000m	25-66°	<2000m	Direct sunlight
Geranium	*Pelargonium*	Temp/Sub-			10°C	32°C			30-50°	<1200m	Light shade
Perilla	*Perilla frutescens*	Tropical							0-50°N		Light shade
Rue	*Ruta graveolens*	Mediterran	17°C	26°C	4°C	30°C	500mm	1500m	30-45°N		Direct sunshine
Vanilla	*Vanilla planifolia*	Tropical	21°C	30°C	10°C	33°C	1500m	3000m	20°S-	<700m	Part shade
Artemisia	*Artemisia vulgaris*	Tem/tropic							0-60°N		Direct sunlight
Tea tree	*Melaleuca*	Sub-	21°C	30°C	10°C	45°C	800mm	3000m	0-	<700m	Direct sunlight
Caraway	*Carum carvi*	Temperate	16°C	20°C	7°C	26°C	600mm	1300m	45-60°N		Direct sunlight
Lemongrass	*Cymbopogon*	Grasslands	24◦C	30°C	18°C	34◦C	1500m	3000m	20° N&S	<1400m	Direct Sunlight

- The C_3 plants incorporate CO_2 into 3-carbon compounds. The stomata (pores in the leaves through which CO_2 is consumed and O_2 expelled during photosynthesis) is open during daylight hours, the enzyme rubisco directly uptakes CO_2. This is the most efficient photosynthesis mechanism within the plant kingdom and works well during cool and moist conditions under normal light as less energy is required. Most plants are C_3.
- The C_4 plants incorporate CO_2 into a 4-carbon compound. The stomata are open only during daylight hours. The vehicle for CO_2 uptake is PEP carboxylase which transfers it directly to rubisco for processing, which is fast and moisture efficient. There are numerous species with this type of respiratory system, mainly plants with habitats in warmer conditions, including most tropical grasses.
- Plants where photosynthesis alternates between the C_3/C_4 mechanisms, and
- Crassulacean Acid Metabolism (CAM) photosynthesis where CO2 is stored as acid before photosynthesis. In this mechanism the stomata opens during darkness where evaporation rates are usually lower. During daylight hours rubisco breaks down the CO_2 for photosynthesis. This mechanism is more moisture efficient than C_3 plants due to night collection of CO_2. When droughts occur the stomata remains closed and the acids are utilised as needed for photosynthesis. Cacti are CAM plants.

The phytosynthesis systems of plants will strongly influence plant adaptation to new environments. Among the C_3 species, the herbaceous annuls, evergreens and non-leguminous plants will adapt better than the perennial woody species, deciduous trees and leguminous plants that fix nitrogen [28]. C_4 species should adapt to higher temperature conditions better than the other metabolisms. A plant genotype may have a number of phenotype variances which exhibit different tolerances to different climatic conditions [28]. Plants are capable of adapting to different habitats, however the introduction of new crops from cooler regions where the photosynthesis system may be very sensitive to heat, may require breeding to improve tolerance in hot weather [29].

Potential upper temperature limits will depend on the level of plant stress to the temperature range in the new environment. Stress is the key issue to monitor. At the lower temperature levels, below 10°C plant growth becomes severely retarded. Effective growth ceases around 7°C for most plants [30]. Thus the most suitable upper and lower temperature levels for plants needs to be ascertained before introduction. The mean temperatures, sunlight and day length will define the maximum limits of potential productivity, while the low temperatures and moisture levels through precipitations will define the restrictions on plant growth. Table 9.4. shows some temperature and other habitat parameters for a selection of aromatic plants [31].

A basic evaluation of moisture requires the review of effective rainfall. Effective rainfall is the amount of rain necessary to commence and sustain plant growth. However some rainfall is lost in evaporation (evapotranspiration) and run-off. Thus a quick measure of determining the rainfall needed to start and sustain plant growth is to add 50% to necessary moisture required by a particular plant and compare this figure to the mean rainfall figures of the area in question.

Historical data for a long period is best to determine the mean and droughts must be taken into account for drainage and irrigation planning during the land preparation stage.

However the above analysis can be misleading as it lacks sensitivity, not taking into account the intensity and distribution of rainfall during the year. In arid and monsoonal regions growth after rain can be vigorous, so additional analysis should be undertaken to determine the annual growing season. Issues such as the number of dry days in succession are important for wilting and growth inhibition. Soil moisture absorption ability, infiltration rate, and the topographic features such as slope, ground cover, etc., also influences how much rainfall actually benefits the crop. These factors also bring up issues of potential for root rot, pathogen development, competitive weed growth and their influences upon growth rates.

A process to make an assessment about the suitability of a particular area for a specified crop would involve the following steps:

1. Obtain weather station and climatic data for the area. Obtain daylight and dark hours for the year. Obtain the number of rain/dry days averages for each year.
2. Analyse the data to obtain mean and extreme temperatures on a daylight and nightly basis for each year. Calculate the effective rainfall and the effective growing periods.
3. Compare this data to the plant habitat data available to see if there is a match.
4. If there is a mismatch, make predictions about the potential adaptability of the plant to the new environment (this may require some garden trials to assist and confirm deductions)
5. Look around for similar plant species growing in the area and observe their growth behaviour and growth periods.
6. Make predictions about possible planting, growth and harvest times based on the above information.

Some other issues to consider are;

- The effect of dry seasons on flora and ground cover as it may have a tendency to put most plants into a dormant state, where annuls without cover crops may become stressed,
- Storm activity may cause high winds and lightening strikes, which can initiate wildfires, and
- Excess rainfall can cause heavy erosion and loss of top soils with channel run-offs, leading to loss of organic matter in the soil.

PLANT AROMATIC MATERIAL COMPOSITION AND PATHWAYS

An essential oil or aromatic material within a plant is primarily a substance comprising of volatile compounds which are formed through the plant metabolism. The plant metabolism is influenced by both intrinsic and extrinsic factors from the field perspective. The chemical, physical and olfactory characteristics of the essential oil are the factors that contribute to the overall quality of the product. Yield has an important bearing on the overall economics of a crop. The regulatory framework prescribes what is and is not allowable in the composition of an essential oil. Thus the starting point in physical crop development is a full analysis of the essential oil and a mapping of the metabolic pathways that produce the composition the essential oil.

The sensitivity and methodology of analytical phytochemistry has improved in leaps and bounds over the last decade to provide an almost complete analysis (80-90%) today, compared to around 40-60% a decade ago for very complex compounds. Table 9.5. shows a summary of the composition of a tansy oil chemotype (*Tanacetum vulgare* L.) [32]. It is important to consider the trace and minor compounds within varying varieties of a genotype and within the desired chemotype, because of their contribution to odour profile, which may be desirable or undesirable in the product. This will be discussed shortly.

Theoretical production ecology is a method based on a systems approach to agriculture to manage crop productivity through quantitative modals. This method identifies the variables and processes related to plant growth and seeks to find the optimum field methods to manage them. A study of the plant physiological and biochemical processes is the foundation upon which field management parameters can be developed and set. Thus, the composition analysis of the essential oil should lead to a study of how the important compounds are formed through the metabolic pathways specific to the plant as shown in Figure 9.3.

Table 9.5. Composition of a Chemotype of *Tanacetum vulgare* L. (Tansy)

a-pinene	5.0%
Camphene	1-2%
Sabine	1.5%
B-pinene	>2.0%
Myrcene	0.5%
a-terpinene	0.5%
Cymene	0.7%
1,8-cineole	16.0%
Gamma-terpinene	0.9%
Terpinolene	0.1%
Camphor	16.0%
Borneol	1.8%
Terpinene-4-ol	2.4%
a-terpineol	1.6%
Mytenal	3.0%
Mytenol	25.0%
Isobornyl acetate	0.5%
Trans-Sabinyl acetate	2.5%
a-Copeane	0.3%
Caryophyllene	0.3%
Spathulenol	1.3%
Caryophyllene oxide	1.0%
Vulgarol	1.0%

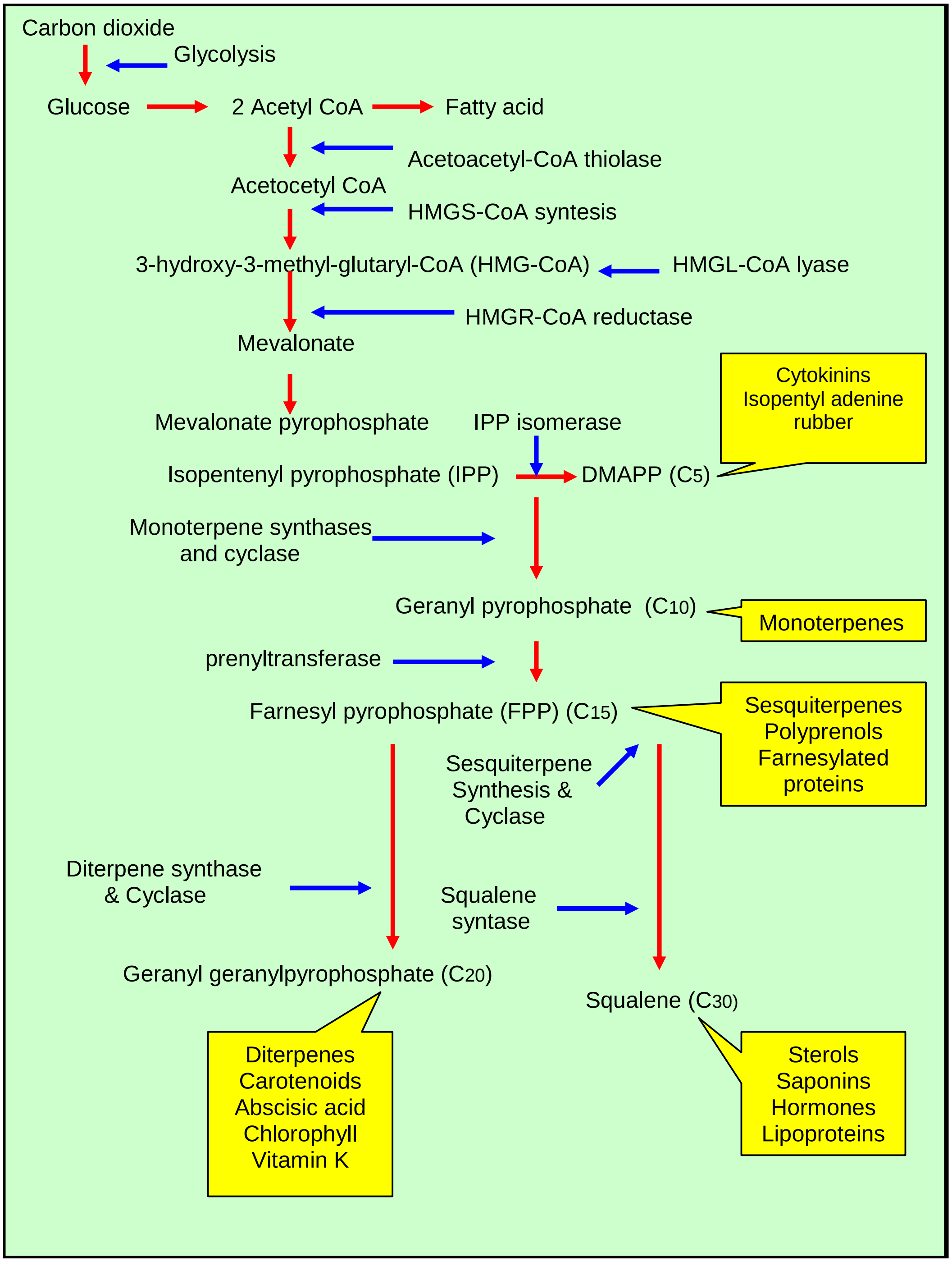


Figure 9.3. The General Plant Metabolic Pathways for Secondary Metabolite Production [33].

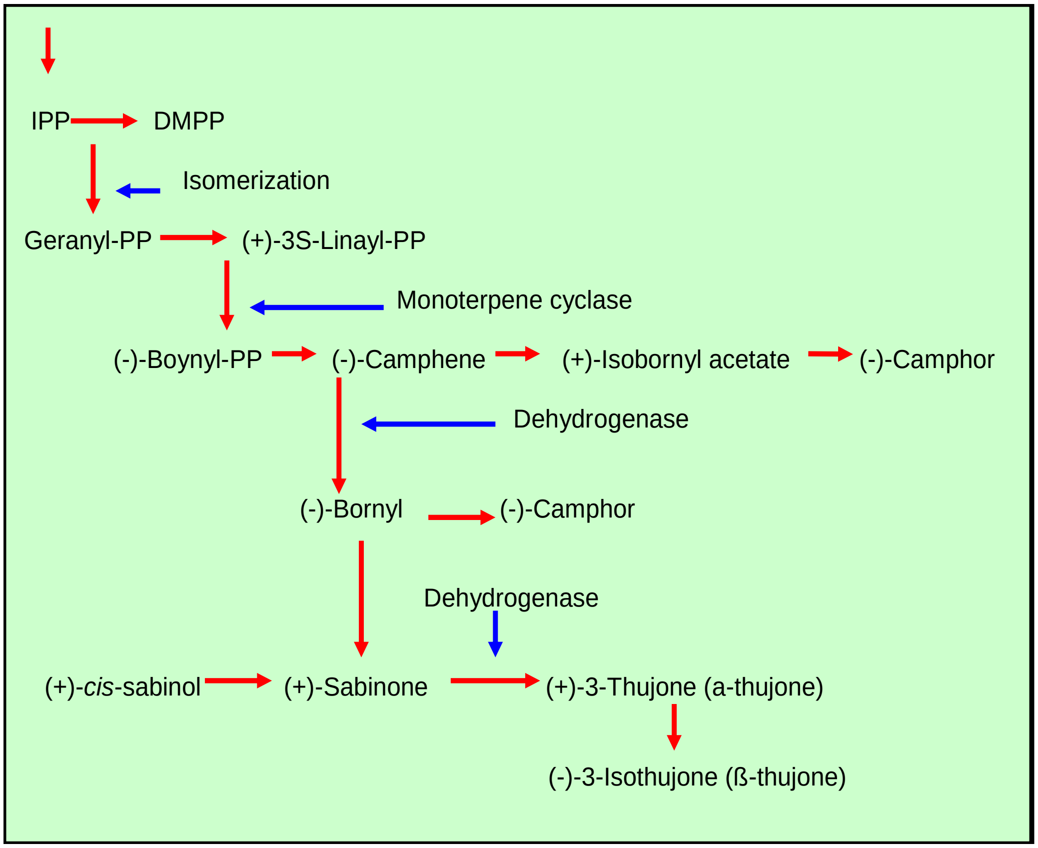


Figure 9.4. The Specific Pathway for the Production of a- and β-Thujone [34].

Investigation of the compounds found in an essential oil can lead to the mapping of specific pathways to the formation of important compounds as is shown in the example of *a*- and *β*-thujone production within the plant metabolism, as shown in Figure 9.4.

Through mapping out the specific pathways, the interrelationships between the various compounds in the essential oil are shown, either as products of, or precursors for. This specific pathway map can provide insights into how the various compounds in the essential oil are formed and perhaps provide some keys as to how to manage optimum quality and yield, through specific nutrition regimes, crop maintenance, harvesting and extraction, when examined with the parameters in production ecology. A production ecology model would examine the factors of heat, light, water and soil nutrients upon the plant metabolism and production of desired compounds within the plants. Then it is a matter of trying to determine what will be the optimal set of practices to produce the most desirable quality/biomass set.

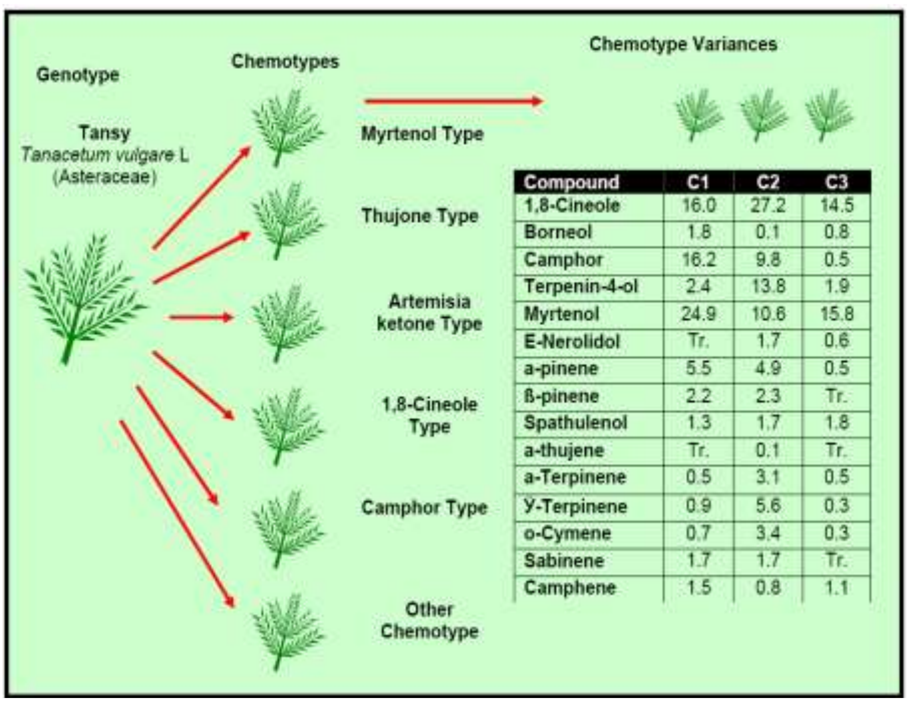
SELECTION AND ACQUISITION OF GENETIC MATERIAL FOR PLANTING

The correct selection of genetic material for planting and cultivation is crucial to the project. Many projects have failed because the selected material was the wrong chemotype or was of poor quality, leading to the production of a commercially unsuitable material.

Tansy is a perennial herbaceous flowering plant in Europe, the United States and Asia. More than five specific chemotype deviations from the main genotype have been reported with a number of sub-chemotypes [35]. Within a small geographical distance, chemo-diversity is large. Figure 9.5. depicts the reported chemical diversity of *Tanacetum vulgare* in Northern Europe.

Chemotype variation is widespread through the plant kingdom, where many species contain chemotypes that are very different in composition from each other as a summary of Australian species in Table 9.6. indicates [36].

There are essential oils on the market that are claimed to orginate from the same botanical species but display very distinct and different characteristics. For example this is the case with basil oil *(Ocimum basilicum* L.*)* where a number of products from different sources are on the market with different chemical and olfactory profiles. Table 9.7. shows the difference in major chemical constituents of basil oil from five different sources with a description of their olfactory profiles [37].



Compound	C1	C2	C3
1,8-Cineole	16.0	27.2	14.5
Borneol	1.8	0.1	0.8
Camphor	16.2	9.8	0.5
Terpenin-4-ol	2.4	13.8	1.9
Myrtenol	24.9	10.6	15.8
E-Nerolidol	Tr.	1.7	0.6
a-pinene	5.5	4.9	0.5
ß-pinene	2.2	2.3	Tr.
Spathulenol	1.3	1.7	1.8
a-thujene	Tr.	0.1	Tr.
a-Terpinene	0.5	3.1	0.5
У-Terpinene	0.9	5.6	0.3
o-Cymene	0.7	3.4	0.3
Sabinene	1.7	1.7	Tr.
Camphene	1.5	0.8	1.1

Figure 9.5. Chemotype Variances within the Genotype *Tanacetum vulgare* L.

Table 9.6. A Summary List of Australian Species with Chemotype Variations

Species	Chemotype	Major Individual Components of Leaf Oil	
Eucalyptus nova-anglica	No. 1	E-nerodial	77%
	No. 2	a- & β-eudesmol	42%
	No. 3	aromadendrene	33%
Eucalyptus camphora	No. 1	1,8-Cineole, Limonene	70% & 5%
	No. 2	1,8-Cineole, a-Pinene	84% & 7.8%
	No. 3	1,8-Cineole, eudesmol	56% & 25%
	No. 4	Eudesmol, p-Cymene	46% & 15%
Eucalyptus cloeziana	No. 1	a-Pinene, β-Pinene	78% & 6%
	No. 2	Tasmanone	96.4%
Eucalyptus crebra	No. 1	a-Pinene, β-Pinene, Limonene, Aromadendrene, globulol	26%, 30%, 7%, 5% & 12.5%
	No. 2	1,8-Cineole	65%
Eucalyptus dawsonii	No. 1	Isobicyclogermacral	44%
	No. 2	Elemol, Eudesmol	16% & 63%
Eucalyptus quadrangulata	No. 1	P-Cymene	33%
	No. 2	a-Pinene, 1,8-Cineole, γ-Terpinene, p-Cymene	10%, 25%, 19% & 17%
	No. 3	a-Pinene, 1,8-Cineole	25% & 55%
Eucalyptus radiata	No. 1	a-Pinene, Limonene, 1,8-Cineole	14%, 5% & 71%
	No. 2	a-phellandrene, p-cymene, 1,8-Cineole	18%, 14% & 13%
Melaleuca viridiflora	No. 1	E-methyl cinnamate	80%
	No. 2	1,8-Cineole	48%
	No. (Var. 2)	a-Pinene, 1,8-Cineole, terpinolene	9%, 0.3% & 32%
	No. 2 (Var. 3)	a-Pinene, 1,8-Cineole	29% & 11%
Melaleuca citrolens	No. 1	Neral, Geranial	<40%
	No. 2	Citronellal, Neral & geranial	20-30%
	No. 3	1,8-Cineole	40%
Melaleuca ericifolia	No. 1	d-Linalool	<50%
	No. 2	1,8-Cineole	<60%
Melaleuca quinquenervia	No. 1	1,8-Cineole, viridiflorol	
	No. 2	E-Nerolidol	<95%
Backhousia anisata	No. 1	E-Anethole	<95%
	No. 2	Methyl chavicol	<78%
Backhousia citriodora	No. 1	Neral & Geranial	>90%
	No. 2	(-)-Citronellal	85-90%
Leptospermum myrtifolium	No. 1	Alpha, beta and gamma eudesmol	>60%
	No. 2	E,E-Farnesol	56%
Leptospermum petersonii	No. 1	Neral/gernaial and citronellal	<80%
	No. 2	Γ-Terpinene and terpinolene	

	No. 3	Germacrene-D, Bicyclogermacrene & Spathulenol	
Archirhodomyrtus beckleri	No. 1 No. 2 No. 3	E-β-Ocimene a-, β and γ-eudesmol Geraniol/geranyl acetate	68-88% 70%
Cryptocarya cunninghamii	No. 1 No. 2	Benzyl Benzoate, bicyclogermacrene 6-nonyl-5,6-dihydro-2H-pyran-2-one	 78-88%
Neolitsea dealbata	No. 1 No. 2	a-, β and γ-eudesmol Germacrone and Furanogermacrone	<70% <90%
Austromatthea elegans	No. 1 No. 2	Benzyl benzoate Benzyl Salicylate	<97% 80%

Table 9.7. Different Major Chemical and Olfactory Profiles of Five Basil Oils

Sample	Linalool	Methyl chavical	Olfactory Profile
India	14.2%	77.5%	A grassy herbaceous and mildly spicy predominating note, with an herbaceous subsidiary note; back notes slightly fruity.
French	55.3%	10.9%	A smooth fresh and diffusive herbaceous note with harmonized cool anisic and slightly balsamic subsidiary notes and warm woody back notes.
Australian	34.3%	34.7%	A clean vegetable type note with a cool herbaceous menthol-like subsidiary note; a green and grassy back note.
Seychelles	27.7%	40.2%	A sharp diffusive clean grassy herbaceous note, with a fruity anisic subsidiary note and a very slightly camphoraceous back note.
Reunion (Australian grown)	3.4%	75.7%	A sharp, if not somewhat dry, anisic note; the subsidiary notes were herbaceous with a slight sweet camphoraceous floral back note.

Chemical constituent variance through a natural population of plants is thought to be the result of a number of factors. Morphological and thus chemical variation of a genotype can be related to soil moisture where differing vegetative environments would be a tell tail sign of this condition [28]. The level and type of nutrients in the soil affects the level of various chemical constituents within plants [39]. Soil topography such as natural drainage [40] and status of the land (cleared or natural habitat) would also influence chemistry and oil content [41]. Certain plants may exhibit varying tolerance to different soil pH [42] and tolerance to cold [43]. Climatic factors also influence variation, where Brophy and Dorland found distinct variances in the main chemical constituents (1,8-Cineole and linalool) of *Melaleuca ericifolia* according to latitudinal changes [44]. Studies of other trees *(Melaleuca quinquenervia)* indicate that abrupt changes in climate can be correlated with chemical variation in natural populations [45]. Plants with similar chemical properties tend to cluster together in locations of similar topography [46].

When bio-prospecting for genetic material it is desirable to select plants that can provide the best possible leaf mass with a high oil concentration in the leaves, good coppicing ability *(tree crops),* resistance to pests and diseases, broad topography and weather adaptability and of a desirable oil quality [47]. A plant variety study is necessary to evaluate different cultivars. It is best to survey a number of natural stands not only in the immediate vicinity, but in other locations around the country to obtain a wider variety of genetic characteristics. Within a single stand, survey plants at least 50m apart so sampling does not include siblings. Also include sampling of plants in different environments (soils, etc.) and select the domineering ones within each stand. Seeking plant genetic diversity in seed collection is one method of creating a crop that has some protection against pest and diseases and generate good re-growth after harvesting.

Seed Collection

Seeds undergo a growth cycle within the ovules of the female plant after they have been fertilized by a male plant or alternatively a plant may fertilize itself from its own pollen. Seeds should only be collected when they reach full maturity and are pollinated. Seeds are ripe when the pods turn green to brown or white and are ready to be dispersed from the plant, *i.e., the seeds in the flower begin to release themselves from its attachments and have changed colour from green to brownish white, or the fruit drops from the tree.* Flowering and fruiting will occur at various times of the year, so regular visits to natural stands are necessary to determine the seasons.

Genetic planting material includes seeds, roots, rhizomes, bulbs or vegetative cuttings. The basic equipment necessary for seed collection includes a large scissors, raw material collection bags, drop cloths or trays to collect seeds falling from the tree, some tin plate with a hammer and nails to mark trees, field distillation equipment, sample bottles, a GPS to take a marking, a camera and a marking pen to mark samples. The general method of collecting genetic material from the wild would be as follows:

1. A general survey of natural stands over a wide as possible geographic area is necessary to sample as much genetic diversity as possible. This is a time consuming activity, as each site will require a number of sample distillations and analysis at a latter period. Each plant where a sample distillation is made should be marked, photographed and a small voucher sample taken. This process will collect an enormous amount of quantitative data to analyse, for example 10 natural stands taking 20 samples will provide 2000 pieces of data to review. The following information should also be gathered about each site;
    a) Information about prior land use, any fertiliser or other chemical application to the area, general soil profiles, type of vegetation in the area, surrounding topography and land use, source of upstream water, etc.,
    b) Voucher specimens of each plant sampled taken so it can be botanically identified as to genus, species, and variety, and

   c) Distillation time taken, the part of plant the leaf collected for distillation sampling and yield.
2. Analyse the data collected to identify a number of potential plants for seed collection based on oil analysis, yield, and plant vitality. Ensure that the final selection is a balanced cross section of the natural stands and not too skewered a cluster.
3. Revisit each site to make a final selection of between 50-100 plants to collect seed. Evaluate seeding, flowering and fruiting times for each stand.
4. Seed collection should be undertaken when seeds are mature and there are dry conditions Ensure seeds are taken from the top, sides and bottom of the plant so maximum diversity is obtained. Branches can be cut near seed pods or flowers onto a tray or drop sheet to collect separating seeds during the disturbance. Fruit should only be collected from the ground before rot and decay sets in. Seeds and fruits collected should be packed into separate bags, ensuring there is not cross sample contamination for separation, drying, sorting and storage.
5. Seeds should be separated from the rest of the plant through vibrating the plant material across chicken wire or a strainer on top of paper, a drop mat or a lighted laminate table top (aspirator) in a specifically set up lab. Raw seeds can then be dried in partial shade or air dried. A roller can be used to separate seeds from their fruits, washed to remove any fibrous material which may contain germination inhibitors with water before drying. The drying phase is critical to seed quality and should not be done too quickly, as this will damage or kill the seed. Some moisture should be retained in the seeds.
6. Once seeds have been dried, use a tweezers to remove any foreign matter and bag the seed in paper or a sealed *ziplock* plastic bag (if air dried) for storage.

The most viable seeds are those that are of good size, relative weight, shinny, with some body around the embryo. Good seed will also exhibit much more strength than dead or over dried seed. Seeds can be graded according the above criteria, separating the most viable seeds from undersized, underweight, immature and deformed seeds, further improving the quality of the seed. Once seeds are sealed and stored, relatively constant temperatures should be maintained. If stored in paper bags, humidity should be fairly constant around 50%. Freezing should be avoided as changing moisture state can damage the seeds. Refrigeration in a crisper is the best option to prolong useable life. Some seeds need a cold environment as a primer to replicate winter periods.

To maintain viability, seeds must maintain their dormancy to prevent them from dying. Seed deterioration occurs quickest under high temperatures and high humidity. To maintain dormancy within a seed, there must some moisture remaining. The level of moisture in the seed will have some influence on how long the seed will remain viable and at what temperatures and humidity it is safe to store it at [48]. For short term use, seeds should be stored with maximum moisture levels. Seed lifespan can vary from a few weeks to hundreds of years. Those with high oil or lipid content will tend to last only a few months [49]. *Recalcitrant* seeds which occur in woody species last only a few weeks unlike *orthodox* seeds in other species. Recalcitrant seeds tend to be large and fleshy and cannot be dried or cooled without being killed. These are mainly tropical species like cocoa and rubber.

The advantage of undertaking seed collection is that seed quality and the source is known. Some commercial or contract seed collectors may collect seeds from a single tree, or group of trees, before seeds fully mature. However there are numerous commercial seed traders who specialize in particular seeds who can supply seed according to specifications.

Bio-prospecting for genetic material has become an ethical and political issue, especially concerning the issues of the rights of indigenous communities. There have been many cases of genetic materials identified from ethnobotanical information, which has been utilized by companies for profit without any benefits returning back to the original communities. Moreover, some companies have taken over patent rights on certain indigenous trees without any prior arrangement with indigenous peoples, like the W R Grace patent on herbicidal activity of neem [50]. Many of these activities are now being successfully challenged in courts [51].

Improvement of Genetic Material through Recurrent Selection

Generally plants propagated by seed are genetically diverse due to the genetic diversity of parent plants where the seeds have been collected. This should *(if plants are of the same chemotype)* result in minor variances in yields and oil composition through a field crop. Seed quality can be improved through selecting seeds based on selected genetic characteristics that are desirable to increase the quality and yields of a crop.

The general principal of an index selection program is to select plants from a population according to a selected single or number of characteristics. The process of *Index Selection* taking seeds from natural stands or from diverse commercial cultivars and planted in seed orchards and a selection made each generation. Poor performing trees eliminated according to a statistically analysed set of complex criteria [52]. These plants become the parents of the next generation, where a further selection is made, thus improving the target characteristic. This process narrows down the seed material to a set of genetically superior trees, where faster coppice growth, higher yields and oil quality are sort.

The *Index Selection* process can take many years and require committed resources to undertake the required measurements for statistical analysis. The breeding process can be more complex through a combined index selection program, weighting various characteristics such as composition, yield, coppice and biomass. In developing an index protocol it is necessary to examine potential correlations between individual traits and weight them according to importance and degree of correlation [53]. Quicker results can be obtained through breeding for single, rather than multiple traits as there are often negative correlations between some variables. Genetic gains in individual traits often diminish as more traits are selected [54]. This method was successfully utilized to improve the overall genetic quality of seed in the Australian tea tree industry over the last decade.

Selective plant breeding is a long term process of is an activity that usually continues in tandem with an emerging industry. Plant material can also be improved through a number of variances of index selection including cross pollination of germplasm, followed by recurrent progeny selection and evaluation of desired characteristics *(i.e., yield, composition, drought resistance, etc)* and DNA marker assisted selection (MAS) of plants with genes that display specified characteristics [55]. A simple *Index Selection* project path is shown in Figure 9.6.

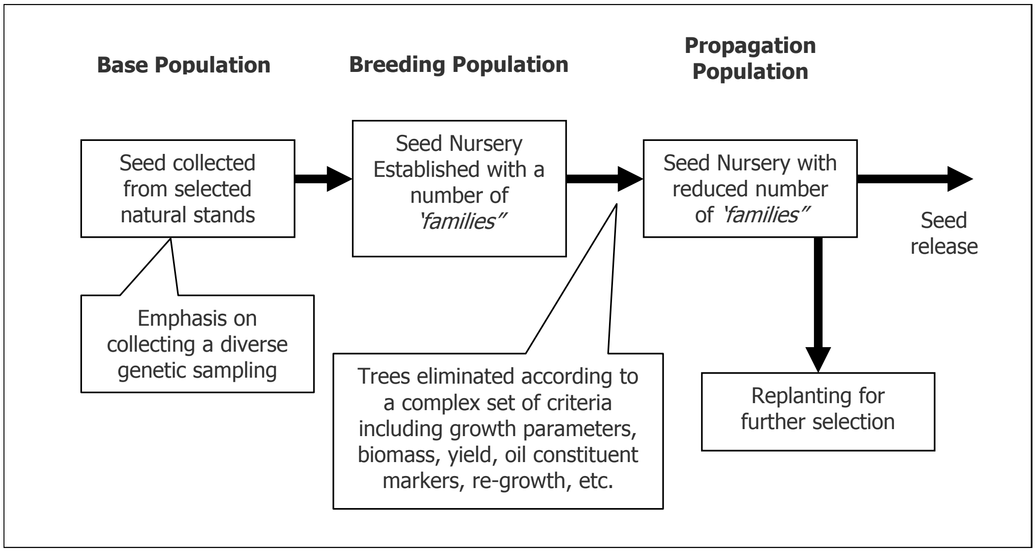


Figure 9.6. A Simplified *Index Selection* Strategy for Genetic Crop Improvement.

An *Index Selection* program whether through seed or vegetative cutting approaches, or a mixture of the two, will improve yields over wild plants [56]. This breeding strategy is advantageous in improving genetic material from natural stands of plants for field cultivation. This would have potential application in the development of essential oil crops currently wild harvested or yet to be domesticated.

Land Selection

Land has a paramount influence on the whole viability of any project. The land will greatly define both the opportunities and limitations upon the project. There may be a choice in location, as would be in the case with an estate company land bank or the ability to purchase new land. In other cases the physical location of the land is set, as it is a family or an existing farm. With community projects, the land maybe a parcel of community smallholdings, grouped together by agreement.

An individual piece of land has a unique set of characteristics, surrounded by a socio-ecological system. These characteristics will either assist or hinder development and as such must be examined in the light of any proposed future project. In addition to the physical and climatic variables, the cost of land in both financial and opportunity terms represents a large outlay of financial and other resources, which creates a large exit barrier should failure occur. In terms of opportunity cost, any activity involves the weighing up of alternative uses, prices, costs, risks and profits. Lands costs, both financially and in terms of opportunities and limitations vary widely and comparisons are necessary before making any final decisions [57]. This section will briefly outline the issues that should be assessed before any final commitment is undertaken.

Any agricultural enterprise will be subject to constraints and incentives based on national, regional or provincial and local government philosophies, laws and regulations. These issues can either add substantially to the cost of a project through taxes, occupational health and safety, environment protection, water management, building and fire regulations, or lower costs through incentives, grants or soft loans to agriculture. Salinity, drought, reforestation issues are putting many governments in the position where they must further regulate and restrict potential activities, and these implications must be considered in costing and appraisal. Zoning laws may have both a present and future influence upon an enterprise. It is important to know the current zoning and how far is the land from or adjacent to a town or city? Can the land be rezoned for housing or industry in the future? This will influence the value (cost) of the land, thus return on assets.

Finally, security of tenure is a consideration. Is the land owned, leased, granted through time based tenure? Are there any revocation mechanisms in any tenure documents?

The factors to consider in land selection are listed below as follows;

- **Socio-Economic Environment**
  - a) General land use and settlement in the immediate region
  - b) Drivers of the local economy
  - c) Patterns of crop specialization
  - d) Townships and rural population
  - e) General economic infrastructure
  - f) Distance to railway/port/airport facilities
  - g) Transport costs
  - h) Available amenities and reliability (electricity, water, etc)
  - i) Agricultural extension in region
  - j) Agricultural research in region
- **Overall Land Topography-Ecology**
  - a) General topography (slopes, rivers, dams, undulation, hills, valleys, etc.)
  - b) Total area available (excluding dams, waterways, throughways, unusable areas)
  - c) Existing land use and vegetation
  - d) Existing fauna and livestock
  - e) Catchment and water storage areas
  - f) Drainage and flood propensity
  - g) Drainage and irrigation infrastructure
  - h) Drought probability
  - i) Internal road grid
  - j) Activities on adjoining properties
  - k) Catchment areas of upstream creeks, rivers and waterways
  - l) Pest and disease assessment
  - m) Altitude
  - n) Previous use of land
  - o) Scenic potential
- **Soil Type, Texture and Characteristics**
  - a) Type
  - b) Texture
  - c) Organic matter content
  - d) pH
  - e) Flow and retention of ground moisture
  - f) Propensity to waterlog

  g) Degradation (salinity, acidity, erosion)
- **Infrastructure**
  a) Existing buildings, premise, processing facilities
  b) Road access
  c) Fencing
  d) Waste management
  e) Ease of building required infrastructure
  f) Fire management
- **Potential Crop Cycle**
  a) Timing and duration of planting, growth and harvest periods
  b) Potential rates of growth
  c) Number of harvests per year
- **Procurement**
  a) Access to spare parts supply
  b) Available source of economic fuel for extraction operations

- **Economics**
  a) Cost/benefit analysis
  b) Cost of development
  c) Land tenure
- **Environmental Assessment**
- **Local Land Governing Laws**
- **Farm Design**

The Socio-Economic Environment

The socio-economic environment is the overall backdrop the venture will interdependently operate within. This not only provides the social surroundings which influence the level of local skills and attitudes where interactions occur through employment and procurement, but also the potential level of integration the project will have with the rest of the local community. General local attitudes will reflect the style of life, education, work ethic, assumptions, beliefs and values and commonly utilized agricultural practices within the community. This also shapes the types of businesses and farming that are owned and operated in the local community and the visions they are based upon. These factors influence the skill level of potential local workers, willingness to accept new practices and commitment. Likewise, these factors will also influence the type of local fabricators available, their skills and engineering sophistication and versatility.

Identifying characteristics as the size of farms in the area, the diversity of crops, the methods of production and mechanization used, markets for produce produced, support businesses and the rate of overall economic growth and prosperity will help identify the local drivers of the economy. This will help assess if there is any potential synergies between equipment already being used in the area and essential oil production. It also can be assessed how the new venture will fit socially and economically into the community. This is important from the point of view of gaining local cooperation and goodwill verses disinterest, skepticism and even non-cooperation.

Labour availability is an issue now common to many areas in the Asia-Pacific region. Rural Australia is now developing acute labour shortages in some rural regions [58], relying on temporary labour from outside the country. Malaysia also has an ageing small holder population base where the younger generation prefers jobs in other sectors [59]. Much of the estate sector now relies upon workers from Thailand, Indonesia, Bangladesh, Nepal and Vietnam [60]. Thailand still has plentiful labour in some parts of the country, but as jobs in the cities pay higher wages such as the construction industry [61], some regional shortages can occur. Countries like the Philippines, Vietnam, Laos, Cambodia and Indonesia have large labour pools, but primarily unskilled. Securing a skilled and reliable rural labour force is now a major challenge facing agro-businesses throughout the whole region and is an issue that can take an enormous amount of time and effort.

Site distance from major towns, cities, ports, railway yards and airports brings up a number of logistical issues from sourcing specialist parts and materials, to picking up potential customers for site visits. Inland freight can be as expensive as international freight to any part of the world. Often local logistics are inefficient where drums may lie around yards for days before being transported to their feeder destinations for overseas shipping. Likewise, the availability or non-availability of amenities like electricity will determine whether power supply is just a simple matter of connecting to the local grid or whether an innovative solution is needed to secure power requirements for the operation.

Nearby research institutions and universities can be identified for potential research synergies and potential collaboration. Universities can be invaluable for collaborative research and analysis. This form of collaboration is invaluable for any new project development. Research institutions and universities have played key research roles in essential oil development in Australia, New Zealand, Thailand and Vietnam.

Overall Land Topography-Ecology

Site topography-ecology is a key factor in the successful growth of crops and sustainability. Topography, soil and climate are three important extrinsic variables that have great influence upon crop growth [62]. Each potential site has its own unique topography which will require site specific practices to manage a crop successfully. Each potential crop will have an optimal environment set that will lend itself for the optimal growth with maximum yields and quality. As it is rarely possible to find a perfect environment for a crop, ‘trade-offs’ and adjustments can be made to site field preparation and crop management techniques to optimize site specific results. Potential problems and opportunities must be identified at site level so that it can be assessed as, a) a potential site to work with, b) a marginal site, or c) a potential site to be avoided. Individual sites will not have uniform conditions, so within the site areas with the best conditions should be identified for initial development.

Each site should be assessed to its suitability to the requirements of the proposed crop(s) and planned infrastructure development. Some of the factors relevant to the issues include;

a. The suitability of land slopes, effective field size, general field drainage, drainage paths, and potential aversion to flooding. Is there access for tractors and machinery to enter and exit fields? What potential general field design and layout are possible?
b. Looking at existing types and vitality of vegetation and crops across the property to gauge some idea about the overall site quality.
c. Assess areas where there is direct exposure to strong winds and other weather phenomena that could be potential damage spots. Look at areas where rainfall can cause potential swampy conditions due to poor drainage.
d. Examine the temperature and number of daylight hours to assess for potential growth vitality.
e. Look at rivers, dams, creeks and streams running through and beside the property, as well as their upstream catchments to assess water supply and what chemicals and wastes will flow into the hydro-system.
f. Examine known pests and diseases in the general area so an assessment of potential threats can be made. Also look at what pests proposed crops are susceptible to and if there is any history of herbivore in the area.
g. Assess local wildlife and livestock and property accessibility for them to look at potential damage and threat to existing fauna,
h. Look at existing road grid, any irrigation system, fencing, buildings and facilities to assess the amount of capital required for building basic infrastructure.
i. Look at activities being undertaken on adjoining properties and the history of activity of the proposed land site, and
j. Assess the scenic potential of the land if any agro-tourism is planned.

Answering the above questions and issues will provide some idea about whether the proposed land site will meet the requirements of the proposed crop. Further assessment should be made about the impact and costs of improving conditions and infrastructure, if the site is selected.

a. What land work would be required to develop the site to a level that it would be suitable for planting the proposed crop (i.e., field gradient for run-off rain, drainage run-off to dams, access roads, processing centre for extraction, workshop and storage area for equipment)? Development can be undertaken in stages, so where would field trials, semi-commercial and commercial production take place?
b. What would be the actual available field area after taking into consideration marginal land, boundaries, dams, built up areas, natural habitats, etc?
c. What effect would the project have on any free roaming fauna at the site? Would it be compatible to the project or become a pest?
d. Can any potential pest and diseases be managed effectively?
e. Can the operation be run without contamination from upstream catchment areas and adjoining properties?
f. What would be the cost to develop the site?

Consultation with local users would be wise to get more insight into the above issues. A site inspection is only a snapshot of a short visit and local information may assist in filling in information about seasonal variation in conditions at the site. The appraisal should through climate and topography assessment provide an understanding of what would be the best nursery propagation, planting and target harvesting seasons and thus how a work schedule would be implemented on the site. Figure 9.7. is a pictorial representation of the issues to consider.

Essential oil crops were mostly produced in their traditional geographical regions of origin until after the Second World War. For example, the production of orris root oil *(Iris pallida* and *florentina* L.) was restricted to Tuscany, as it was believed very specific topography, soil and climate was required for production [63]. Now orris root is cultivated in around the rest of Italy, France, Germany, Morocco and India [64]. Similarly lemongrass, citronella, rose and a host of other oils were subject to disruption caused by post colonial power struggles, wars and political upheavals, rising costs and other factors which forced production to spread to new regions. This change in production geography brought about a change to the generally accepted belief that essential oils should be cultivated in their traditional areas for the best qualities. Now it is believed that differing chemical profiles of essential oils from different regions tend to be more related to differences in genetic characteristics than with topography [65].

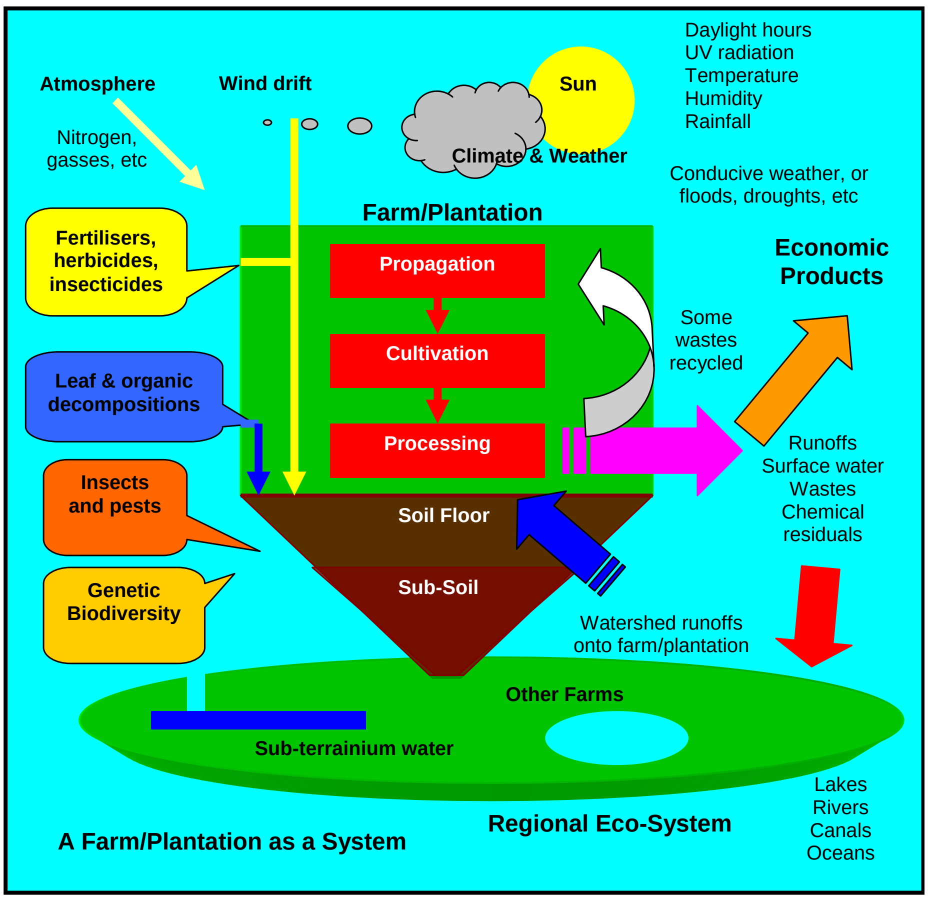


Figure 9.7. Topography-Ecology Issues to Consider in Land Selection.

Altitude

The existence of mountainous regions in Papua New Guinea, Indonesia, Malaysia, Thailand, Laos, Vietnam and the Philippines enables a number of micro climatic environments where a number of temperate crops are grown. Various altitudes, together with factors as the slope of the mountain, prevailing winds, cloud cover and precipitation create further diversity in altitudinal climates [66]. Different landforms such as rocks, boulders and stones also play a role, as well as fauna interactions, competition between species and human intervention [67]. With a 1000 feet rise in altitude there is approximately a 1.5° decrease in mean temperature until around 4,500 feet ASL, where the fall in temperature is more rapid [68]. For every rise in 1,000 feet there is a 30.6 mb drop in air density. The effect of reduced O_2 and CO_2 pressures on plants is still not fully understood [69]. Depending upon distance from oceans and latitude, the diurnal variations in temperature can be very wide. Even with similar temperature ranges to temperate areas, adaptation can be difficult because of these extreme diurnal changes, difference in daylight hours [70] and the inability of some plants to go into dominancy because of little seasonal variation in the tropics [71].

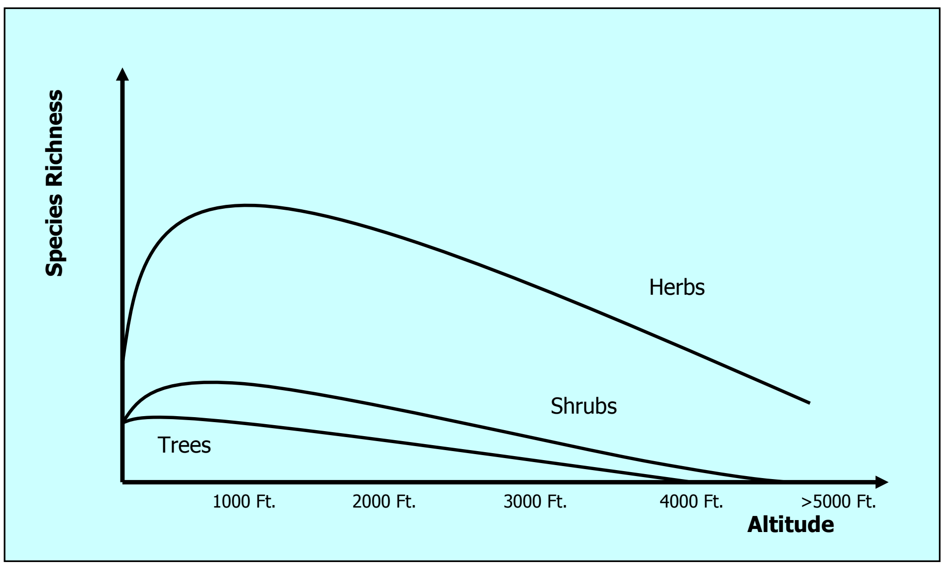


Figure 9.8. A General Depiction of Flora Species Richness with Altitude.

Plant species introduced from temperate climates can adapt to high altitudes by changing morphologically where it adapts photosynthesis, particularly C_4 types [72]. Plants can undergo slow evolutionary adaptation, or undergo ontogenetic modifications which are non reversible or through acclimatization adjustment. However these adaptations will have an effect on biomass [73]. These adaptive plants can be called ecotypes [74], which will display ecotypic differences from their parent species [75].

In a study of biodiversity richness with altitude in the Indian Himalayan region, Kharkwal et. al., listed the number of species of each genus of flora according to altitude. Although many other factors like drought inducing factors influence growth at altitudes [76], this study provides a specific spectrum of flora distribution for the Himalayan area [77].

Although other mountainous regions will have their own specific spectra of flora distribution due to localized factors, this study is a good indication of flora distribution with altitude. The general species richness spectrum according to altitude is hypothetically depicted in Figure 9.8.

Soil

The soil is a dynamic ecological system which provides moisture and nutrients, a medium to receive waste products and tissue and as a support foundation for plants. Soils also act as a filter for eliminating toxins in groundwater through filtration. Soil is the most critical ingredient in selecting land suitability for a selected crop.

Soil develops primarily through the weathering of the surrounding area where parent material is deposited upon the landscape from local rocks, minerals and flora. As minerals dissolve into the soil, they undergo change and transform through chemical reactions using soil moisture as the medium into different materials. This process is aided by the topography, rainfall and climate. The soil contains a number of compounds like oxygen, iron, calcium, potassium and magnesium. Microorganisms form through decaying plant matter and interaction of plant root systems within the soil layers, in the form of fungi, filamentous and single celled bacteria, algae, small animals and insects like worms, snails and ground boring insects. These organisms play a role in the formation of other organic matter called humus.

Humus, along with other minerals plays a role in the colour of the soil, and along with clay controls water retention and the cohesion of the soil. Mineral compounds come in different shapes, structures and sizes and form the texture of the soil. The soil structure is formed through the layering and clustering of these materials.

Soil is a three phase structure made up of gasses, moisture and solids. The particular content mix determines soil ventilation, water intake, storage and drainage capacity. Where soil pores are small, the soil will have good water holding capacity, but when pores are large, rapid drainage and evaporation of the soil surface occurs. The surface pores of the soil are the medium where chemicals are absorbed and reactions and decomposition of organic materials takes place. Through deeper pores nutrients and moisture is diffused through the soil to plant root systems for uptake.

The root system of the plant is the organ through which plants take moisture and nutrients and release waste products into the soil. Root interaction with the soil also encourages microbial growth within the soil. Plants obtain the elements they need through soil moisture and the soil itself. Through the soil plants obtain nitrogen, phosphorus, sulfur, potassium, calcium, magnesium, iron, manganese, zinc, molybdenum, nickel, boron and chlorine. Through soil water plants obtain carbon, oxygen and hydrogen [78]. Figure 9.9. shows the nutrient take up through the plant root system which provide precursors for the metabolic system discussed in chapter 4.

Numerous soil classification systems exist throughout the world [79] and are not necessarily directly comparable. Most soils are a combination of each classification type. One example is the Australian Soil Classification which describes soils under a hierarchy as order, sub-order, great groups, sub-groups and families [80]. Table 9.8. shows a summary of soils useful for agriculture at the order level, where sub-orders are distinguished from the main orders by colour.

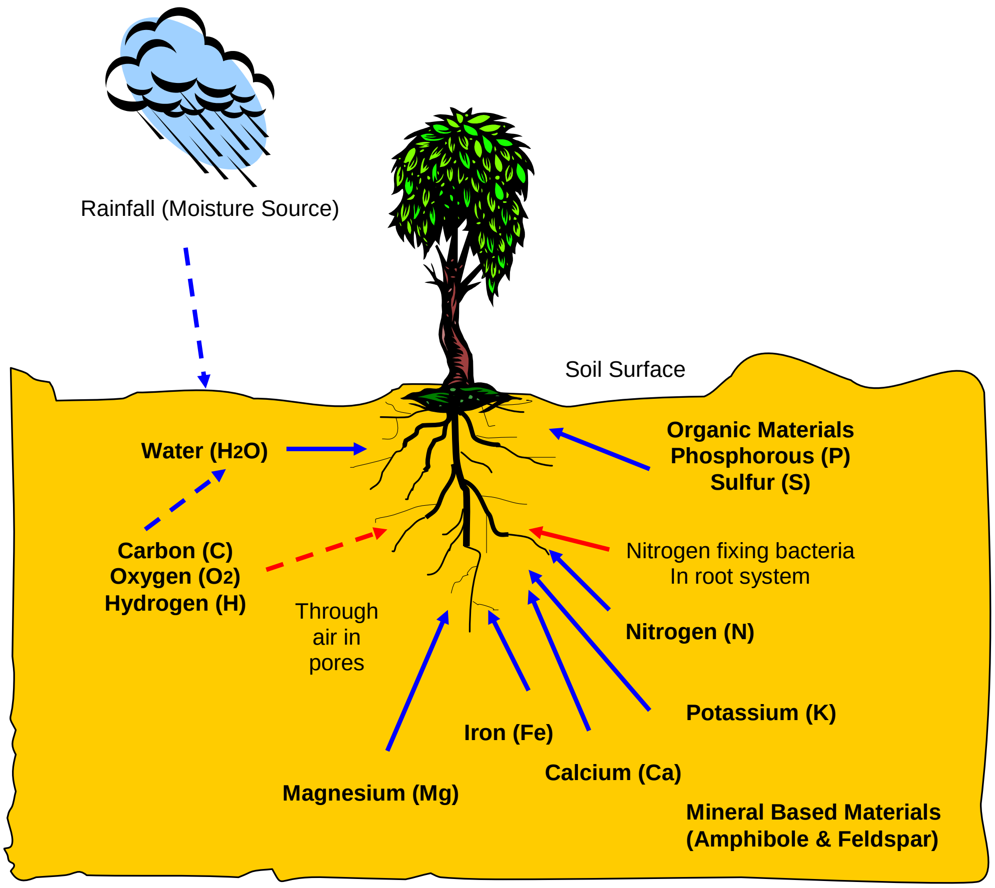


Figure 9.9. The Nutrient Take-up Route Through the Plant Root System.

Many other names occur for these soils across different regions and classification systems, as well as common and informal names by local populations. Another more general system existed before many classification systems were developed and are still in common use today [81]. This system provides a useful comparison of soil morphology on the basis of textural changes and takes three primary forms;

- Uniform Soils (U) have little of any textural changes with increasing depth. If the general texture is sand or sandy loam, the profile is classified as Uc (coarse texture). Uniform loam and clay loam profiles are designated by Um (medium texture) and can be sub-divided into non-cracking clays (Uf) and cracking clays (Ug).
- Gradational soils (G) become increasingly finer-textured (more clayey) with depth. The major sub-divisions are calcareous soils (Gc) and non-calcareous profiles (Gn).
- Duplex soils (D) have clearly defined texture contrasts between the top and sub-soils. They can be sub-divided into red sub-soils (Dr), yellow sub-soils (Dy), brown sub-soils (Db), dark sub-soils (Dd) and greyed sub-soils (Dg).

Table 9.8. A Summary of the Orders in the Australian Soil Classification

Order	**Description**
Anthroposols	Human made soils
Organosols	Soils mostly dominated with organic materials.
Rudosols	Almost complete lack of horizon development other than organic materials on the A1 horizon. Occur above bedrock with good water availability and capacity for deep rooting.
Tenosols	Intermediate between Rudosols and Kandosols, in which B horizon development is clearly expressed with more than 15% clay. A wide variety of soils in this group. From a diverse range of siliceous alluvial and Aeolian deposits and acidic rocks. Grassland and open forest. Moderate to high water availability, well drained with little root limitations, susceptible to erosion, low nutrient availability, slightly acid soils.
Podosols	Usually bleached A2 horizon and coloured B horizon through accumulation of organic compounds, aluminum and/or iron deposits. Usually coastal soils with quartz, sandstone, granite and/or gneisses deposits. Wide range of vegetation shrub and tree. Usually long sandy plains. Low to high moisture availability depending on depth, very well drained and aerated, siliceous pans can restrict root depth, prone to wind erosion, poor carrier of nutrients.
Vertosols	Dry clay soils with shrink-swell properties which crack on drying. Soils vary in colour and range from acidic to alkaline. Moderate water availability, adequate aeration but layers can restrict, plough pan development can limit root growth, high erosion during tropical rainfall, commonly deficient in sulfur and zinc.
Hydrosols	A wide range of soils that are permanently saturated, occurring in swamps or low lying depressions.
Kurosols	Clear or abrupt texture contrast between A and B horizons. Upper part of B horizon exhibits strong acidity. Moderate water holding capacity in root zone, surface may be water repellent and aeration may be restricted at B horizon, tough clay sub-soil may limit root penetration, susceptible to wind erosion, with low nutrient content and high acidity.
Sodosols	Clear and abrupt B horizon. Vary widely in both morphology and chemistry, with horizons ranging from clay loam. Moderate to very low water availability depending upon thickness of A horizon, relatively poor drainage and can remain saturated, dense clay sub-layer may restrict root growth, low organic matter so will be low in nutrients and deficient in nitrogen, phosphorous and zinc.
Chromosols	Strong texture contrast between A and B horizons, but not strongly acidic like kurosols and sodosols. Water availability

	varies widely, poor to good drainage depending on B horizon, generally adequate aeration, root restrictions due to B horizon, low contents of phosphorous and nitrogen.
Calcarosols	High presence of calcium carbonate throughout the profile, absence of texture change in B horizon. Low water availability in root zone, well aerated in upper areas, calcrete fragments may restrict root growth, low nutrient availability in carbonate zones.
Ferrosols	Very permeable clay type soils with relatively high contents of iron oxide. No strong texture changes between A and B horizons. High to very high water availability, well drained, but short term saturation under heavy rain conditions, no serious root restrictions unless compacted, often serious erosion on slopes, shows deficiencies of nitrogen and phosphorous.
Dermosols	Strong structured B2 horizons, lacking strong texture changes between A and B horizons. A wide range of sub-types. Medium water availability, relatively well drained, effective rooting, can harset if low in organic matter after rains, highly variant in nutrient availability. Can degrade under cultivation.
Kandosols	Soils with weak sub-soil structure, clay content of 15% in B horizon, no strong texture contrasts, soils often very deep (3.0M). Mostly well drained, well aerated, severe erosion on slopes, usually low in nitrogen and phosphorous.

The description also includes an addition of specific characteristics such as structure, consistency, bleaching, mottles, and pH, to complete the code. Charman added an extension to the system to provide additional information about top-soil, through the use of a number to describe one of the six textural groups [82];

1. Sand
2. Sandy loam
3. Loam
4. Clay loam
5. Light clay, and
6. Medium-heavy clay.

Another figure is added to represent the strength of the aggregate structure;

1. Weak structure
2. Moderate structure
3. Strong structure
4. No Structure.

Another value is added to indicate the depth (in centimeters) of the top-soil, (for example 025, 25 cm). Thus a full description can be obtained, i.e., Dy3.43-2/0/015, a yellow mottled duplex profile with a bleached A2 horizon, with an alkaline hard setting topsoil, with a sandy loam topsoil 15cm deep.

Soil is a major determinant of the basic site suitability and must be heavily weighted as a factor in final selection. Texture, horizon depth, organic matter content, moisture content and pH should be assessed and taken into consideration with the local topography when matched against the requirements of the proposed crop.

Texture is determined by the particular mix of sand, silt, clay and organic matter present within the soil. It is important to seek the optimum soil texture that will enable clear root growth and expansion so plants can take up moisture and nutrients from the soil. High clay soils can inhibit moisture retention and proper root development. In high rainfall areas, they may provide an unstable anchor and allow trees to move during times of high winds. Sandy soils allow rapid root growth and expansion but very quickly lose moisture due to evaporation.

Horizon depth will determine how much moisture will be stored within the soil during dry seasons. Depth also determines anchoring stability of tree crops for stability in high winds. The moisture and nutrient supply to crop root systems is also influenced by the horizon depth of the soil, thus shallow soils should be closely examined for root growth hindrance during growth. Horizons close to the surface will restrict growth and may restrict roots and absorption of moisture and nutrients.

Organic matter in the topsoil promotes water retention due to its absorbency. Organic matter also retards soil evaporation and acts as a protective layer against soil cracking in dry conditions. The top organic layer is important to initial growth as it allows easy root permeation. Many sites have lost topsoil layers leaving very little residual organic matter. The available soil moisture in planting and early crop growth is very important. Soil moisture is also very important as a medium in chemical reactions within the soil that provide nutrients to the plant through the root system. Soil pH is important to some crops. A too acidic or alkaline soil can act as an inhibitor of growth.

Generally, the ideal site should have the following soil characteristics;

- Have a sandy loam to light clay textured soil that is deeper than 50 cm
- Have an organic matter content
- Be neutral or slightly acidic
- Not form seals or crusts, and
- Should not have restrictive layers in the top 50cm.

Simple field tests can be undertaken to examine the characteristics of the soil.

Texture: A small piece of moist soil can be rubbed between the hand and forefinger to feel the texture and type. Small gritty particles can be felt in sandy loams. Loams will feel very smooth with some gritty particles. Loam soil will tend to maintain its shape if some soil is extruded from a closed fist. If the soil is chunky and doesn't break up easily, this soil should be avoided as it will tend to inhibit root growth. Clays will be almost completely smooth in their feel and will maintain its form, if manipulated and squeezed into strips. These soils should be avoided as they would tend to inhibit root expansion.

Placing some soil in a sealable jar of water, shaking it and allowing it to settle will settle back in layers. Any metallic gravels will settle at the bottom, sand will settle on top of that, followed by clay and then silt. Most organic material will float to the top, being less dense than the other segments. These can be then accorded a percentage of total soil make up through measuring the size of each layer in the jar.

Layer depth: A simple auger can be used to dig out a sample of soil and laid on a table to determine the layers closest to the surface. Soil profiles can also be viewed through cut away parts of the land, *i.e., a road*. The hardness of the first soil horizon should be closely examined to determine potential root penetration. Ant or termite mould can also be examined as these are usually constructed from the top soils.

Organic matter: can be roughly quantified (allowing for density) in a sealed jar (explained under texture). A small piece of soil can be placed onto a small laboratory glass plate or dish and a few drops of hydrogen peroxide solution applied. The solution will bubble and foam as it reacts to any organic matter present. The vigour of the reaction is roughly proportional to the amount of organic material present.

Moisture content: can be determined by weighing a sample of soil and then placing it thinly in an oven to evaporate the moisture present. The sample can then be reweighed and the difference pre- and post drying. Some garden nurseries sell soil moisture meters.

pH: Special soil pH tests are usually available at garden nurseries and are inexpensive to purchase. With some skill, pool water test kits can also be utilized. Alternatively the soil can be mixed into a sludge and litmus paper used to acquire a rough indication.

Soil is further discussed in chapter 10.

Infrastructure

During the site evaluation, potential sites should be selected for infrastructure facilities. These would include maintenance workshops, nurseries, irrigation pump-houses, dams and waterways, roads, drains and ditches and the extraction processing area.

Potential Crop Cycles

Usually the weather cycle is the prime determinant of the particular crop cycle for a crop. In tropical and monsoonal areas precipitation or access to irrigation water can compensate for lack of seasonal variation, subject to temperature differentiation between the dry and wet seasons. Factors like temperature will accelerate plant growth. Where crops have been moved to a region with higher temperatures, there are possibilities of gaining extra bio-mass and harvests over an annual or bi-annual period. The limitation to this is the availability of water all year round, the soil fertility and the impact of the temperature range on plant stress. The determination of the potential crop cycle is important in estimating field development timing and scheduling for nursery propagation, field preparation, planting and harvesting times, etc. It is important to consider the impact of the rainy season on the access of tractors to the field *(i.e., soil compactness)*, as this will influence potential harvest times.

Procurement

The locality of the land site should be accessed as to the ease of acquiring spare parts and basic utilities such as electricity, availability of fabrication services for repairs and modifications of plant and equipment, available analytical facilities and other necessary items. A key issue is the potential procurement of both fossil and alternative energy sources for the power source of any future distillation operation.

Economics

The potential site should be assessed as to the economics of operations. Some of the costs that need to be assessed are;

- The cost of labour in the area,
- The skills of labour in the area, as low skills will require training,
- The cost of fossil fuel in the area,
- The cost of contractors in the area,
- The cost of spare parts in the area,
- The cost of utilities in the area,
- The cost of capital goods, and
- The cost of developing infrastructure on the site.

A forecast should also be made of the probable operational costs should the land be developed. These estimates can be compared to the costs of other potential sites for comparison.

Environmental Assessment

In some locations environmental assessments are compulsory before any development and operations take place. The format and studies required will vary. Part of this information may be required for the granting of organic and Good Agricultural Practice (GAP) certifications. Potential areas of study that may be required in an environmental impact study would include some or all of the issues listed in Table 9.9.

The above issues and factors would be assessed according to their magnitude, permanence, reversibility and cumulative effect.

Local and Governing Laws

Various laws may exist at potential land sites restricting activities and/or increasing costs for use of natural resources. Many governments in their stewardship over the environment are implementing *'user pays'* principals for the use of natural resources such as water [83]. There maybe restrictions on planting [84], restrictions on building [85] and restrictions on the utilization of foreign labour [86]. Areas where local laws and regulations may apply include;

Table 9.9. Impact Prediction and Assessment of an Agricultural Site

Issue	**Areas of Study**
Soil erosion, water quality and hydrology	• Soil erosion from related operational activities • Surface erosion due to development • Increase sediment into waterways • Effect on water table • Flood hazard due to increased run-off (downstream) • Soil damage (compaction, removal of organic matter, topsoil and nutrients) • Water and waterway pollution • Usage of fertilizers, herbicides and other agricultural chemicals
Terrestrial and aquatic fauna ecology	• Potential loss of fauna activity/diversity • Wild life of importance • Effect of effluent on fauna ecology • Usage of fertilizers, herbicides and other agricultural chemicals
Human-animal conflict	• Effect of development on wild life
Flora ecology	• Potential loss of flora diversity • Indigenous/verses introduced flora competition
Socio-economics	• Employment opportunities • Effect of foreign labour on society • Effect of business on local community • Injection to local economy • Loss of other opportunities • Impact on surrounding area • Land use changes
General ecological disturbance	• Creation of dust, noise and nuisance from operations upon surrounding community • Potential change in habitat
Green house effects	• Green house gas atmospheric emissions • Carbon output
Biomass and waste management	• Potential waste and effluent and proposed handling • Potential waste applications
Pest and disease management	• Effect on existing pests in area • Potential of introduction of new pests and diseases • Pest and disease strategy
Forest fire management	• Potential fire hazard and effect on ecology
Cost-benefit analysis	• Benefit to local employment and economy (short & long term) • Environmental costs verses human benefits

- Land use (type of activity, percentage of land that can be used, buffer zones such as fire breaks)
- Restrictions on development
- Use of Machinery and equipment (Occupational health & safety, Environmental protection, etc)
- Building
- Use of natural resources (water)
- Employment
- Storage of chemicals
- Waste management

Farm Design

The final aspect of land selection is to determine whether the land allows a functional design for potential operations. The best micro-sites should be selected for cultivation and other sites for infrastructure establishment. Small areas should be put aside for seeding nurseries, biodiversity collections and ongoing trial plots. Development plans should also be phased according to field trials, mini commercialization, full commercialization and later downstream activities to space investment over a wider time period.

Based on the above assessment of the land according to the socio-economic, topography-ecological, soil, infrastructure, potential crop cycles, procurement issues, economics, environmental assessment, evaluation of governing laws and potential farm design, potential sites can be categorized in a matrix. There are three basic sets of issues to consider with each potential land. Firstly, there are the biophysical aspects like soil, topography, climate, water supply, etc. Secondly there are the man-made aspects of available infrastructure, proximity to population centres and irrigation, etc. Thirdly, there are intrinsic factors like access to knowledge, access to inputs, markets and credit facilities and the cultural attributes of population within the area. All these will influence an input/output ratio for the land after investment in research and development for each particular piece of land. The potential land can be categorized into one of the matrix quadrants. Because it is too complex to directly quantify the data and strengths and weaknesses of each piece of land, each potential land can only be positioned relative to each other in the matrix, on the basis of an informed value judgment.

Propagation and Planting Material Development

The propagation and the production of planting material is a key activity for any plantation. The establishment of a nursery will involve building specific infrastructure and developing specific set of procedures and practices to produce planting material for cultivation. The three most important aspects of this process are producing the correct quality of planting material, producing the required volume and the cost of production.

Nursery and propagation facilities need to be designed for efficient production of planting stock. There is usually a choice that can be made from a number of different methods, and this choice will usually be made on the basis of the plant physiology, time, ease of production and cost. The methods selected have usually been refined and ‘tailor made’ for the specific situation, based on trial and error, accumulated knowledge, practice and convenience. Thus most nursery practice will be adapted from the basic methods of propagation of seeds or other asexual methods of vegetative propagation, cuttings, grafts, marcotting, and micro-propagation.

The first aspect in planning a nursery will involve the selection of its location. Issues to consider include the micro-climate, exposure of the potential site to adverse weather and temperatures, the topography of the land (require relatively level land), the drainage, available clean and hygienic soil and other planting media, the available water supply, potential for pest and disease infestation *(including insects and nematodes)* and access to labour.

Once the site is selected, the layout can be planned to include preparation areas, seed germination areas, seedling transfer areas, tube and/or irrigated seedling standing areas, compost and media mixing areas and adequate storage areas. If seedlings are to be sown directly onto soil beds or propagation undertaken through vegetative cuttings, enclosed and protected soil bed arrays are required. This must be designed on a scale adequate enough to produce enough seedlings for required planting. Where the plantings will have a field life for a number of years, most of these required nursery facilities would be constructed for temporary, rather than permanent use.

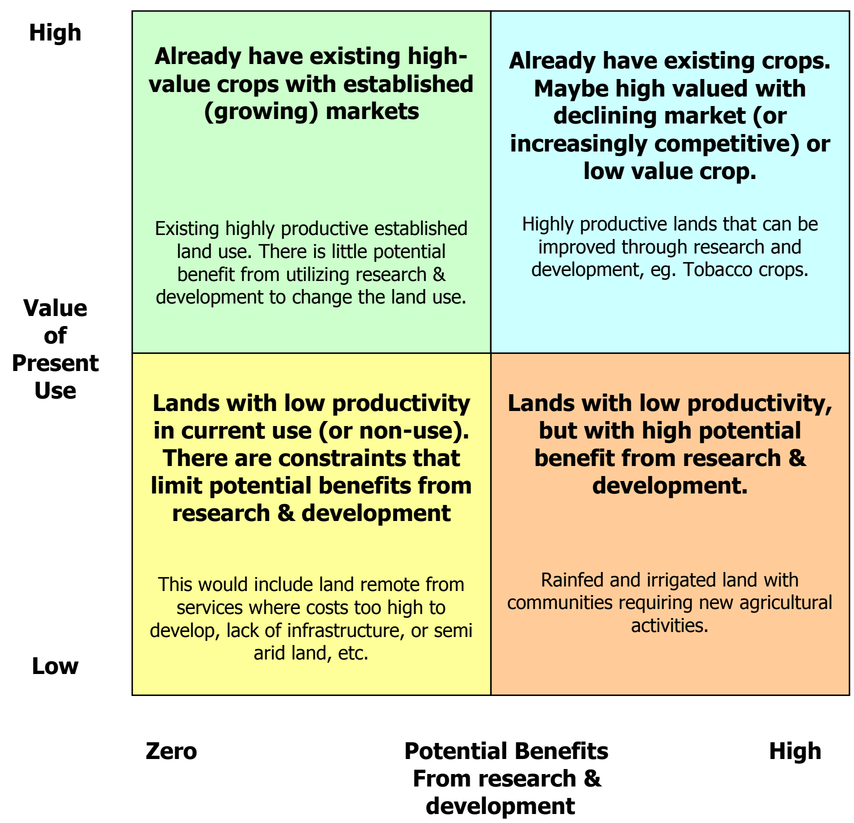


Figure 9.10. Potential Benefits to Land from Research and Development Matrix.

Figure 9.11. Tray array for seed sowing.

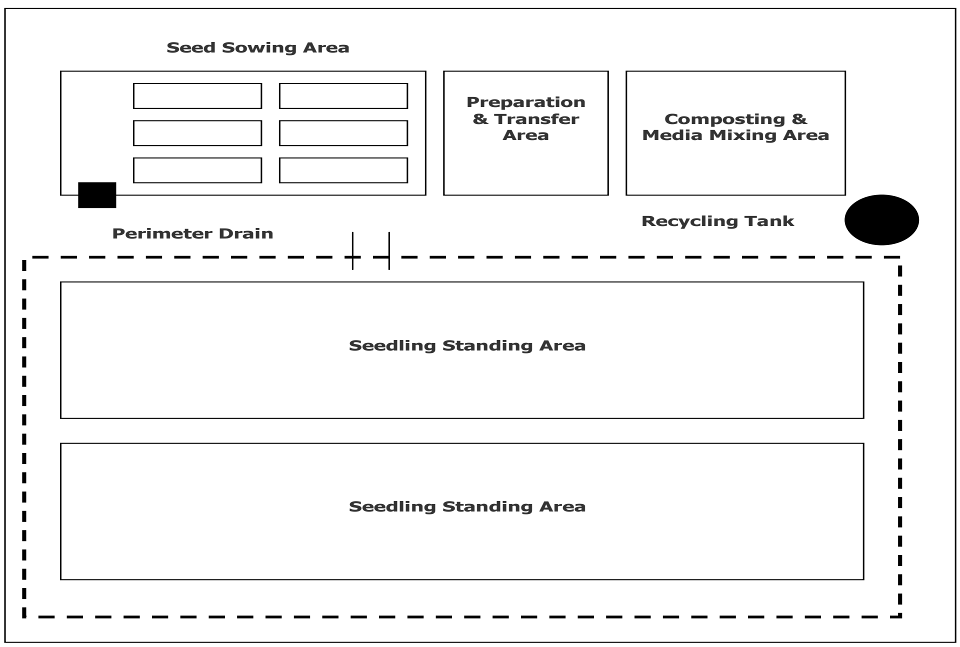


Figure 9.12. A Typical layout for a Nursery.

When propagation is undertaken through seed, an area must be constructed where seed can be sown either directly into seed beds or into media trays. The right conditions should be created (temperature, soil moisture and humidity, pH, and water holding capacity), through the materials chosen for the roof and walls, soil bed structure, media selection and type of irrigation. Preferably, the seed propagation area should be closed off to prevent outside predator insects away from germinating seedlings. Trays have a great advantage over soil beds, as they require much less soil and can be placed in water baths that take up water into the media. The capillary action can be regulated through the percentage of sand in the media mix. Figure 9.11. shows a seed sowing area using a tray array for sowing in Perlis, Malaysia.

Adjunct to the seed sowing areas should be an area where trays can be prepared for sowing and seedlings from trays or seed beds can be transferred to either single cavity trays, tubes or containers. This should also be accessible to a compost mixing area for mixing specific soil and media requirements. The next area should be the seedling standing area where seedlings are brought up to the point where they can be transplanted to the field. There should also be an area where all nursery equipment, trays and beds can be either washed in hot water and/or treated with steam to avoid any contamination of future germinations. A simple diagram of a nursery layout is shown in Figure 9.12.

Studies have shown that water stress tends to hinder plant growth more than the lack nutrient supply [87], thus irrigation is of central importance to any nursery operation. There are two major choices for nursery irrigation, either an overhead or a drip system. Overhead systems can cover large nursery areas and are relatively cheap to construct, requiring only a small pump to create enough pressure if a tower is not available for gravity feed. Further, overhead systems are easy to operate, provide an uneven water supply to seedlings and encourage bacterial growth in areas where the nursery is over-watered. Unless the nursery has a cement floor, the ground will continually be moist. Overhead irrigation systems are most suitable for tree seedlings.

Drip systems will save up to 60-70% of the water that overhead systems require and are suitable for areas where there is a shortage of water. However their drawback is that they are much more expensive to construct and require moving and adjustment when seedlings are moved in and taken out of the standing areas. Drip systems are less affected by wind and create much less wasted water.

A third system utilises sand beds creating a capillary sub-irrigation system. Water flows through capillary action to seedlings in containers resting on the sand beds. Thus the nursery seed beds will slope slightly. This system is claimed as very efficient in-terms of water management and labour requirements [88] although it can promote weed growth and encourage seedling root growth into the sand beds. A basic comparison between the three systems can be seen in table 9.10.

Table 9.10. A Comparison between Major Nursery Irrigation Systems

	Overhead Sprinklers	**Drip Irrigation**	**Capillary Sand Beds**
Installation cost	Moderate	Moderate/High	High
Maintenance	Low	High	High
Durability	Excellent	Low	Moderate
Labour	Low	Moderate	Low
Water Distribution	Fair	Good	Good
Water Use Efficiency	Poor, wasteful	Good	Good
Pump Requirement	Large, high pressure	Small, low pressure	Small, low pressure
Water Volume Requirement	Large	Small	Small
Wind Influence	Serious	None	None

The perimeter of the irrigation area requires a ditch to collect water run-off for the purpose of recycling and meeting regulatory requirements in some jurisdictions. Run-off can be reduced through grassing the slope around the nursery area. Alternatively the perimeter of the nursery can be tiled to capture and direct surplus water to run-off tanks for recycling.

Propagation and nursery management methods are wide and varied and have been specifically developed for the crop in question. A textbook approach is usually taken at the beginning, where adjustments and modifications to the methods are made according to local conditions. Finding out what works best is as much trial and error as theory. Through experience a set of best practices and management techniques can be developed. Therefore it is not uncommon to see the propagation of the same crop approached in slightly different ways at different locations. A brief description of the major methods will be given below.

Seed germination is used very widely in nursery propagation for a wide range of plant species. The seeds used in germination will have either been collected or purchased from a seed supplier. Seeds deteriorate at very different rates after collection and this has a great bearing on their successful germination. Some seeds can be dormant for hundreds of years, while others only a few weeks. Seed life span is related to temperature and dormancy mechanisms. For example, some seeds become dormant from seasonal temperature variation. This may require cooling and warming of the seed to a certain temperature before used for nursery propagation [89]. Other seeds may have protective coatings that need to be peeled or soaked off before being able to germinate. Seed germination may require a specific range of soil temperature (min. & max.) before there is any response. The moisture level of stored seeds will affect their sensitivity to temperature and vigor, where seeds with lower moisture levels 5-8% are more responsive to chilly conditions than seeds with 10-15% moisture, where germination rates decline [90]. Seeds containing lipids are more hardy and tolerant towards cool temperatures [91]. Thus it is important to understand the dormancy mechanisms, optimal germination and storage conditions of the seeds required for the project.

In temperate and sub-tropical zones, it is important to pass the time of year where temperatures will fall below the minimum threshold temperature for the selected plant. This reduces the risk of the temperature falling and preventing germination. The colour and moisture levels in soils are also important in heat conductivity, where darker and drier soils will tend to conduct heat better. The location and extent the seed beds are exposed to the sun will also influence soil temperatures. Excessive high temperatures can inhibit germination, where sprinklers can act as a cooling mechanism. All these variables can be manipulated to create optimum germination conditions.

The quality and vigor of potential seeds for nursery propagation requires assessment before use. The minimum seed emergence rate can be determined through small pre-germination trials of sample seeds, before the commercial germination proper.

Once seeds have been sown and germinate from either seed beds or trays, they must be transferred to either trays where multiple cavities exist for seedling placement or single containers, tubes or pots. Containers improve the handling of seedlings for planting and very advantageous for transporting to remote sites from the nursery. Containers allow the use of special potting mixes and nutrients mixed with latex paints inside the container for slow nutrient release [92], to assist in the growth of the seedling. Depending upon the size of the container, the need for root pruning prior to planting is not required. However, containers are labour intensive, require precision irrigation and can inhibit the growth of seedlings in the field if the root system becomes *root-bound*.

The choice of container used will affect root growth, the growing medium, nursery handling, durability, and transport precautions. The types of containers used in nurseries include;

- The standard container used in nursery production is a black round plastic container which can be reused a number of times. These vary in size according to the type of seedling propagated and root circling is prevented through the use of a slightly over sized pot for the plant and good time management. These pots are sturdy, but sometimes create problems to the root system when separating them from the seedling during planting.
- Plastic tubes are a cheaper version of pots. They are usually thin like plastic bin liners and suitable for large volume seedling propagation. The plastic tubes are disposed of during planting, which like plastic pots can potentially cause some issues with the root system of the seedling. If not immediately collected after use, they can also cause a litter problem in the field. Plastic tubes do not eliminate root circling unless they are large enough. Alternatives to plastic tubes include pots and tubes made of organic materials like banana leaves and biodegradable plastics. The advantage of biodegradable materials is that the seeding can be directly planted into the field without the need to remove the tube, thus ensuring the root system is intact. Plastic tubes and their organic alternatives can be made up at the nursery, subject to labour costs.
- Bottomless pots allow taproot growth through the bottom of the container where it can be *air pruned* (when roots are exposed to dry air they will turn black and die off) [93] to encourage lateral root growth. Usually a non-soil, fibrous media is used and seedlings managed in this way will very quickly establish themselves in the field due to the very strong lateral root system. This system is most suitable for trees and tree like woody scrubs with strong tap roots.

The choice of soil media and potting mixes is very important in nursery operations. Commercially available pre-packed soil media and potting mixes can be expensive for large operations, so the option of blending, composting and mixing specific media and mixes is often viable. Soil media and potting mixes are the medium through which plants receive water, nutrients and air to the root systems. As different plants have their own specific requirements, custom blends should be advantageous to plant growth and wellbeing in the nursery.

The major materials that make up potting mixes include soil, sand, composts and a number of other materials that can be introduced into the blend to increase nutrient content and physical characteristics.

Soil media can either be soil based or soil free. Soils usually make up the major component of media, if they are to be soil based. As soils vary greatly in composition, selection of the right soil for the proposed plant is necessary, so examination of clay and sand content is important. As soil is a carrier of diseases, it must be treated by solarisation, steam pasteurization, or oven heating to eradicate soil borne diseases. These soil treatments however will not eliminate heavy metals, pesticides and other toxicants in the soil.

Figure 9.13. Seedling trays for individual seedlings (Photo Courtesy of Azaharuddin Hassanuddin, Institute of Development Studies, Sabah).

Sand directly influences media and potting mix porous characteristics and bulk density. Drainage properties improve as the sand is coarser and decreases when sand is finer. Very fine sand can greatly slow down drainage through blocking the open pores in the soil structure. Sand should be well washed until the pH is nearly neutral. It will have no nutrient value acting primarily as a bulking agent. Sand is very good for assisting the stability of top heavy woody type plants.

Composts are an important part of media and potting mixes, usually making up between 20-50% of the blend [94]. Composts perform many roles in media and potting mixes, which include, holding water and moisture, decreasing specific gravity and compaction, being a provider of nutrients, and providing humus which may contain beneficial organisms to assist in suppressing diseases [95]. Composts provide nutrients to plants that soils and sands lack. In the mid to high latitudes of the Northern and parts of the Southern Hemispheres, peat moss is heavily utilized in composts using mosses like *Sphagnum*. In sub-tropical, tropical and monsoon regions alternatives like coconut husk fibres, rice paddy straw and palm oil wastes can be utilized, which contain potassium, sodium and chlorine [96].

Composts undergo a decomposition process where the organic substances are broken down. This usually involves three phases. Firstly, the temperature rises to between 49-56° C where basic organic materials are broken down. In the second stage the temperature rises between 49-60° C, where cellulose, weed seeds and plant pathogens are destroyed. Finally, when organic materials are broken down the temperature begins to decline where the compost cures. It is during this stage that humus develops and some beneficial organisms re-colonise the compost. This of course depends upon where the compost is mixed, so bacteria has the ability to reach the compost heap [97]. The compost process can be initiated through the use of aeration through turning of the compost, *effective microbes (EM)*, *Verma-Composting,* the use of manure piles, or mechanical forced aeration methods [98].

Table 9.11. Some Potential Compost Additives with Nutrient Values and Release Time [99]

Material	N%	P%	K%	Release Time	Other Nutrients
Alfalfa	2.5	0.5	2.0	Slow	
Blood & Bone	8.5	4.5	0.4	Constant	
Eggshells	1.2	0.4	0.2	Slow	Calcium
Fish meal	10.0	5.0	0.0	Medium	
Kelp meal	1.0	0.5	8.0	Slow	High sodium
Manure - cow	2.0	2.3	2.4	Fast	
Manure - horse	1.7	0.7	1.8	Fast	
Manure - poultry	4.0	4.0	2.0	Fast	
Manure – sheep	4.0	1.4	3.5	Fast	
Rock phosphate	0.0	18.0	0.0	Very slow	
Wood ash	0.0	1.5	5.0	Fast	Alkaline
Commercial (Synthetic)					
Osmocote®	13-20	6-15	12-14	3-9 months	
Precise®	12	6	6	3-4 months	
ProKote®	20	3	10	7-9 months	

A number of materials can be introduced into the compost to provide and increase specific nutrients and characteristics into the blend. This provides great flexibility to provide specific nutrients at different plant growth stages in the nursery. Different types of barks can be used in the mix, although some barks can be toxic to plants. Pine barks can be very high in lignin, which are slow to decay. Barks greatly decrease media density and water holding capacity. Due to good drainage characteristics, they are suitable for herbaceous plants. Other examples include animal manures which can be introduced into the blend to provide a range of nutrients. Alfalfa contains nitrogen and kenaf *(Hibiscus cannabinus)* can be used as a replacement for bark. Minerals like perlite and vermiculite help soil drainage and limestone or calcium carbonate and calcium magnesium carbonate provide nutrients and adjust pH levels. Various materials like kelp meal can be added to provide nutrients to plants on a slow release basis. Synthetic and commercial fertilizers can also be added. A list of some potential compost additives are listed with their nutrient and time release characteristics in Table 9.11.

Other materials that can be used include newspaper and sawdust that can add volume to the media. Care must be taken to utilize standard and not glossy newspaper or chemically treated sawdust.

Vegetative Propagation

Vegetative (asexual propagation) covers a number of methods which include cuttings, grafting, marcotting, micro-propagation and tissue culture. The principal of vegetative propagation lies in plant cells containing two sets of chromosomes where any material is capable of generating itself into a complete plant.

Cuttings

Vegetative cutting propagation is a common propagation practice with many plants, shrubs and trees. This involves severing a plant part from a parent and allowing the part to re-generate itself, forming a whole new plant. This can be practiced in many forms including;

- Stem cuttings
- Tip cuttings
- Medial cuttings with stem nodes
- Leaf cuttings
- Root cuttings,
- Rhizome division, and
- Bulb separation

Stem cuttings are the most common method to propagate a number of woody plants. Shrubs are much easier to propagate than tree species, although much research is being undertaken in this area [100]. Generally propagation of tree cuttings is usually much more time consuming and expensive than propagation by seed [101]. Root systems best develop from cuttings under warm and humid conditions. This is aided by hormones *(1-Naphthylactic acid and Indol-3-yl-butric Acid)* that assist the plant material develop rooting systems. Generally the types of plants that can be propagated through cuttings include;

- Herbaceous plants that are non-woody, where 8-15 cm stems can develop roots quickly.
- Softwood shrubs and trees where new wood can develop shoots suitable for rooting.
- Semi-hardwood trees where flushes occur from mature wood, which can develop roots, and
- Hardwood trees where flush occurs from dormant stems in late autumn or early spring.

Stem cuttings should be clean of any buds, flowers or large leaves, so energy can focus on producing new stems and roots systems. It is best to take cuttings from the middle to upper parts of healthy plants and trees without any nutrient deficiencies. Cuttings are best taken early morning and kept cool and moist. When propagating cuttings in the nursery, stems can be treated with root promoting compounds available in the market.

Many species of plants have nodes along the stem and when a stem is cut cleanly between two nodes, the node is capable of generating a new root system. A few plants can be propagated through a leaf cutting, where the leaf stem can generate new roots. A few plants can even be propagated from a partial leaf. Methods of leaf cutting propagation include the split vein method where a leaf vein is cut down the middle where the leaf forms a wedge, leaf-bud cuttings where some of the stem is cut off with the leaf and emerged in the soil, and root cuttings where the plant can be regenerated from a section of the root. Rhizome division can be undertaken by cutting the rhizome clumps into smaller pieces and is generally very straight forward. Rhizomes take best where each division contains one or two ‘eyes’ or leaf stem, as with ginger and cardamom species. Likewise bulbs can be collected around parent plants.

Layering is another method of vegetative propagation where a stem is induced to produce roots while it is still attached to the parent plant. The method is quick and usually has fewer problems than other methods and is used for citrus and woody shrubs. This method called air layering or marcotting and involves clearing any leaves from a stem for approximately 10 cm each side of a cut made into the stem with a knife. The cut area is then covered in moist soil media or compost, which is wrapped in a polyethylene film and tied up on each end. New roots will grow from the injured area, which can be then separated from the parent tree. Another variation of layering is where a stem is partially cut from a parent plant and wrapped in a biodegradable cloth like coconut fibre and placed under the soil, so that roots can form. Once root systems are formed they are removed from the parent plant for planting. Jasmine, rose, hibiscus, citrus trees, cassia, croton, Leptospermum, Melaleuca and other similar plants and trees can be propagated via one of the many methods of layering available.

It is often the case when plants can be propagated both through seeds and cuttings. Generally plants propagated by seeds grow better in the field [102].

Budding and Grafting

Budding and grafting are two asexual propagation techniques, which are usually utilized to create plants with new characteristics such as drought tolerance, hardiness, and pest and disease resistance. These techniques utilize parts from two different plants to grow a single new plant entity. Budding involves taking a bud from one plant and joining it to the stem of another. Grafting involves joining the upper part or scion with the root system of another.

Most woody plants and trees can be budded and grafted. These methods have been used to produce new cultivars have better disease or drought resistance and/or high yields of essential oil. Budding and grafting has been used successfully in Indonesia to improve nutmeg tree production by producing higher yielding clones and smaller trees that are easier to harvest by using different *Myristica* species rootstocks [103].

Micro-propagation and Tissue Culture

Micro-propagation and tissue culture is used to produce a large number of clone material for field planting or as a method to improve the characteristics of a plant through transferring the protoplasts, anthers, microspores, ovules and embryos from one plant to another to create new genetic plant lines. For example, the pollen for one rose species can be transferred to another species to produce a hybrid, which will contain the chromosomes from both the parents, thus exhibit different genetic characteristics, such as being more drought or disease resistant. This is the basic process of developing new rose hybrids. Although these techniques are not new, they are now considered part of plant biotechnology.

Table 9.12. Common Methods of Propagation and Planting for Some Essential Oil Crops

Name	Method of Propagation	Planting Methods
Australian Tea Tree, *Melaleuca alternifolia*	Sown from seeds into beds. Seeds usually germinate in 7-10 days. Once 3 cm high, transfer seedlings to trays and at 8-12 cm, transfer seedlings to polybags (can by-pass and use trays). Plant at approximately 30 cm, usually obtained after 4-5 months. Propagation through cuttings shows limited success. Also can use tissue culture for clone plantations.	Either plant from trays (removing seedling) or from polybags into field. Utilise spacings according to machinery 0.5 x 0.8, 0.6 x 1.0 m, etc., or two and three row configurations.
Basil, *Ocimum basilicum and sub-species.*	Usually through sowing of seeds on a bed. Germination will occur in 5-7 days. Once germinated, individual plants should be separated. Also through cutting where a node and tip exists.	Seeds can be directly sown into field or seedlings planted 0.3 m apart.
Black Pepper, *Piper nigrum*	Through a variety of methods including seeds, vegetative propagation (best method), grafting and marcotting. Cuttings usually allowed to root before planting.	Must be planted with support, something like a vineyard. Single plants planted approximately 1.3 m apart. Often pruned and trained during early growth.
Calamus Oil, *Acorus calamus*	Through the breaking up and division of old rhizomes.	Broken up rhizomes planted in the soil, usually set out 0.3 x 0.3 m.
Cananga/Ylang Ylang, *Cananga odoratum*	From seed sown in beds and later transferred to pots. As taproot easily damaged, biodegradable pots can be planted directly into the ground. Seed should be soaked in warm water to end any dormancy period. Also can be propagated from cuttings.	Trees should be planted between 4-6 meters apart. Area can be inter –cropped in early years. Area should be maintained free of weeds through mowing. Trees allowed to grow to 3-4 meters and topped and pruned to maintain uniformity and maximize flower yield.

Table 9.12. Continued

Name	**Method of Propagation**	**Planting Methods**
Cassia Bark, various *Cinnamomum* species	*C. cassia:* from seeds or soft-tip cuttings, sown or placed in beds, usually localed in shaded areas. Seedling or cutting takes 4-6 months to develop root system vigourous enough to plant in bags or pots. Can be field planted after 2 years. Rooting is slow with cuttings, taking about 3 years before field planting. *C. verum:* usually vegetative propagation. Also through seeds collected from pods. Also through rootstock division. Cuttings generally much faster method than through seedlings.	*C. cassia:* Usually planted in rows with 50-60 cm x 1 m spacings, when seedlings 18-24 cm high. *C. verum:* direct sowing of seedling into holes in the field approximately 2-3 m apart. Cuttings and seedlings cultivated in the nursery are planted after 2 years in the field.
Citronella, *Cymbopogon nardus*	Usually a small land area is planted to grow clumps, which are comprised of individual stalks. The clumps are harvested and the stalks separated.	Usually 2-5 stalks are directly planted into holes either manually or mechanically.
Coriander seed, *Coriandrum sativum*	Can be sown from seed directly into the field. Germinates in around 5-7 days.	Plant in firm soil in rows around 10-15 cm apart.
Geranium, many species and hybrids of *Pelargonium*	Usually propagated through root, split or stem cuttings from parent plants. Also through the use of tissue culture and micro-propagation.	Either mechanized or manual direct field planting. Soil should be ridged and moist. Areas should be completely free of weeds and root systems of other plants.
Ginger, *Zingiber officinale and other species*	Most often through vegetative propagation of the rhizome. Can also be micro-propagated.	Planting in large plantations is mechanized. Can be intercropped. Soil should be warm and moist for optimum growth. Stems would emerge from the soil after 14-60 days, depending upon temperature and soil conditions. Cooler climates can use poly sheeting to raise temperatures.
Jasmine, *various Jasminum*	Normally propagated by soft-tip cuttings.	Cuttings are planted in well ploughed soil to rid it of all other root material. Cuttings

species.		should be 10-20 cm long from terminal shoots. Placed in prepared holes around 15-20 cm apart and watered regularly. Allowed to grow up a wire system, similar to a vineyard.
Lemon scented gum, *Eucalyptus citriodora*	Sown from seeds with germination between 5-10 days. Seedlings at 5 cm can be transferred to polybags. Seedlings reach 30 cm height within 3 months and are suitable for planting.	Seedlings in polybags planted into the field. Tree spacings should be between 1.5 to 3.0 m, depending upon equipment used.
Lemon Scented Tea Tree, *Leptospermum petersonii*	Usually sown from seed on beds of sterilized soil to prevent fungus and mold growth, which kills seedlings after germination. Germination after 5-6 days. After 3 cm transfer seedling to trays. Also need to control insect attacks. Trees can be planted after 3-5 months at 25-30 cm height.	Planted in rows 0.5 x 1.0 m either manually or mechanically.
Lemongrass, *Cymbopogon flexuosus*	Usually a small land area is planted to grow clumps, which are comprised of individual stalks. The clumps are harvested and the stalks separated. Can also be planted from seed collected from old flowering stock.	Usually 2-5 stalks are directly planted into holes either manually or mechanically.
Nutmeg, *Myristica fragrans*	Sown by seed into beds for germination. Germination takes between 30-60 days. Also vegetative propagation from female trees, and cloning through tissue culture. In established plantations, seedlings growing under parents can be transferred.	Seedlings can be transferred to the field in bags at around 25-30 cm height around 18 months after germination. Must be careful not to break roots while planting, use either banana leaf or biodegradable pots to sow tree intact. Spacings should be between 8-12 m between trees. Should be planted 9:1 ratio female to male trees.
Palmarosa, *Cymbopogon martini, var. motia* and *sofia.*	Cultivated from seeds collected from natural stands and sown into beds. Seeds usually germinate around 10-15 days and can be planted in the field after 6-8 weeks, around 20 cm high. Can also be propagated from stalks and cuttings	Usually 2-5 stalks are directly planted into holes either manually or mechanically.

Table 9.12. Continued

Name	Method of Propagation	Planting Methods
Patchouli, *Pogostemon cablin*	Normally propagation from cuttings, about 5-10 cm long and containing at least one node. Cuttings are ready for planting when 30-45 cm long.	Cuttings are usually planted in the field at a 50-65° angle to the soil surface to maximize multiple stem growth from the nodes. Cuttings are usually planted in spacings between 30 x 30 cm to 100 x 100 cm, depending upon soil fertility and threat of weed growth. Planting is easily mechanized.
Peppermint, *Mentha piperita*	Usually a field is maintained as planting materials at a ratio of 1:10 i.e., 1 Ha. for every 10 Ha. planted.	Rooted stock planted along furrows usually mechanically. As a temperate crop, it is usually planted in the early spring.
Rose. *Rosa species (usually R. centifolia and damascene)*	Usually established using cuttings in a nursery. Can be planted in the field after 12-24 months.	Plants produced from cuttings planted at the density of 8000-12000 per Ha.
Sage, *Salvia officinalis*	Usually sown from seed. Seeds can be sown on beds in a nursery and then transferred direct to the field. Can also be grown from cuttings.	Usually sown directly into the field and excessive seedlings thinned out and planted in rows a distance of 0.3 m apart, where plants can be placed 20-30 cm apart.
Sandalwood, *Santalum album and S. spicatum*	Seeds prefer a nitrogen rich host to attach to for germination, which include many tropical forest trees. Seed should be treated with a fungicide and sown with the seed of the host tree into pots or through direct sowing, which is often less successful. Seeds usually germinate in 10-18 days and grow to 30 cm in the first year and 70 cm in the second.	Seedlings can be planted in the field after a period of 2 to 3 years.
Tasmanian Blue Gum, *Eucalyptus globulus*	Seeds can be sown into beds or trays. Seeds usually germinate in around 5-8 days and once reaching 5 cm in height, transferred to polybags. Seedlings can be planted after reaching 30-40 cm in height,	Seedlings can be transferred into swallow holes dug in most types of ground, although they must be well drained to prevent trees falling over in soggy soils. Trees can be planted around 2-3 meter spacings. Weed control very important during the

	taking about 3-4 months.	first year to minimize competition.
Vertivert, *Vetiveria zizanioides*	Usually cultivated from stalks into clumps, which are separated for planting.	Stalks are planted where rhizomes should be placed approximately 20 cm under the soil surface. Rhizomes must be planted in a moist soil media that will allow very quick divisions. Approximately 100,000 stalks required per hectare. Either planted randomly or in rows to suit mechanical harvester.

The cost of tissue culture propagation has been brought down dramatically in recent years with the design and building of village based facilities which are 20-30 times cheaper to construct than conventional facilities and utilize tissue culture medium from domestic sources [104]. Such facilities should be built within a dedicated room within a well sealed house or office complex which is free from contamination and foot traffic, in a controlled air environment. The area should have enough space for a glassware cleaning area, a media preparation and sterilization area, a primary growth room and an aseptic transfer area. These areas should be well fanned with air filters and utilize good UV light [105]. Low cost micro-propagation of vetiver is being successfully undertaken in Vietnam [106].

Table 9.12 shows the common methods of propagating and planting a number of essential oil crops.

Table 9.13. Some Nutrient Source Materials that can be Used through Irrigation Systems

Nutrient	Source	Comments
Nitrogen	Fish waste	Can be liquefied
	Manures	Can be liquefied
	Spray dried fish	
Phosphorus	Micronised rock phosphate	Can be sent through irrigation system
N,P,K	Fish materials	
	Liquid manures	
Calcium	Limestone	Can be sent through irrigation system
Sulphur	Micronised sulphur	Can be sent through irrigation system
Trace Elements	Compost teas	See chapter 10
	Kelp extract powders & liquids	
	Rock dusts	Can be sent through irrigation system

Fertilisers

During all phases of plant growth in the nursery cycle there must be adequate levels of nutrients for plants to grow and foliate. With in-house soil media and potting mix production nutrients can be incorporated into the mix as discussed previously. The second way nutrients can be delivered to plants is through the irrigation system where fertilizers can be mixed into the water before it is sprayed or dripped into the plants. This is very effective through drip systems. The disadvantage of a spray system is uneven delivery, where some plants may be over fertilized and others receiving very little.

Nursery media and irrigation delivery systems allow for very specific fertilization of plants both in terms of what nutrients are fed to plants and timing. Most materials can be dissolved and converted into liquid fertilizers for efficient delivery. Table 9.13. shows some nutrient source materials which can be dissolved into water emulsions.

Within a modern nursery, the irrigation system can wash away nutrients from the soil media into the surrounding environment. This creates two problems, external contamination of the surrounding area with nitrates and phosphorus and nutrient deficiencies in the nursery. The release time of irrigation water to plants is a critical method of controlling run-off, as too much watering will disperse nutrients into water run-offs. Commercial slow release fertilizers can also assist in preventing nutrient run-off during watering. Another major issue with irrigation system delivery of fertilizers in the nursery is the clogging of micro-sprayers with organic materials. Most commercial fertilizers are totally water soluble and freeze dried organic materials like fish emulsions have been found not to cause clogging problems [107].

Pest and Disease Control

Agricultural practices over the last decade have been moving towards the concept of *Integrated Pest management (IPM)*, which is seen as a sustainable method of pest management utilising the natural environment as a barrier, physical traps and devices, pathogen resistant plants, building populations of beneficial organisms, introducing predators, using chemical pesticides for spot treatments as a last resort. *IPM* involves studying pest types and populations and setting minimum acceptable pest thresholds with relevant treatments. *IPM* also requires constant surveillance of plants to make an early detection of pest infestation.

Nursery location is the first defence against pests. A nursery should be located away from crops that may attract known and harmful pests, such as fruit orchards. Critical parts of the nursery like the seedbeds should be covered in a netted enclosure with double-netted entrances. Location and protection will minimise the need for using chemical pesticides. However there are natural alternatives to chemical pesticides like neem, citronella and tobacco mixtures. Neem and other trees useful for pest control can be cultivated around the nursery as barriers and material collected for making up insecticide mixtures, as required. These are discussed in the next chapter.

The pre-treatment of the soil mixture and potting mix through steaming and solarisation can destroy much soil borne disease, as discussed early in this section. Many types of compost contain beneficial organisms, which can also assist in the control of disease. Good hygiene practices like sterilizing knives for cuttings and spades, etc, help prevent carrying contamination from one plant to another. Seed beds and pots must not be allowed to be waterlogged as these create good conditions for bacteria growth, which could be harmful to the plants.

Weed Control

Weed growth competes against seedlings and is therefore undesirable. The general construction of the nursery compound, *i.e., cement or brick floors will greatly restrict the ability of weeds to flourish within the area.* This is assisted through the process of treating soil media and potting mixes before use in the nursery environment, which is the best protection against unwanted weeds. This is supported by good housekeeping, as keeping an area clean helps to prevent weeds from settling in soil. This protection is enhanced by having the nursery compound out of the way of direct exposure to winds which can carry weed seeds. It is inevitable that weeds will always find their way into a nursery environment through spores attached to clothing, etc. Plastic sheeting and textile barriers can also be used to keep weeds from breaking out around pot areas. Many nurseries use both pre- and post-emergent herbicides to control weed growth, as it is convenient. Flaming, hand weeding or use of a touch herbicide stick can assist in controlling and eradicate any small contaminations. In temporary nurseries, plastic sheeting and mulches can assist the suppression of weeds.

Within the last couple of years bio-herbicides have come onto the market. Corn gluten meal, a by-product of corn syrup manufacture is used as a pre-emergent herbicide. It also contains nitrogen and thus acts as a slow release fertiliser. Other bio-herbicides are manufactured from wheat gluten meal and pelargonic acid. These kill weeds by drastically changing the pH of the sprayed plant. There are also a number of products on the market based on vinegar or acetic acid. Recently a further derivative of corn syrup, corn gluten hydrolysate, much more powerful than straight corn gluten meal is available [108], as well as natural herbicides based on essential oils, discussed next chapter.

FIELD DEVELOPMENT – PREPARATION AND PLANTING

Most of the physical land development must be undertaken before planting, usually within a window before major rains (in tropical monsoon regions). The crop fields need to be prepared with a slight gradient so the rainwater will drain off without carrying excess amounts of top soil with it. Without tractor utilities and laser leveling equipment this is a major task taking many days per hectare to prepare. Laser leveling equipment will allow the preparation of a few hectares at one time, within a day or so.

Within practical limits, the soil should be prepared as much as possible to suit the intended crop. Most soils will lack nutrient content due to lack of humus and topsoil. Many soils also lack the ability to hold moisture. In most cases some simple corrective measures can be undertaken to improve general soil quality. Animal manures and composts can be added to the soil to increase the level of nutrients and compost. Rock salts can be used to buffer pH levels. Deep ploughing to breakup the subsoil will increase the ability of plants to grow deeper root systems and improve water infiltration into the soil. Where top soils crust up upon drying, cover crops can be used to keep them moist and add nutrients and organic matter or limestone or gypsum used to assist. With some herb crops, canopy trees, under some multi-cropping arrangement can be used for shade which will increase moisture contents in the soil by slowing evapouration.

Within each field there will be patches of unsuitable soil that will lower yields. Parts of the field may be deficient in fertility, drain water very poorly, or are too compact, etc. Some areas can become boggy or swampy after heavy rains and decrease yields substantially in these locations. These areas will be very prone to the growth of bacteria and therefore need to be identified and corrected. The method of correction will depend upon the problem. Soil with poor nutrients can be corrected with the addition of humus rich composts. Composts and sand may help poorly drained soils, as well as compacted soils.

Irrigation and drainage is a major issue in land preparation and requires extensive infrastructure development. How much work required depends upon the level of rainfall in the area, the availability of outside water sources and the amount of water required to be stored for future irrigation purposes on site. Irrigation design will depend upon;

- Agronomic issues like crop responses to climate and soil moisture variables,
- Environmental issues like climate, soils and topography,
- Social issues like experience, education and labour availability,
- Economic issues like capital requirements, capital availability, operating costs, and product returns,
- Historical issues like existing infrastructure, previous farming systems,
- Hydrological issues like river flow, groundwater, surface flow,
- Engineering constraint issues like hydraulic design, pump limitations, pipes and storage capacities,
- Regulatory policy issues like legislation on water access in rivers, surfaces and groundwater, and
- Administrative procedures like licensing requirements [109].

First, the water source must be identified and a delivery system from that source to both water storage facilities and the fields must be developed. This may involve developing a pump system from either, a river, a dam or an irrigation waterway, through channels, canals or pipes to on-site water storage facilities and the fields. Alternatively or as a support system, a bore may be dug into the water-table to pump water to the surface for use. Where a river, dam or irrigation canal does not exist within feasible distance of the property, a catchment and dam system for harvesting rainwater can be developed. Generally in South-East Asia this is not highly regulated, but in Australia rainwater catchments on private property are subject to a number government restrictions and water licenses [110].

Any existing water storage dams or tanks should be assessed for their holding capacity and whether this is sufficient for farm operations and contingency storage. If farm water storage doesn't exist or existing facilities are not sufficient, then new and additional water storage facilities need to be designed and developed. The size and extent of these facilities will depend upon the volume of water required, water requirements verses expected rainfall, and the distance water must be transferred to the fields. In addition, topographical features that can provide natural catchment areas will influence where and what size any dams will be constructed. Final development may involve a central dam or irrigation tank or a number of dams and tanks closer to the fields.

An on farm distribution water system from the water storage facilities to each field is required. These can be earthen or cement lined channels, gated pipe or a pressurized system. Once at the field, the water will be applied to the crop via drip irrigation, micro-jets, overhead sprinklers, or traveling irrigation sprinklers. Each system has its own advantages and disadvantages summarized in Table 9.14. and suitability for particular crops. Finally to complete the irrigation system, there must be a drainage system to collect excess water and return it to the water channels for reuse or re-channeling back into dams.

The type of crop cultivated, height, spacing, density and life span will influence the irrigation system selected. Predicted rainfall reliability will also influence the type of system chosen. Some crops require little irrigation if they are drought resistant. Economics will play a large role in whether irrigation is developed in the fields.

Table 9.14. The Advantages and Disadvantages of Different Types of Irrigation Systems

Type of System	**Advantages**	**Disadvantages**
Drip Irrigation	Very precise field application Very little water waste Difficult for weeds to nourish from system Dry leaves make it difficult for disease to set in Can be used for delivery of fertilizer (fertigation and chemigation *pesticides)* No run-off	Very expensive to set up Drip systems easily clogged, damaged, and regularly repositioned Require regular use as limited water release zone Difficult to handle during harvests utilizing machinery
Under-tree mini and micro sprinklers	Very precise application into small areas (larger than drip systems) Can be used for delivery of fertilizer (fertigation and chemigation *(pesticides)*) Better for weed control than wide overhead systems Usually no water run-off	Like drip irrigation, an expensive system Sprinklers can be easily damaged Need to be checked regularly as ants block them Difficult to handle during harvests utilizing machinery
Permanent Overhead Sprinklers	Generally longer life cycle than other systems Relatively maintenance free	Distribution patterns distorted by wind and fluctuating pump pressure High water loss from run-off and evaporation Can leach away fertilizers and pesticides Difficult to handle during harvests utilizing machinery
Mobile Sprinkler	Very cost effective system Very portable and can be rapidly	Require moving and setting up each time used

Systems	deployed where needed Low maintenance	Distribution patterns distorted by wind and fluctuating pump pressure High water loss from run-off and evaporation
In-Field Channel Systems	Low cost system Can cover wide areas Also act as a field drainage system	Very limited system for effective irrigation of many crops Promotes drastic weed growth Extremely wasteful of water Requires high maintenance to keep ditches deep enough Promotes lateral root growth in tree crops Requires high water channels in relation to the field to deliver water

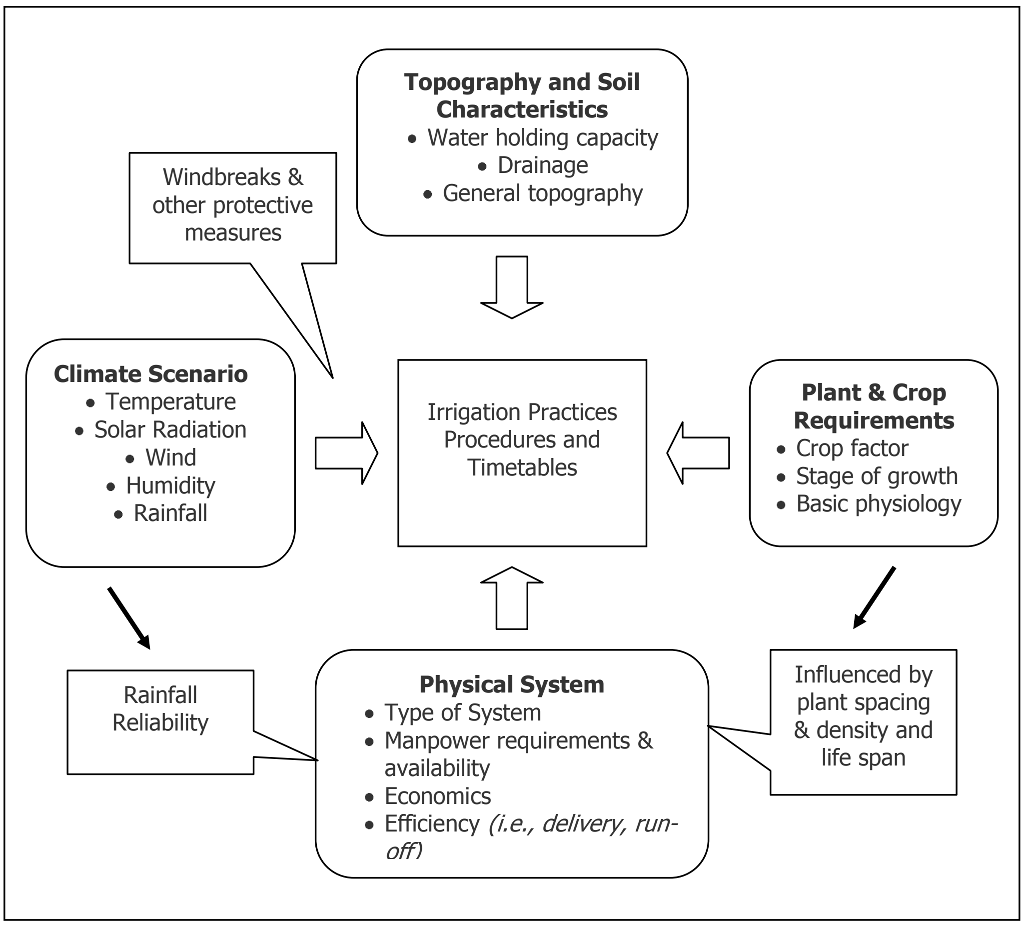


Figure 9.14. The Variables Influencing Irrigation Practices for a Crop.

Finally an irrigation management system needs to be developed to provide the optimum level of moisture to the crop within an economical framework. The factors influencing the amount of irrigation required in terms of frequency and volume are shown in Figure 9.14. It will often be necessary to determine optimum moisture application rates through an experimental study, which is discussed later in this chapter. There are software systems available to manage irrigation systems available [111].

The crop factor is the ratio of plant water use to evapouration loss. A crop with a crop factor of 0.8 will require 8.0 mm of water when the daily loss of water through evapouration is 10.0 mm. Most vegetable crops have a crop factor of 0.8-1.0, tree crops from less than 0.5 to 1.0, depending upon the time of year and stage of development. Tropical grasses grow well if irrigation is based on a crop factor of 0.6 [112].

Fencing is most likely required around fields to prevent either cattle or wild animals from straying into the fields and damaging the crop. Roads to transport farm equipment and workers are also required. Their construction (gravel/stone, tar and chip or asphalt road) will be influenced by the extent of rain and erosion on site. Field development also includes the connection to grid power or setting up of generators for electricity and building to house farm equipment and machinery, harvesting and distillation equipment.

Finally, strategies to control erosion in non-productive field areas of the farm are needed to maintain top soils. Vetiver is successfully used in tropical climates by roadsides, along hill and terrace slopes and along the sides of rivers and drains [113]. Jiji grass *(Achnatherum splendens)* is also used in China. Other methods to control erosion in South East Asia include developing contour ridging, minimum or zero tillage, intercropping [114] and the planting of hedgerows [115]. Generally, appropriate land use should be selected for the specific land in question. Much erosion prone land is marginal on slopes and thus appropriate techniques mentioned above can be employed. Developing organic material in soils will aid in resistance to erosion as water holding capacity will be improved. This can be partly achieved through returning crop residues in a crop rotational plan in the field. Grassing waterways with crops like hay is another common practice. Steeper slopes can be terraced to prevent soil erosion [116].

Fire Breaks

Fires are not just a threat to the dry areas of the Australian outback and are just as likely to occur in the green lush tropical areas in South East Asia. Thus planning for potential fires is important to protect crops from potential fire outbreaks. This is also very important for essential oil crops which contain flammable volatile oils that will aid a fire.

Fires usually ignite from lightening strikes, human error and malice. The propensity for an ignition source to spark a fire depends upon temperature, relative humidity, wind speed, oxygen and available biomass buildup. Dry, hot and windy conditions are the best conditions for fires to spread unhindered.

One of the best methods to protect crops from potential fires is to build a firebreak by either burning-down vegetation or ploughing up an area around a crop. Firebreaks can be designed in the farm as road access to fields for the transport of machinery, etc. If a firebreak cannot be built around the whole field, then a break can be built along the windward side of the crop, as this is the most probably direction any potential fire will come from. Firebreaks can produce other problems like soil erosion and thus should be grassed and well drained.

Controlled burns to create firebreaks should be undertaken during low temperatures, light winds and when soil is moist. They should be very closely supervised to prevent them getting out of control and the supervisor and team should plan the burn with a number of contingencies very well beforehand.

Planting

Planting is one of the major operations of an essential oil farm or plantation and follows directly on from the nursery stage. Planting can be undertaken either manually or mechanically. If labour is a small cost of the total operation, plentiful and undertaken only on an occasional basis, then manual planting will usually be practiced. If labour costs are high, labour supply scarce and planting undertaken on a seasonal or annual basis, then mechanical planting methods are usually practiced. Often the planting season is very short and all materials, seedlings and labour must be available and ready.

Planting is a logistical operation that must be undertaken with good planning and coordination to maximize seedling and vegetative material survival once planted in the field. It is not uncommon for plant survival rates to be poor after planting if seedling preparation was not undertaken in a satisfactory manner. Other causes of planting failure include poor seedling preparation in the nursery, poor supervision of planters who damage root systems during planting, mis-calibration of mechanical planters which also damage seedlings, and the failure to water plants within a reasonable time after planting. These all cause unnecessary plant loss. Seedlings from the nursery must be in optimal planting condition and fields fully prepared for planting. A delay in seedling preparation, field preparation or labour availability can drastically shorten the planting window.

Before planting, seedlings and plants in the nursery are usually hardened off by reducing watering over the three to four week period. This period prepares the seedlings for the conditions it will face in the field and can reduce "shock" which will hinder the seedling taking to the field. Alternatively, plants can be removed to the field into a temporary mini-nursery, a few weeks before planting to adjust to conditions if a watering source is available. This process must be very gradual to prevent any plant stress. Plants should also be screened in the nursery to eliminate any plants that are small, poorly formed or lack general vigor.

The weather and season will have great impact on the planting time. Ideally, the planting time will be calculated back from the projected harvesting time, so the planned cultivation cycle can commence. This cycle must also take into account the season, *i.e., spring for peppermint planting so a harvest can be made during mid summer.* In tropical areas an ideal time to plant is towards the end of the rainy season, so plants have little competition with weeds, especially tree crops. As well as taking season into account, weather during the planting period should be favourable so that minimum stress is given to the plants. Planting during period of rain often save effort in having to undertake early irrigation after planting.

Soil moisture levels should be at their optimum for planting. Planting during early rains may not be the best time as soils have not yet absorbed enough moisture. Planting during extreme rain periods can waterlog some plants and create "shock", as some plants prefer dry conditions. Excess water in poorly drained soils can promote the growth of threatening bacteria and disease to the plants.

Plant Populations and Spacings

The term plant population refers to the number of plants per unit of land and plant spacings refers to the arrangement of plants within a planted area, usually expressed as a two dimensional measurement, *i.e., 0.5 m x 0.6 m.* The plant population and spacings has a bearing on the physical growth of the plant, the size of plant features, *i.e., stems, leaves, fruits and flowers,* and the eventual yield and quality of essential oil.

The determination of optimal plant populations and spacings for a crop is complex as climate, soil fertility, plant physiology, and the intended methods of planting, managing and harvesting the crop all have some bearing. Generally plants perform better at uniform spacings than in non-uniform arrangements [117]. Uniform row arrangements provide workers access to the field for the purposes of inspection, maintenance and the application of fertilizers and pesticides. Under a mechanized regime, rows are arranged to suit the size and width of machinery, so there is minimal crop damage.

Plant densities depend greatly on lateral growth above the ground and root systems. As root systems generally resemble above ground plant growth in a wide range of species, then minimum densities roughly follow the width of lateral growth above the ground. For example, if a tree crop has lateral branches spreading out 50 cm from the trunk, then the minimum spacing should be roughly 1.0 metre under average conditions. Where climate and soil nutrients are more favourable, plants will usually extend their vertical and lateral growth, so minimum spacings could be wider to take this into account. It follows when conditions are less favourable, *i.e., a slightly cooler climate where growth is not as favourable*, the minimum plant spacing would be less. Understanding the basic parameters for plant growth will provide the basic information required to determine potential plant spacings.

Initially, plants placed in higher densities than their optimum spacings will increase yields, but this will not be sustainable as inter-plant competition both above and below the ground will become severe. With tree crops like tea tree, canopies will cut out light to the base of the trees and drastically reduce lower leaf growth. Under higher densities, plants will not reach their full height and take longer to mature, leading to poorer plant biomass. When plant densities are reduced, more leaf and rhizome growth [118] is promoted. The effect of varying plant density does not have uniform effects on all plants and understanding responses requires specific field spacing trials.

In practice varying plant densities can develop some desired effects in the crop like increased flower [119] and fruit population, increase leaf growth, increase stem growth [120] and bring quicker and uniform harvest times. However some studies show inconsistent results [121] making it difficult to draw definite and general conclusions about the effects of plant densities. Plant spacing are often arranged for mechanical harvest convenience, especially for extensive crops like tea tree and eucalyptus tree coppicing, or for worker ease of access where manual harvesting is required for rose and jasmine.

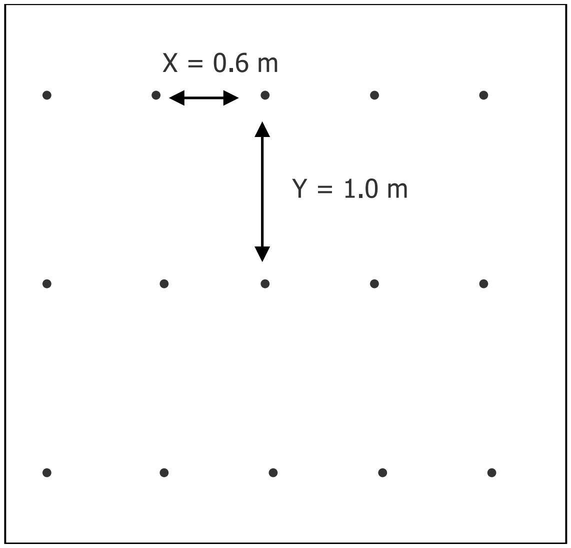


Figure 9.15. Square Planting Pattern Showing Spacing Distance.

To calculate plant density and spacings, the space needed by each plant should be determined and doubled, becoming (X) and (Y) which will become the calculated distance needed between the rows, based on the type of access needed. For example where conditions provide for a tree to grow 0.3 m laterally, 0.6 m is the distance required between each tree (X). If 1.0 M is required for access between the rows, then (Y = 1.0m) as shown in Figure 9.15. To calculate density or the number of plants required for a particular area, *i.e., 1.0 Hectare*, divide 100 m / 0.6 m = 166 and divide 100 m / 1.0 m = 100, then multiply 166 X 100 = 16,600 plants per hectare.

Determining the Optimum Cultivation Parameters through Research and Demonstration Plots

When cultivating a crop it is important to know the optimum levels of moisture, fertilizer to achieve the best yields and best levels of herbicides, pesticides and fungicides to eradicate any potential weed, pest and disease problems. The plant species, cultivar, site, weather and season will all influence what these optimum levels are. The only way to satisfactory to determine these levels is by conducting field trials or experiments.

Conducting field trials requires asking questions about what factors are the most influential in effecting crop and oil yields and controlling weeds, pests and diseases. Due to the large number of factors, some elimination is needed to narrow down the issues to a few variables which can be readily tested in the field through experiments.

Field experiments must have a clear and simple objective so that it can be designed simply and clearly to provide the relevant information required to determine optimal field applications. The variable that is being tested must be clearly decided and then tested at various levels or treatments in well defined field plots to observe its effectiveness in achieving the objective. Usually a standard plot either with the existing treatment or with no treatment is also undertaken as a reference plot to compare results. This is called the control plot. Information collected from all the plots is called data and this is statistically collated and analysed to provide an objective result. This is called a factorial experiment.

In the experiment, each level of treatment is usually repeated in more than one plot to create more reliability in the result. This is in case one of more plots encountered something unforeseen that affected the result. All plots will have minor differences which will give variances in the data collected, so these results are statistically averaged and smoothed out. This is called replication. As individual plots may provide extraordinary data, reliance on only a single or couple of plots for data on a variable may not give a reliable and realistic result. Therefore the more replication that exists the less chance there is for irregularities to influence the result of the trial or experiment. The number of replications used depends on what is being tested, how close together the plots are, the size and how wide the variations in the treatment are. Usually 4-6 replications are used in a trial.

To further increase the reliability of an experiment, each level of treatment is not placed in any connecting order, but placed randomly among the plots. This helps eliminate any factors or unintentional biases, like differing sunlight levels or soil fertility along the plots, influencing the result according to sequential treatment levels.

The determination of the size of each plot that a single treatment will be applied to depends on both biological and logistical considerations. In determining the biological need for plot size, a size that can adequately show a response to moisture or fertilizer application, insect damage, weed incidence or disease severity, is the major factor to consider. For example, to see the effects of fertiliser and moisture application may take a much larger plot than is required to monitor pest and disease or weed issues. The ease of collecting data must also be considered, as counting the incidence of insects in a large plot may be much more difficult than estimating and measuring the biomass of a plot. Finally plots must be larger enough so that the effect of any chemical application on one plot does not affect any connecting plot. Logistical plot size considerations concern the size and nature of cultivation and harvesting equipment that is used. Alternatively only part of a plot can be used to collect data from and buffer rows can be used between trial plots to prevent connecting plot influence.

Before setting up a trial block of plots, it is important to understand any potential soil variances, drainage patterns and water logging, the direction of wind, weather and insect migrations, etc. The design is usually allocated in a blocked plot formation where each block (if possible) is laid across any variances (soil changes and shade hours, etc.) so all various treatments are exposed to soil or sunshine hour variance, etc. If possible a small channel should be dug between each plot so water run-off from one plot will not contaminate the next plot. Through blocking any potential effects of non-experiment variances on the data collected, better statistical integrity can be achieved. A block will usually contain a single plot of each treatment level decided in the experiment. As each block contains each treatment level it is also called a replication. For example Figure 9.16. shows a field where the shaded areas represent soil variances. The replicated treatment plots are laid randomly in blocks across the field, so all levels of treatment variation, in what is called a randomized compete block design. If the experiment was to assess the effect of nitrogen on crop yield, each block would have a pre-determined level of nitrogen applied, for example A= 50 kg/Ha., B= 80 Kg/Ha., C=110 Kg/Ha. and D is the control plot with no nitrogen applied.

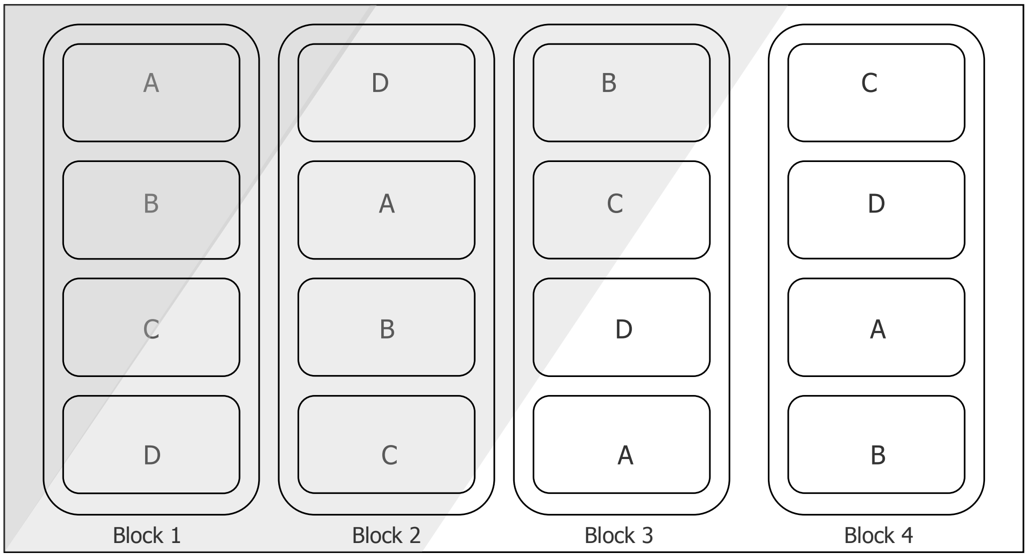


Figure 9.16. Diagram Showing a Randomised Complete Block Design for a Field Experiment.

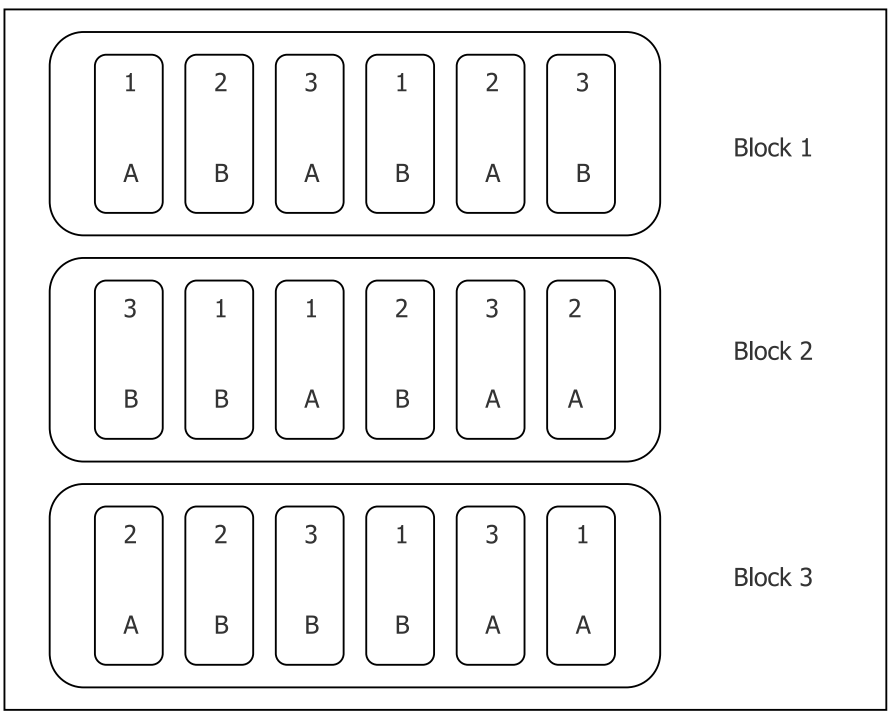


Figure 9.17. A Factorial Arrangement of Treatments (Moisture *(A)* and Nitrogen *(B)*) in a Randomised Complete Block Design.

When more than one factor is tested in the one experiment at the same time, it is called a factorial experiment. For example, factorial experiments are useful if the combined affect of two treatments are applied to the experimental crop, such as nitrogen and moisture. Only be combining these variables can the effect of both together be known. This is particularly useful when there is likely to be some interaction between the two factors. Where a factorial experiment is taking place, all treatment levels of one factor must be combined with treatment levels of the other factor. If two moisture applications and three levels of nitrogen application are tested, this would be referred to as a two by three factorial to express the number of factors tested during the experiment, thus requiring six field treatments. Such an experiment testing 3 levels of fertilizer with 2 levels of moisture application would be laid out in a factorial arrangement in a randomized complete block design, shown in Figure 9.17. where A and B represent moisture application levels and 1, 2 and 3, represent the levels of fertilizer application.

The data collected from the experiment depends upon the treatment or variable being measured. If yield is the primary function of the variables *(i.e., Moisture and fertilizer),* then a harvest and distillation will have to take place, measuring biomass and oil recovery amount. Likewise, if particular constituent levels in an essential oil are the objective of the experiment, an analysis is required to determine the response level of the constituent to the variable *(i.e., the response of citral content in lemongrass to nitrogen application)*. Likewise if the effect of a pesticide is being tested, a headcount of target pests is required in the plot. During the experiment other data like rainfall and temperature is useful to collect, as these variables will have some bearing on the result. It must also be decided for how long should data be collected for, one harvest or two or more harvest cycles, if collecting information on yields.

Field plots should be coded and specific treatments not disclosed to avoid any unconscious bias by collectors of data. With coded plot identification there is any elimination of the tendency to make any favourable estimation for plots expected to do well and unfavourable estimates for plots expected not to do well. Data collected should be statistically analysed to detect and see true treatment outcome trends, with the impact unusually low and high results smoothed out of the results. It must be pointed out that experimental results are not always transferable from one field to another or one location to another because of different climates, weather, seasons and soil fertility. These variables require very site specific testing, although results from other locations may assist in making basic assumptions about fertiliser, moisture, pesticide, herbicide levels to use, etc.

CROP FIELD MAINTENANCE

All crops go through a period between planting and harvest where they grow and mature to a point where harvest takes place. During this period certain crop maintenance should take place to produce specific plant characteristics that lead to a desirable product, *i.e., oil composition* and financial viability, *i.e., yield*. The period between planting and harvest can range from a couple of months to over 15 years for certain tropical trees. This length of time is also critical for the financial viability of the crop, as neglect during this period will most likely drastically affect the return on investment.

The manipulation of certain variables during the crop field maintenance period can in the majority of cases speed up this period in order that quicker harvest times can be achieved. These variables should have been identified and tested during field experiments discussed earlier in this chapter. For example, there are great differences in yields and oil constituents during the growth of plants [122] and different fertilizers will have different effects on the growth of plants [123], which will differ by crop and to some degree be influenced by climate and site specific issues. Amino acids such as proline, its analogues and N-methyl amino acids, known as betaines comprise important osmoprotectants which can be used as soil additives to improve stress tolerance in crops against drought, heat, cool weather and soil salinity [124]. The use of specific propagation techniques like bud grafting can speed up tree growth [125]. Finally, some purpose built machinery like flaming can be used to perform specific maintenance operations like rust prevention in mint crops [126].

The major crop maintenance issues are feeding the correct and right volume of nutrients to the crop, pest and disease management, weed control and irrigation. These practices and methods will be developed into a comprehensive crop maintenance strategy based on various elements of prevention, cultural, mechanical and chemical control, outlined in Table 9.15,;

Table 9.15. Strategy Guideline for Conventional Crop Maintenance

Practice	Explanation	Example
Prevention	Using practices and methods to prevent something like weed growth or pest and inhabitation	Cleaning tractors and other agricultural equipment before entering a field to prevent the spread of weed seeds or spores.
Cultural Control	Choosing the best cultivars and planting materials, engaging in practices that will promote growth and protect crops, etc	Selecting high yielding seeds through index selection, use of intercropping to improve soil fertility, select best seasonal planting times to prevent weed competition with crop.
Mechanical Control	Mechanical methods to assist with crop maintenance.	The use of flaming to control diseases like root rust and control weeds, utilizing no-till approaches to prevent weed seed spreading and maintain soil fertility.
Chemical Control	The use of chemicals to assist in crop maintenance.	The use of pre-emergence herbicides to prevent weed growth, the use of pesticides, etc.

Fertilisers

Fertilisers are chemical compounds, either naturally or synthetically derived that are applied to plants to assist in growth. Fertilisers are either applied through the soil for root uptake or by foliar feeding, for leaf uptake. Fertilisers provide plants the necessary nutrient elements for growth. Various fertilizers differ in their nutrient compositions. The primary fertilizers comprise of nitrogen (N), phosphorus (P) and potassium (K) in different ratios, as plants require these elements most, sometimes with secondary plant nutrients, calcium, sulphur and magnesium. Specialised fertilizers may also contain the micronutrients, boron, chlorine, manganese, iron, zinc, molybdenum and copper for specific plant applications or for use in specific geographical areas where soils may have certain nutrient deficiencies or plants particular nutrient needs.

Table 9.16. The Primary, Secondary and Micro Plant Nutrients

Nutrient	Application
Primary Nutrients	
Nitrogen (N)	Nitrogen is part of all living cells including proteins and enzymes. Nitrogen is also involved in the plant metabolic processes and in the synthesis and transfer of energy, thus it is the primary nutrient responsible for the flush growth of a plant. Basically nitrogen produces biomass. Nitrogen is also a part of chlorophyll, important for photosynthesis. Too much nitrogen can *'burn'* a plant and make it susceptible to disease.
Phosphorus (P)	Phosphorus is essential for the process of photosynthesis and involved in the formation of all oils, sugars and starches. Phosphorus encourages plant rooting, flower blooming and fruit production. Phosphorus also helps plants withstand stress. It is very important in the early growth of a plant and the development of fruits, flowers and vegetables.
Potassium (K)	Potassium helps to build protein and in the process of photosynthesis. Potassium also helps plants resist disease and aids hardiness, especially in cold climates. Like nitrogen, too much potassium can *'burn'* plant foliage.
Secondary Nutrients	
Calcium (Ca)	Calcium is an important part of the cellular structure of plant walls and provides for the transport and retention of other elements. Calcium is important for building the strength of a plant.
Magnesium (Mg)	Magnesium is required by crops to assist in the production of chlorophyll and in the photosynthesis process. Magnesium also assists in plant respiration, and the activation of enzyme systems related to the growth of the plant.
Sulphur (S)	Sulfur is essential for protein production and the development of enzymes, vitamins and chlorophyll production. Sulfur is required by the plant for root growth, flush growth, seed production and resistance to cold. Before it is consumed by plants sulphur must be converted to SO_4 by bacteria in the soil.
Micronutrients	
Iron (Fe)	Iron aids in the formation of chlorophyll.
Boron (B)	Boron helps in the regulation of other nutrients and aids the production of sugar and carbohydrates. Boron is also essential for seed and fruit development.
Manganese (Mn)	Manganese assists with the enzyme breakdown of carbohydrates and with the nitrogen metabolism.
Copper (Cu)	Copper aids in the root metabolism, utilization of proteins and is an important element for reproductive growth.
Chlorine (Cl)	Chlorine is an important element aiding the plant metabolism.
Molybdenum (Mo)	Molybdenum assists the use of nitrogen in plants
Zinc (Zn)	Zinc is essential for the transformation of carbohydrates, regulates the consumption of sugars and assists enzymes which regulate plant growth.

Primary fertilizers are called NPK or compound fertilizers. They are usually labeled according to their nitrogen, phosphorus and potassium content, *i.e.*, *NPK.*, where nitrogen is reported directly, phosphorus is reported as phosphorus pentoxide (P_2O_5), the anhydride of phosphoric acid, and potassium is reported as potassium oxide (K_2O), the anhydride of potassium hydroxide. For example, a 10-25-20 fertiliser would have 10% nitrogen as N, 25% phosphorus as P_2O_5 and 20% potassium as K_2O. The remaining 45% would comprise of a filling agent. Under the NPK naming convention, the nitrogen value would be 10%, phosphorus level would equal [P_2O_5] x 0.436, and potassium level would equal [K_2O] x 0.83. Therefore the 10-25-20 fertiliser would have 10% nitrogen (N), 11% phosphorus (P), and 16.5% potassium (K) [127].

The 13 essential nutrients are absorbed by plants through the soil, dissolved in water and absorbed through the root system. The primary nutrients provide a source of materials for the plant to build the basic cellular structures of the plant. This is a continual process so these nutrients must always be regenerated into the soil, as plants continually deplete these materials. Nitrogen fertilizers are both fast and slow release, while organic fertilizers generally release nitrogen more slowly into the soil. Nitrogen also is carried by rain where between 2-10 kilograms of nitrogen are absorbed into a hectare of soil each year. Legumes such as peas, beans, clovers, and alfalfa are also able to fix nitrogen into the soil. Phosphorus is available as a liquid or solid fertilizer and is often used to boost flower and fruit blooming. Phosphorus moves very slowly through the soil and needs to be applied well in advance of when it is required. Bone meal and super phosphate are sources of phosphorus. Potassium is supplied to the soil through fertilizers, soil minerals and organic materials. Continual supplies of potassium are needed in soils which quickly leach nutrients like sandy soils.

The secondary nutrients are usually available in the soil, unless specific needs of a plant require greater quantities than are usually available. Calcium is available in dolomitic lime, as calcium carbonate, gypsum and super phosphate. Deficiencies of calcium are likely to occur in acidic peat soils and sandy soils, easily leached by rain and irrigation water. Magnesium comes from fertilizers, minerals and dolomitic limestone, which contain magnesium carbonate. The availability of magnesium is often related to soil pH. Sandy soils usually are low in magnesium due to their high leaching potential. Sulfur is usually available in fertilizers, gypsum and is produced through decaying organic matter.

Table 9.17. Soil Descriptions According to pH Levels

pH	Soil Description
< 5.5	Strongly acidic
5.5-5.9	Medium acidic
6.0-6.4	Slightly acidic
7.0	Neutral
7.1-7.5	Very slightly alkaline
7.6-8.0	Slightly alkaline
8.1-8.5	Medium alkaline
> 8.5	Strongly alkaline

The micronutrients or trace elements are usually available from the soil through decomposing organic matter. The non-mineral nutrients hydrogen (H), oxygen (O) and carbon (C) are available in the air and water, thus plentiful. These are important elements in photosynthesis where carbon dioxide is changed into starches and sugars as the plants basic food.

Generally, fertilizers are absorbed by plants through the soil. Thus the characteristics of the soil are a major determinant upon how effective fertilizers are. The major determinants of nutrient delivery to the plant root system are soil texture and pH.

The soil make up of sand, clay, silt and organic matter or soil texture effects how nutrients and water will be retained in the soil, as the plant nutrients rely on water to carry them to the plant's root systems. Clay type soils are generally better than sandy ones where nutrients can easily leach away as water drains from the soil.

Soil pH influences nutrients in a number of ways. Outside the neutral pH range microbes are unable to thrive and assist in the decomposition of organic materials, thus leading to a reduction of nitrogen and sulphur levels. This locks up nutrients in the soil where plants cannot draw upon. Where soils are acidic with a low pH, the macronutrients like nitrogen, phosphorus, potassium, calcium, magnesium and sulphur tend to be lacking. Micronutrients like iron, boron, manganese, copper, chlorine, Molybdenum, and zinc are lacking in alkaline soils with higher pH levels.

The pH scale is logarithmic where the scale is at the power of ten, *i.e., a pH of 6 is ten times more acidic than a pH of 7.* Soil descriptions according to pH levels would follow the following table below.

Table 9.18. Types of Weeds

Weed Type	**Comments**
Annual Weeds	An annual weed has a lifecycle in a single year. Annual weeds usually produce a large number of seeds and depend upon favourable climatic conditions to survive. Annual weeds consist of two groups, summer annuals, which germinate in the spring, reaching full maturity in the summer or autumn, dispersing seed and dying, and winter weeds that germinate during autumn, grow slowly over winters and speed up growth during spring weather, disperse seed during the summer and die.
Biennial Weeds	Biennial weeds have a life span of two years and grow from dispersed seed during springtime. During the first season these weeds store up food in fleshy roots. Their foliage is usually limited to a rosette of leaves, low on the ground. During the second season the plant draws upon its stored food and grows vigourously, producing seed during the second summer and dies.
Perennial Weeds	Perennial weeds live for long periods of time. Simple perennials spread by seed, bulbous perennials multiply through bulb or tuber multiplication and creeping perennials spread by root growth.

Most plants grow best in the range 6.5-7.2 soil pH. pH levels can change over time due to rain and river silts from local geographic features with acidic or alkaline materials like lime. Consequently it is sometimes necessary to raise the pH level of a field into a more suitable range that suits the plant and allows soil microbes to convert nutrients into forms that plants can absorb. Where soils are acidic, treatment with lime will buffer the pH to the neutral range. Poultry manure and wood ash can also assist in raising pH levels. Where soil pH is too alkaline, the use of sulfur and aluminum sulfate will bring down pH, as they change into acids. Aluminum sulfate is a much quicker agent than sulfur as it produces acidity as soon as it dissolves in the soil. Sulfur on the other hand will take time to convert to sulfuric acid with the aid of soil bacteria. Changing soil pH will have a similar effect to fertilizer application, as nutrients will once again be released and taken up by plants.

Nitrogen fertilisers are often made up of ammonium nitrate or urea and are used either directly onto the field or mixed with water. Naturally occurring inorganic minerals like sodium and potassium nitrate, rock phosphate, and potassium chloride and sulphate are used in NPK type fertilizers. These are usually in granular form and applied directly to the field. There are a number of fertilizers produced commercially in granular, pellet or liquid form which contain specific secondary and micro-nutrients. These fertilisers can be applied directly or through irrigation systems. Secondary and micro-nutrients are usually present in relatively small percentages compared to the primary nutrients. A number of natural materials like manures, composts, compost teas are also used as organic fertilizers. These are discussed in more detail in chapter 10.

Much research concerned with the use of fertilizers has focused on the application of nitrogen to biomass, which does not necessarily correlate with oil yield. Specific fertilizer use recommendations from crop bulletins and other sources are of limited value due to location differences. Some fertilizer research on essential oils leads to contradicting conclusions, most probably due to different site conditions and different methods [128]. A large volume of essential oils, particularly those produced in developing countries probably have very little, if any fertilizer application, due to lack of capital and the nature of subsistence farming methods [129]. Nutrient management requirements differ between crops and locations because of different soil conditions. Therefore specific trials are necessary to determine the actual effects of fertilizers on crops in specific locations. Cultural practices also play a role in the effectiveness of nutrient management and minor element treatments will be greatly influenced by the fertility of the soil.

Weed Control

Weeds are plants that generally interfere with crop activities through some negative characteristics they possess in terms of crop health and wellbeing. These plants have no use in crop development and are thus considered noxious and a menace to farming activity. Weeds are usually classified according to their life span, as shown in Table 9.18.

Generally speaking the perennial group of weeds is the hardest to control, requiring multiple strategies to eradicate them. The impact of weeds on crops is to reduce yields, reduce crop quality, harbor insects and disease that can affect crops, displace native vegetation and threaten environmental diversity and introduce toxic materials to the crop. Weeds collected during mechanical harvesting can contaminate essential oils.

Table 9.19. The Advantages and Disadvantages of Pre and Post-Emergent Herbicides [130]

Herbicide Type	Advantages	Disadvantages
Pre-planting soil applied	Easy control of weeds Minimizes early competition with crop Weeds can be controlled in wet and windy conditions	Perennial weeds difficult to control with this method Less effective under dry and cold soil conditions Herbicide residues may restrict crop rotations in following years Soil erosion may be a problem as tillage is required
Pre-emergent soil applied	Early control of weeds Minimizes early competition with crop Weeds can be controlled in wet and windy conditions Planting and herbicide application can be done in one operation	Less effective under dry and cold soil conditions Perennial weeds difficult to control with this method Heavy rain may leach herbicide down to the germinating crop in sandy soils Wet and windy conditions after seeding can delay application until crop emergence and prevent herbicide application Residue may restrict crop competition the following year Soil erosion may be a problem as tillage is required
Post Emergence foliar applied	The type and density of the weed is known before application Less chance of soil residues Top growth control of perennial weeds is possible	Specific application required on both crop and weed Flush weeds may still occur after spraying Wet and windy conditions can cause delays in spraying

The aim of weed control is to suppress weed growth through suppressing weed seed production, reduce weed seed storage in the soil and prevent or reduce of weeds on the surface. Most weed control within conventional farming systems is carried out with chemical means utilizing herbicides, supported with some prevention, cultural and mechanical methods. As the effectiveness of herbicides is influenced by a number of factors including the stage of weed growth, the stage of crop growth, temperature, soil moisture and soil pH, etc., early crop research would usually involve trials to select the most appropriate herbicide and usage methods.

Herbicides can be applied to soil, where it is taken up by root systems to the stem and leaves of the plant. These can be used as a pre-emergence inhibitor, where it prevents the germination of weed seeds. These types of herbicides are usually slow acting, taking a number of days to show effects. Other herbicides are sprayed onto the weeds as contact herbicides to destroy plant material in direct contract with it to prevent plant photosynthesis. These types of herbicides are not very effective on perennial plants, where new shoots can grow from rhizomes, roots or tubers. Pre-emergence herbicides usually need a secondary treatment to maintain effectiveness. For example where triazines are used as soil based pre-emergence herbicides, other treatments like bromoxynil, and primisulfurons are used as foliar treatments and sprayed onto emerging weeds. A comparison between soil and foliar applied herbicides is shown in Table 9.19.

Herbicides act upon weeds in a number of ways. Acetyl coenzyme A carboxylase (ACCase) inhibitors affect cell membrane production in plants, particularly grasses. Acetolactate synthase (ALS) enzymes strave the plants of amino acid production which inhibits DNA protein production. These types of inhibitors include sulonylureas, imidazolinones, triazolopyrimidines, pyrrimidinyl oxybenzoates and sulfonylamino carbonyl triazinones. EPSPS enzyme *(enolpyruvylshikimate 3-phosphate synthase)* inhibitors which prevent the synthesis of tryptophan, phenylalanine and tyrosine in plants. Synthetic auxins that mimic the natural plant hormone auxin and photo inhibitors that reduce electron flow from water to NADPH2+ in the photosynthesis process, that cause the oxidation of chlorophyll cells, which cause the plant to die. The triazine herbicides and urea derivatives are photosynthesis inhibitors [131]. Through the selection of herbicides that act on specific plant pathways, it is possible to use them with some selectivity on plants. Some of the major herbicides used today are listed in Table 9.20.

Table 9.20. Some of the Major Herbicides Used Today

Herbicide	**Description**
2,4-D	A broadleaf herbicide usually used in turf, grass and no-till agriculture. Often blended with other herbicides, so lower volumes of herbicides can be used in the field.
Aminopyralid	A broadleaf herbicide used to control broadleaf weeds on grasslands.
Atrazine	A triazine herbicide used in corn crops to control broadleaf and grass weeds. Low cost and works very well with a braod spectrum. Usually used with other herbicides to lower residual contamination levels.
Clopyralid	A broadleaf herbicide used in turflands for control of thistle type weeds.
Dicamba	A post emergent broadleaf herbicide with soil activity, used in turflands and corn fields.
Fluroxypyr	A systematic and selective herbicide used in the control of broadleaved weeds.
Glufosinate ammonium	A braod spectrum contact hherbicide used to control weeds after they emerge. Also used for “total vegetation control”.
Glyphosphate	A systemic non-selective herbicide used for no-till weed control.
Imazapyr	A non-selective herbicide used for the control of a wide range of weeds.
Imazapic	A selective herbicide used in both pre- and post-emergent control of some annual and perennial grasses and some broadleaf weeds.
Linuron	A non-selective herbicide used in the control of grasses and broadleaved weeds.
Metolachlor	A pre-emergent herbicide used for control of annual grasses.
Paraquat	A non-selective contact herbicide used in no till agriculture.
Pendimethalin	A pre-emergent herbicide widely used to control annual grasses and some broadleaved weeds.
Picloram	A herbicide mainly used to get rid of unwanted trees in fields.
Triclopyr	A systemic foliar herbicide used to control broadleaved weeds, while leaving grasses and conifers unaffected.

The effectiveness of a herbicide is influenced by a number of factors including;

- The nature of the weed leaves where the herbicide must penetrate, thus its physical characteristics such as wax content, hairs, leaf angle, all partially influence how the herbicide is retained and absorbed.
- The climate, where under cool conditions plants grow slow and the translocation of systemic herbicides through the plant is slow. Cloudy conditions also slow down translocation through the plant. High temperatures and low humidity increase herbicide evaporation from the weed leaves. Warm temperatures and high humidity are generally the best conditions to administer systemic herbicides into the field. Winds will cause herbicide drift during spraying and rainfall soon after spraying can wash the herbicide off leaves and away into the soil.
- As spraying relies on temperature and light to be most effective once touching the weed leaves, spraying in the mornings will be most effective as this allows a number of daylight hours to assist in herbicide penetration.
- Early growth stage weeds where the growth metabolism is most active, is the most susceptible time for herbicides to be effective. Perennials are best affected when buds and early flowers exist.
- Herbicides best affect weeds when their nutrient levels are high and the weeds are growing vigourously.
- Soils with high organic matter require more herbicides than sandy soils.
- Silt and clay soils require more herbicides than sandy soils due to a larger surface area for chemical binding.
- Some soil moisture is required to assist the herbicide in working in a solution for weed uptake [132].

Herbicides are not without their problems. They can stress the crop and incorrect use can lead to crop damage. If herbicides are not used correctly, *i.e., following recommendations on the minimum number of days a herbicide can be used before harvest,* this can result in herbicide residues in crops. Herbicides are also known to leave residues in soil and water tables, and herbicides are potentially an occupational hazard due to the need to spray them over crops.

In recent times a number of organic herbicides have been developed as an attempt to decrease herbicide toxicity and are in the marketplace. These include those based on essential oils and vinegar based products. More is discussed about these products in chapters 10 and 11.

Herbicides are supplemented with preventative, cultural and mechanical methods *(discussed in chapter 10)*, where the concept of *integrated weed management* places importance on a combination of weed control strategies, rather than reliance on herbicides only, to maintain manageable weed populations. These supplemental strategies include grazing, land fallowing and biological controls, as outlined in Table 9.21. With correct timing of herbicide use, herbicide application needs on the field can be reduced dramatically.

Table 9.21. Supplemental Weed Control Strategies

Strategy	**Description/Comments**
Preventative Strategies	
Seeds	Use of certified or planting material under own control to ensure not contaminated with weed seeds.
General Housekeeping	Machinery and equipment should be washed down and cleaned before moving from one field to another to prevent weed seed contamination.
Crop Management	Cut down weed infested crops before they have the chance to seed.
Physical Strategies	
Tillage	Use of soil tillage to attack weed survival mechanisms, tillage before weed seed production prevents new seed germination. Existing seed stock in the soil can be depleted through allowing seeds to germinate and grow and then undertake tillage to kill the stock. Tillage can push small weeds under the soil surface where they will die from lack of exposure to light. Destruction of underground root stock of perennials can also be undertaken through tillage to bring roots and rhizomes to the surface, where they will dry out. Swallow tillage is used to kill off weeds prior to planting of new crops.
Weeding	Hand weeding is effective in removing annual, biennial and non-creeping perennials.
Mowing	When there are too many weeds to hand weed, weeds can be destroyed by mowing. Where perennial weeds exist, this process must be done regularly.
Grazing	Grazing often prevents weed growth.
Burning	Where weed seed production has occurred, many seeds can be destroyed through burning. This will usually destroy most seeds above the surface but will fail in killing seeds already below the soil surface. The wide use of burning can destroy good organic material on the soil surface.
Flaming	The use of a propane torch to burn off the heads of weeds is used as an alternative to hand weeding. This method is good in preventing the dissipation of airborne seeds and does not have the effects of wider burning in destroying organic material on the surface.
Mulching	Mulches eliminate light from the top soil, thus forcing weeds to deplete through stored food and die. Mulches include, organic composts, manures, straw and paddi wastes, saw dusts, newspaper and plastic sheets.
Cultural Strategies	
Crop rotations	Continuous crop rotation decreases weed populations because compatible weeds with particular crops have less chance to establish themselves.
Plant competition	Plant competition prevents weeds from growing due to a stronger plant adversary. During the early growth of a crop, there is great competition between weeds and the crop. However as the crop grows and its canopy controls the light, root systems gather most of the soil

	nutrients and moisture, and they take up most of the space, this environment becomes very hard for weeds to compete in.
Cover crops	Cover crops act in a similar way to mulches and also increase competition for weeds.
Biological Strategies	
Biological control	Biological control looks at what natural enemies particular weeds have and are introduced into the eco-system to assist in its control. Insects, nematodes, fungi, viruses can be used for the control of weeds.
Chemical controls	
Amending soil pH	Through amending the pH of soil, some weeds may lose their ability to compete against crops.

Integrated weed management requires an understanding of the eco-system to manage the land in a way that weeds are prevented from breaking out. This requires knowledge of potential invasive weeds and a mapping out and monitoring of weed population and potential damage to the fields. Based on the knowledge of the potential damage weeds can make, control decisions are made, which may include a combination of methods to reduce the weed population in the field. The basic steps in undertaking an integrated weed management program are;

1. To identify the problem

   In an integrated weed management approach, weeds are seen as a symptom of something not right with the soil, rather than being the problem itself. Poor soil may be caused by poor land preparation where perennial weeds already exist and crops were planted into this environment, no treatment was undertaken prior to planting, thus weed problems would be expected. Other soil issues that would be expected to cause weed problems are poor drainage, where wet soils encourage weed germination, suitable soil pH for weeds, diseased soil decreasing the competitive advantage of crops against weeds, poor soil fertility, and weather favouring weed growth such as heavy and prolonged rainfall. Identifying the problems required knowledge of potential weed threats and their cycle and growth characteristics.
2. Plan a weed control program

   Once the weed problem has been identified, its population should be mapped throughout the farm. Weeds should all be identified and plotted against existing crop sequences. Once mapped, potential factors that could be encouraging weed growth including poor drainage, poor soil fertility and pH can be identified and investigated. Once major causes are identified and rectified a control strategy for the weed population should be determined. Weed control strategies should be selected according cost and environmental impact on the surrounding eco-system.
3. Program Implementation

   Once a plan has been devised, it should be implemented correctly. If chemical control using herbicides is used, efforts must be made to ensure the herbicide is registered for the crop in question, the spray equipment, particularly nozzles are adjusted correctly to ensure droplets are not too large and bounce off leaves, effective adjuvants are used and spraying is undertaken during the best weather conditions and time of day to prevent washing away and UV degradation. Herbicides should not be wasted on parts of a field not infected with weeds.

4. Monitoring Success and Failure

   The effectiveness of the program should be monitored and recorded for evaluation and modification if necessary. Data collected and evaluated can greatly assist in developing future strategies in crop and habitat management to prevent future weed outbreaks.

Table 9.22. A Summary of Pest and Disease Organisms

	Pests and Beneficial Animals
Classification	**Description**
Arthropods	Arthropods are a group of animals which include insects, spiders, crayfish, millipedes, etc. Different groups within this category are distinguished from each other through their body parts.
Insects	Insects are animals which have three pairs of jointed legs, which include a number of sub-groups, termites, grasshoppers, crickets, roaches, earwigs, lice, bugs, beetles, grubs, butterflies, moths, caterpillars, fleas, flies, gnats, maggots, bees and wasps. Insects undergo a lifecycle where grubs and caterpillars for example are, the immature stages of the insect development through stages or metamorphosis. Many pests are easier to manage at different stages, where pesticides may not be effective against eggs or adults.
Arachnids	This class contains mainly spiders, but includes mites, ticks and scorpions. Spiders are most often the predators of insects, using silk webs to trap insects. Some mites are herbivores, thus eat plants, while others are carnivores and eat other mites and insects. Parasitic mites eat the blood of their hosts, while saprophytic mites feed on dead materials, assisting in decomposing organic material. Ticks are blood sucking mites which generally live on animals. Ticks often carry disease which can affect plants.
Snails and Slugs	Snails and slugs belong to the mollusk group with an unsegmented body, sometimes having a hard shell. They tend to live in dark, moist and humid areas. They usually feed on decaying plant matter but can also devour live plants.
Centipedes and Millipedes	Centipedes are predators of insects, while millipedes break down dead plant material, although they can feed on live plant material. Centipedes and millipedes like damp and dark conditions.
Termites	Termites are social insects that live in colonies in the soil. They feed on wood and can kill trees if they do extensive structural damage to the lower trunks.
Bees and Wasps	Bees and wasps are beneficial social insects which control harmful insect pests and pollinate many crops.
	Plant Pathogens

Table 9.22. Continued

	Description
Fungi	Fungi are the largest group of plant pathogens and often occur in colonies. Fungi are spread by spores through the wind, rain or through animal transfer and enter host plants directly or through damaged plant tissue. Fungi growth in a host produces substances which destroys plant tissue. Common fungi diseases include powdery mildew, rust, leaf spot, blight, root and crown rots, damping off, smut, anthracnose and vascular wilts.
Powdery Mildew	Powdery mildew appears as a white to grey powdery growth on leaves and stems. It will not usually kill the plant, but can dramatically weaken them. Powdery mildew is host specific.
Rust	Rust appears as orange or dark red spore masses on leaf tissue. Rusts usually develop during cold weather and spread by the wind, splashing of rain or irrigation water. Rusts are host specific.
Leaf and Spot Blight	Leaf and spot blight is a common leaf-spotting disease that can cause defoliation of plants. It is most likely to occur during wet seasons and spread by the wind and splashing of rain and irrigation water.
Root and Crown Rots	Root and crown rot are water mould diseases that can attack a wide variety of plants. They cause damage to the roots and crowns of plants, which results in poor growth, leaf yellowing and stunting of the plant.
Stem and Twig Cankers	Stem and twig cankers are raised, broken, split open, sunken or discoloured stems or twigs.
Vascular Wilts	Vascular wilts are where the fungus attacks the vascular system of the plant until it is clogged, preventing the flow of water and nutrients.
Smuts and Molds	Smut fungi are black spores which grow on leaves, stems and fruits.
Bacteria	Bacteria produce chemicals which destroy plant tissue and cause abnormal growth. Bacteria can enter a plant through wounds, stomata, and other natural openings. Bacteria can help promote the growth of other diseases in a plant.
Mycoplasmas	Mycoplasmas are cells which do not have walls, and are spread from one plant to another via insects.
Viruses	Viruses are organisms spread by insects, nematodes and humans. Viruses often cause plants to spot, discolour, or develop some abnormal growth.
Nematodes	Nematodes are microscopic wormlike organisms that feed on roots. They can also attack leaf tissue causing swelling of stems, irregular branching and deformed leaves. Nematodes suck out nutrients and inject damaging substances back into the plants. This results in damaged plant cells or interferes with plant primary and secondary metabolite production and regulation.

Pest and Disease Control

Hundreds of different types of insects exist within the crop eco-system, playing both a beneficial and destructive role within a well developed food chain. Pests may always inhabit a crop, but will only become a pest during a particular stage of their lifecycle. These pests may only pose a threat to the crop if their numbers rise above certain thresholds. Today, insects, nematodes, and disease pathogens destroy more than 30% of the world's crops. Tens of Thousands of plant diseases are known, which are also responsible for more than 10% of crop failures around the world. A summary of pest and disease organisms are described in Table 9.22.

There has been a heavy reliance on applying chemical controls at regular intervals in the treatment of pests and diseases. Chemical controls can be broken up into the inorganic group, organochlorine compounds, organophorous compounds, carbamates, and plant extracts.

Inorganic compounds are usually heavy metal compounds *(lead, mercury, arsenic, fluoride, salts, sulfur, polysulfides and borax)*. Most of these are toxic and no longer used. Organochlorine compounds are organic and contain chlorine. DDT or *dichlorodiphenyltrichloroethane* is an organochlorine compound. DDT was one of the first modern insecticide compounds developed, with low toxicity to mammals. It is almost odourless, tasteless and chemically stable, which is a disadvantage as it remains in the soil and water tables for a long period of time. DDT breaks down to DDE, which accumulates in the fat of animals high in the food chain, like birds, interfering with oestrogen production. Many insects have also developed resistance to DDT, as surviving insect enzyme systems detoxify DDT. Many biodegradable derivatives of DDT are now produced like *methoxychlor*. Methoxychlor can be further modified by removing the chlorine molecules into a number of insecticides, which can be broken down in the environment through oxidization. Also in the organochlorine group are compounds like aldrin, chlordane, dieldrin, heptachlor and endrin. These compounds are all broad spectrum insecticides but toxic to mammals and like DDT accumulate in body fats and nervous system.

Organophosphorus insecticides include a large number of compounds. These compounds are very effective and persistent, so applicable for field utilization. These became popular to manufacture because of their ease and cheapness to produce [133]. Well known insecticides in this group include tetraethylpyrophosphate (TEPP), parathion, malathion, dimethoate, and dichlorvos. These compounds are contact poisons. Parathion is extremely toxic and dichlorvos is carcinogenic. Dimethoate is much less persistent than the others and can be detoxified by plants much more rapidly than the others. Another group carbamates, act in a similar way to organophosphates. These compounds are based on carbamic acid.

A number of early compounds were developed from natural sources. The pyrethrums are extracted from the pyrethrum flower of the *Chrysanthemum* species. These compounds had very good knock down ability, but couldn't kill most insects and are not stable in UV light. However they are extremely low in toxicity to mammals. These compounds are strengthened through the use of synergists like piperonyl butoxide, which help to deactivate insect enzymes that detoxify insecticides. A number of other natural extracts from plants are used as insecticides, which are discussed in chapters 10 and 11.

Chemicals and improved cultivars have not brought down the rate of crop destruction from pests and diseases since the 1940s [134]. Pests and diseases over time have been able to build up resistance to chemicals, making them less effective in pest control. Consequently, there is a move by farmers to utilize biological, mechanical, cultural and chemical methods together to control pests and diseases, which is slowly leading the way towards ecologically based pest management or integrated pest management (IPM). In contrast to the chemical approach, IPM relies on the balanced use of a number of methods based on a predetermined strategy, which is discussed in detail in chapter 10.

Plant disease is primarily caused through a susceptible host plant, a pathogen, and environmental conditions which favour disease infestation of the plant host. Plants have different genetic make-ups, physical features like waxy leaf surfaces, secondary metabolites like enzymes that kill pathogens or growth patterns which make them resistant to certain pathogens. Susceptible hosts have a genetic make-up which allows the build-up of specific pathogens. As shown in Table 9.23. above, pathogens can be living or biotic, fungi, bacteria, viruses, mycoplasmas or nematodes. Most diseases are host specific and have a specific cycle of infection. Specific environmental conditions must also exist for the pathogen to infect the host plant. These conditions are different for various pathogens. The general environmental conditions that influence pathogen infestation include;

- Moisture: humidity, soil water, rainfall, dew or water from irrigation. Water is a critical factor in the spread of pathogens. Constantly water foliage from irrigation, continually damp seedlings in un-sterilised potting mix, will promote disease infestation, particularly fungi.
- Temperature: Each pathogen has its optimum temperature range for growth and multiplication, some preferring cool and others warm weather. Cool wet soils promote fungal growth and root diseases, while warmer weather promotes the spread of powdery mildew. Temperature, either cold or warm can cause plant stress, weakening plant resistance to disease.
- Wind, Sun and Shade: The wind, sun and shade influences how quickly plant surfaces dry. The faster the plant foliage dries, the less susceptibility to disease. Wind can spread airborne pathogens from one plant to another and one area to another. Plants which don’t receive enough sunlight can become stressed and more susceptible to disease.
- Soil and Fertility: Some is a major influence both on plant and pathogen growth. Soils low in nutrients affect plants ability to cope with disease. Excessive nitrogen in the soil can also promote the growth of pathogens. Nitrogen deficiency can cause plant stress and greater disease susceptibility. Soil pH also affects the growth of certain pathogens. Light sandy soils with low organic matters favour the growth of nematodes.

Thus a general environmental disruption such as a drought, heavy rainfall and flooding, insect or weed infestation, the building of a major road, logging, forest fire destruction, loss of biodiversity, nutrient overload or deficiency and change of land use patterns can all contribute to the increase of pathogens in a geographic location [135].

The host plant must be at a specific stage of growth with certain environmental conditions that makes it susceptible to infection. The stages of pathogen infection and development consist of the inoculation stage where the pathogen is carried to the host through wind, rain, insects, birds or people, incubation, where the pathogen grows into a form that can enter the plant, penetration, where the pathogen actually enters the plant through wounds or natural pores, and infection, where plant tissue becomes damaged. Understanding the environmental and plant conditions which favour disease infection is important in preventing these conditions arising.

Diagnosing a plant disease requires logging down all the plant symptoms on all parts of the plant. A close up inspection of the disease symptoms through a magnifying glass or microscope would usually be necessary. Cutting into the branch or stems may assist in seeing symptoms of vascular disease, such as discolouring. If possible the sequence in which each symptom occurred should be determined. Environmental conditions and characteristics should be examined to determine what diseases these conditions would encourage, what stage of growth is the crop, insect populations in the area, and what cultural practices are being carried out within the area and whether the crops are stressed in any manner. Environmental events should be matched against the appearance of symptoms to see if they correlate in terms of time and whether they are generally occurring to plants or plant specific infections. All the information can then be referred against known crop diseases and conditions for infection.

Table 9.23. A Summary of Prevention and Treatment Methods for Plant Diseases

Disease	Treatment
Powdery Mildew	Providing adequate sunlight, air circulation and lower relative humidity to prevent powdery mildew. The use of fungicide sprays to treat powdery mildew.
Rust	Watering early in the day to prevent rust. The application of fungicidal spray to treat rust.
Leaf Spot and Blight	Use resistant cultivars, maintain plant vigour through adequate fertilizer application, the enhancement of leaf drying through pruning and watering early in the day will help prevent spotting and blighting. Fungicides able to assist in preventing leaf spot and blight but poor in eradicating it.
Root and Crown Rots	Prevent through creating a well drained soil environment.
Stem and Twig Cankers	Prevent through maintaining plant vigour and removing diseased parts. Fungicides of limited use in treating stem and twig cankers.
Vascular Wilts	Prevention through resistant species, maintaining plant vigour and soil sanitation. No effective fungicides for treatment.
Smuts and Moulds	Use of resistant cultivars and fungicides to protect. No effective fungicides for treatment.
Bacteria	Protect through the use of disease resistant cultivars and good soil sanitation. Use of sterilization in nursery operations to prevent contamination. Streptomycin and copper sprays help to slow the spread of bacterial disease. Chemical sprays unreliable for treatment of bacterial diseases.
Viruses	Control virus carrying insects, animals and humans around crop area. Remove and destroy infected plants.
Nematodes	Difficult to control.

Table 9.24. Some Know Diseases for Some Essential Oil Crops

Plant	Botanical Name	Cultivation Area	Known Disease
Camphor Tree	*Cinnamomum camphora* L. and *C. verum*	Throughout South-East Asia and Indo-China.	Fungi, root rot, and canker.
Cinnamon	Various *Cinnamomum species*	Throughout South-East Asia	The fungi *Corticium salmonicolor* and *Phytophthora cinnamomi* (a root rot) attack the bark and stems of various cinnamon species. Also attacks, rubber, cocoa and citrus species.
Clove	*Eugenia aromatica,* Kuntze	Indonesia, India, Sri Lanka	Nematodes attack root systems. A bacteria, *Pseudomonas syzygii,* insect vectored can kill clove trees [136]. Die-back disease gradually kills trees, caused by unfavourable soil conditions [137]. Leaf spot and sooty molds in the leaf, thread blights and wilt.
Eucalyptus	*Eucalyptus species*	Australia, Brazil, India, Spain, China	Various fungi which attack foliage, viruses, including tobacco mosaic can drastically decrease foliage. Die-back disease from root rot caused by fungi, usually from continually wet soils. Cankers and blights can occur on seedlings and juvenile woods.
Geranium	Various *Pelargonium species*	Reunion, Morocco, Egypt, Kenya, India and China.	Nematodes attack the shoots and leaves, anthracnose, leaf spots, rust, root rot, viruses transmitted through aphids, and stem wilt.
Ginger	*Zingiber officinale* and other species	Indonesia, India, Thailand, Sri Lanka, Vietnam, China	Rhizome rot, where the rhizome will soften and degenerate, where plant death will follow. This is usually caused through waterlogged and poorly drained soils. Also leaf spot are common, bacterial wilt, which can affect the rhizome.
Jasmine	*Jasminum grandiflorum, J. sambac, J. auriculatum*	India, Thailand, Egypt, Morocco, China.	Nematodes attack jasmine roots. Root and stem rot caused by fungi of the *Botrytis, Fusarium, Phytophthora, Pythium,* and *verticillium* species. Leaf spots, powdery mildews, and bud rot.

Table 9.24. Continued

Plant	**Botanical Name**	**Cultivation Area**	**Known Disease**
Nutmeg	*Myristica fragrans, M. officinalis, M. moschata.*	Indonesia, India, Sri Lanka	Fruit rot destroys the fruits *(Diplodia and Gloeosporium spp.).* Blight, root rot and wilt attacks the roots of many tropical trees. Spot and legions can attack the leaves.
Patchouli	*Pogostemon cablin*	India, Indonesia, China, Malaysia and Vietnam	Nematodes *(Heterodera marioni)* in Indonesia and Malaysia. Root fungi, especially when intercropped with rubber. Leaf spot, leaf blight and viruses *(Patchouli Mosaic virus)* in India, through the insect vector [138].
Pepper	*Piper nigrum*, L. and other species.	Malaysia, India, Sri Lanka, Indonesia, Vietnam, China.	Nematodes attack root systems. Nematodes also lead to other disease conditions like yellowing [139]. Pepper also susceptible to fungi and root rot caused by *Phytophthora palmivora*, and *P. capsici*, which wilts the vines and yellows the leaves, where they eventually defoliate. Also bacteria, crown rots, blights and viruses can deteriorate pepper vines.
Pimento	*Pimenta racemosa*	Caribbean, South America, Sri Lanka, East Africa and Indonesia.	Leaf rust which attacks young leaves and shoots, which can result in defoliation. Die-back syndrome also occurs.
Rose	*Rosa damascene, R. centifolia* and other *Rosa* species.	Bulgaria, Turkey, Morocco, India, China, Thailand and Vietnam	Rose rust caused by *Phragmidium* attacks all the rose bush above the ground. Also powdery mildew, black spot attack the leaves and young shoots, and damping off and root rot.
Sandalwood	*Santalum album*	Australia, India and Indonesia	*Ganoderma applanatum* and other varieties cause various types of rot and molds. A number of insect vectored viruses that are destructive on the tree, which easily spreads through a local population.

Diseases are harder to control than prevent. Essential oil producers will be more interested in diseases that affect foliage and rhizomes in the case of crops with rhizome oils. The most important strategy in disease control is prevention through the selection of planting times that avoid disease incidence and the use of disease free planting materials. This should be an important part of the cultivation strategy. Cultural practices that promote healthy plants should be used to prevent plant stress. Insect control is important to prevent the spread of insect vectored diseases like nematodes, viruses, mycoplasmas, bacteria and fungi. A short summary of prevention and treatment methods is shown in Table 9.23.

The chemical treatment of plants for disease is much less effective than for insects. This is probably because plants lack true circulation and excretion systems which can distribute and expel treatments and poisons. Most contact fungicides are designed to treat the fungi before it penetrates the plant. Early on, inorganic chemicals like heavy metals were used. Some compounds like captan can be used, which liberate thiophosgene from fungi, but with limited results.

The investigation of potential diseases is important during the research stage of a new essential oil crop. Potential diseases may be found through observing the natural habitats of new indigenous essential oil plants. However, potential disease factors are unknown for essential oil plants introduced from other geographical areas, as it is unknown whether known disease spores exist in the soil in the introduced location, or whether new or unknown diseases will attack the plant. This is one of the major reasons why national quarantine services are usually very strict on the import and introduction of new plants to prevent disease contamination to new areas. In all cases of new plant introductions, cultural practices must be developed to create a preventative disease environment for the crop. Table 9.24. shows diseases known for some essential oil crops.

In addition to plant disease caused by infectious pathogens, noninfectious diseases can affect specific plant populations caused by environmental stress such as salinity, excessively hot or cold weather, lack of sunshine, lack of water or drought, soil water logging, and soil nutrient deficiencies or toxicity from heavy metals. Stress causes the hormonal balance of the plant to alter, causing growth decline. Sometimes plants can adjust to changing conditions such as lack of water and slow down their metabolisms, slowing down growth, which will have economic costs. Other plants will become susceptible to pest and disease infestation. In some cases, pest infection or disease may be the result of plant stress due to poor resistance. The pest or disease may only be a secondary factor.

Plant stress is a factor that assists in aligning perennial plants with the season. For example the warmer weather, rain and sunshine of spring will promote the production of auxins that promote growth and reduce the production of abscisic acid, which inhibits growth. Likewise during autumn when the temperature starts to cool, the production of auxins and abscisic acid will reverse, slowing down growth of the plant. Understanding the relationship of the environment to hormone production in plants, assists in regulating the crop with water, fertilizers, and pruning, etc., to prolong growth periods and induce greater biomass of the foliage.

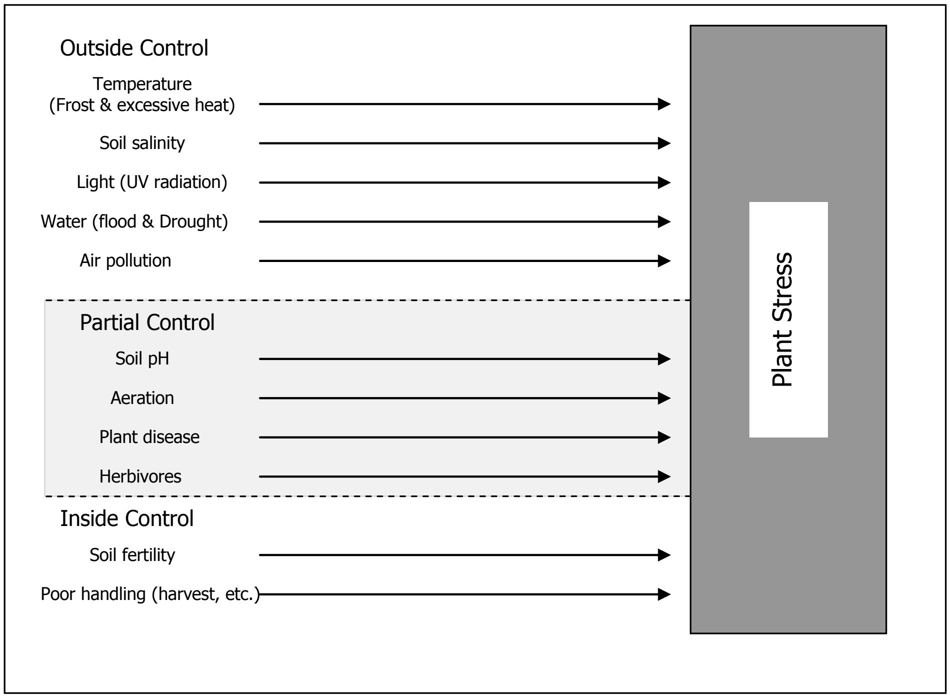


Figure 9.18. Some of the Major Sources of Plant Stress.

THE LEVEL OF FARM MECHANISATION

Farm mechanization considerations must balance crop, site, economic, social and cultural issues together to develop a working strategy. Mechanisation, especially harvesting is often a major challenge and not always possible due to the particular issues some crops present. The costs of mechanization may far outweigh the costs of manual methods of planting, maintenance, harvesting and distilling the crop. The farm site size, layout, topography and weather patterns may provide either a positive or hostile environment for mechanization. Economic considerations relate to the comparative cost of manual verses mechanized production methods and relative costs in relation to competitor cost structures. Social issues involve the availability, skill level and quality of labour. Finally, cultural issues involve considerations about the way farms and production is organized and accepted by the surrounding community.

The purpose of mechanization is to increase labour productivity, decrease the cost of production and increase the return from a unit of land. There are many levels of mechanization ranging from the development and construction of simple labour saving devices, which can often be seen on subsistence farms to precision agriculture systems on large commercial farms. The general difference between a subsistence farm and a commercial farm is shown in Table 9.25. There is generally little opportunity to transform subsistence farms through mechanization, other than through the innovation of some simple labour saving devices, because of little access to technology and capital. Commercial farming ventures will normally have been developed with a specific and preconceived level of technology, so the venture can enjoy some comparative cost advantage. Usually shortages of labour force farms to develop higher levels of mechanization, so less workers per unit of land are required.

Table 9.25. Comparison Between a Subsistence and Commercial Farm

	Subsistence Farm	Commercial Farm
Size	Usually small, sometimes just sustainable.	Usually a medium to large acreage on an established estate.
Labour Orientation	Usually family and extended family labour.	Usually well mechanized in developed countries. Tend to rely more on labour in developing countries but this changing due to labour shortages.
Technology level	Mainly use of manual tools, some very low capital labour saving invention/innovations. Use of either farm animals or *Kubota* equipment.	Usually a blend of own innovation/development and purchase of high capital specialized machinery.
Knowledge & innovation level	Very little outside knowledge other than what knowledge may be brought in through extension agencies.	Management widely travels and looks at industry developments and innovations.
Management	Family	Can be either a family managed or corporation, or incorporated family management.
Yields	Usually low due to lack of infrastructure and fertilizers.	Usually high with the use of farm equipment, irrigation equipment and fertilisers
Access to finance	Almost none, maybe micro finance	Bank loans and mortgages.
Ownership	Family with no separation of ownership and management	Family and/or corporation, sometimes separation of ownership and management
Method of costing	Revenue to cover living expenses, personal and farm accounts the same.	Separated accounting system from individuals and farm.
Market Orientation	Production orientation only	Can be either production or marketing orientated. Now more commercial farms undertake their own marketing and branding.
Succession	Can create many problems as land is most often divided among the children who if cannot work together split the land into even small units.	Usually transferred as a corporation.

Table 9.26. General Aspects of a Farm System That Can Be Mechanised

Activity	
Nursery	• Seedbed planters • Some aspects of micro-propagation • Irrigation, pesticide and fertilizer delivery • Conveyer flow for efficiency • Compost, potting mix and media mixing
Tillage	• General field preparation • Laser leveling • Moisture conservation • Accurate herbicide, pesticide and fertiliser delivery • Minimising erosion potential
Planting	• Vegetative and seedling planting • Accurate spacing placement
Crop Maintenance	• Weed control and eradication through roto-cutting and flaming • Automated drip or overhead sprinkler systems • Sensor array for field moisture and nutrient assessment
Harvesting	• A combined harvest, mulching and boxing process for foliage (applicable to some crops only)
Distillation	• Box distillation system

With few exceptions, a farm is never fully mechanized. It is more likely that some aspects of a farm will be more mechanized than other aspects, as the result of years of evolution, *i.e., mulching, fertilizer application.* Focus has most likely been put into issues where labour can be saved and efficiency improved, rather than looking into the whole farm process as a complete system. For example, a farm maybe very efficient at planting, with mechanical planters and maintaining weeds with the latest roto-slashing equipment for weed control, but still maintain a distillery that is manually orientated, as focus has been on saving field labour. Aspects of a farm operation that can be mechanized are shown in Table 9.26.

Mechanisation development has a number of costs associated with it. The development of crop specific harvesters may be of little interest to outside support agencies like research institutions and universities. The total effort will rely on the farm enterprise to develop the technology.

With mechanization, there will be a requirement to have a workshop with some engineering equipment like lathes and a number of spare parts in storage to maintain the equipment. This may also require the employment of additional support staff. Mechanization may require additional infrastructure such as all weather roads on the property and equipment shelter and housing.

In some cases mechanization may take some years to implement in farms with tree crops. For example, plant spacings may have to adjusted to allow for new roto-weeders and harvesting equipment. It may only be economic to change plant spacings when the current trees come close to the end of their economic life and replanting is required.

Some farms have been mechanized in an *ad-hoc* way, where individual mechanical innovations are not part of any complete mechanized farming system plan, but rather a specific solution to a farm labour problem. These mechanized aspects of farm production have evolved in an unplanned way to increase productivity where opportunities for improvement have been seen. They don't usually operate together in any integrated way. This is in contrast with other farms with extensive crops like tea tree and peppermint, which have been planned and developed with mechanization to counter the cost and lack of labour availability, cope with the a large farm area where a very high capital investment is required. These farms have been designed with both an efficient and systematic flow to ensure production efficiency and minimum cost of production, complying with certification schemes like HACCP.

There are a number of issues to consider in evaluating the extent to which a farm should be mechanized. Some of these issues are briefly discussed below.

Operational requirements: The extent of mechanization that can be undertaken will depend upon the task requirements of the farm operation. Methods and specifications of field tillage often differ between crops and farming systems, requiring different equipment. Mechanisation must also consider whether other operations like herbicide dispensing will also occur during tillage operations, or whether there is an opportunity to do so. The number of different crops cultivated is another consideration, as individual crop characteristics may differ, requiring different machinery to handle them. The wider the individual crop requirements, the more expensive it will be to automate and mechanise a farm system that needs to cope with diversified crops. In contrast a mono-crop farm can develop specific equipment that will handle all the farm output much more economically.

Performance: Developing an integrated farming system, *(planting, maintenance, harvesting and processing),* that will perform reliably under different weather and soil conditions is difficult. Parts of the system that are purchased as standard farm equipment, with no or little modification can be trial tested or observed in operation at other farms, but purpose built machinery is usually more expensive to build, requiring many modifications during field trials, before it performs reliably. The field equipment must be able to enter fields to maintain and harvest crops at the time required. Equipment that cannot be used in all weather and soil conditions is a questionable investment.

Repetitive Task Frequency: Machinery that is designed for tasks that are undertaken regularly on a cyclic basis is a much sounder investment than for machinery that is untilised only for irregular tasks. Therefore the frequency of operational tasks like planting, weeding, irrigating, harvesting, etc., needs to be assessed. Thus seasonal and annual crops that require annual planting are much more feasible to automate than crops that may require planting after a number of years.

Task Window: Another consideration is the length of task windows available for planting, crop maintenance, harvesting and distillation. Some crop yields and harvesting times can be affected by planting times. Some crops like peppermint have very tight harvest windows where delays in harvesting will result in an commercially unsuitable oil. Generally, the tighter the task window, the more there is a need for mechanization to ensure the task can be completed in time. However, an issue to consider is the reliability of the machinery and the probability of any downtime when the task must be undertaken.

Task Man-Day Requirement: The comparative cost between undertaking a task manually or mechanically requires analysis. A task undertaken manually will take a certain number of man-days to complete, which can be easily calculated. The cost of manually undertaking a task will be directly affected by the wage rate, relatively low in developing countries and much higher in developed countries. Labour costs can be directly compared with the direct costs of mechanically undertaking the same task, *i.e., labour and fuel.* However some allowance should be made for the capital cost, maintenance and machine time, to recognize the capital costs involved in mechanization of the task. A simple cost comparison of a planting operation is compared in Table 9.27.

Availability of Labour: The availability of labour is a major issue for farms around the Asia-Pacific Region. There are reports of labour shortages on farms in Australia [140], New Zealand [141] and parts of South-East Asia like Malaysia [142] and Thailand. This has prompted these governments to develop guest overseas worker schemes to supplement local worker availability, which is not sufficient. The more attractive wages and salaries in other sectors like construction are also making it difficult for many farmers to attract workers to their farms.

Short term guest labour has a number of downsides. Firstly attracting enough labour for peak periods like planting, weeding and harvesting is difficult, often leading to losses on the part of farmers. Secondly, mobile worker population means that workers have to be continually trained which results in productivity losses and extra costs in training [143].

Farm Size: As the size of the farm increases, more labour is required to work it. Size leads to labour constraints, where the difficulty of getting more labour increases and overtime hours cannot be increased, thus leading to the limits of manual working of the farm, where mechanization must be brought in so that all required tasks can be completed in timely fashion.

Table 9.27. A Comparison Between Manual and Mechanical Planting of Tea Tree in Malaysia (per Hectare)

Activity	Manual	Mechanised
Labour	25 man-days @ RM 20.00 per Man-day = RM500.00	2 man-day @ RM 75.00 = RM150.00
Fuel	Transport seedlings to field = RM25.00	RM75.00
Machine Time	N/A	As depreciation Cost RM 225,000, depreciated straight line over 7 years with RM 50,000 residual (serving 200Ha farm) = RM125.00
Maintenance Amortisation	N/A	RM1,500 per annum amortised over 200 Hectares = RM 7.50
Total Planting Cost	RM 525.00	RM 357.50

Weather: The weather, particularly rainfall is a major factor that will influence the ability of machinery to enter the field. The number of days in a year farm machinery can access and work a field will influence the viability of mechanisation.

Overall Investment Cost: The overall cost of investment, the repayment costs, and operational costs will heavily influence the choice to mechanise. If any capital investment cannot recoup the cost of labour over a given period, then the capital costs cannot be justified on purely economic grounds, unless issues like labour availability are major considerations.

THE SIZE OF FARM MACHINERY

Farm machinery capacity depends upon the field days required to complete field operations. This depends upon the number of crops cultivated on the farm and the ability of the same machinery to handle the crops, the number of field operations required, *e.g., tillage, planting, maintenance, harvesting, etc.,* the length of each task window and the number of days farm equipment can enter and work in the fields per annum due to weather factors.

Farms which have a number of different crops with different requirements will require different equipment. This means that equipment should be small scale as individual crops require different pieces of equipment. Where a single crop like peppermint is cultivated, machinery can be of a much larger capacity, as it can be used across the whole farm. Larger equipment is needed where there are a larger number of field operations to keep down the field days on each task, so they can be completed on time. Likewise where tight task windows like peppermint harvesting exist, larger machinery is needed. The less time farm equipment can access fields, the larger should be the machinery, so the field area can be covered quicker.

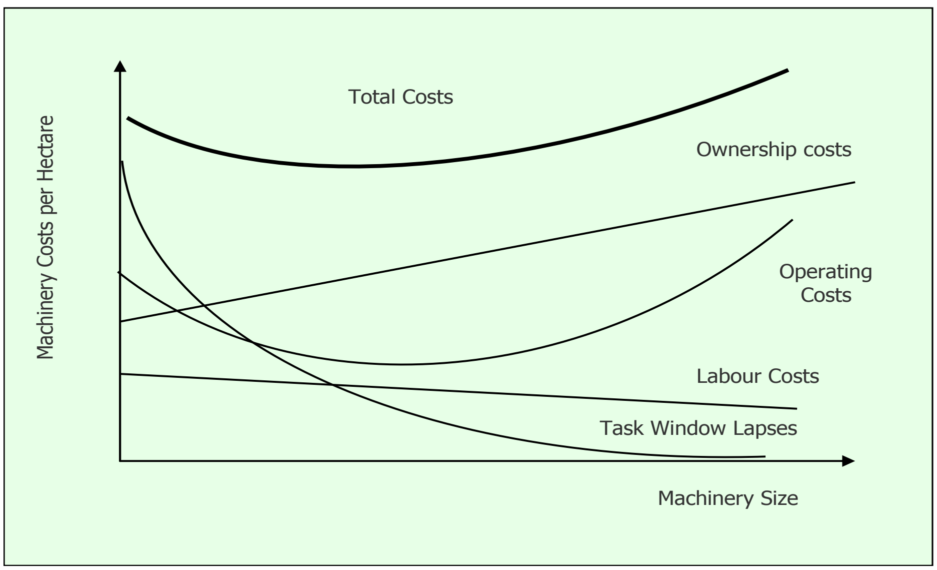


Figure 9.19. The Relationship between Increasing Machinery Size and Machinery Costs.

Table 9.28. The Length of Harvest Time and Method of Harvest for Some Essential Oil Crops

Common Name	Time from initial planting to first harvest	Method of Harvesting
Australian Tea Tree, *Melaleuca alternifolia*	Usually can make first harvest 8-12 months after planting. Second and subsequent harvest every 6-13 months, depending upon climate.	Usually mechanized harvesting where the whole tree is cut and mulched for easy distillation. First harvest tree will be a single trunk, but after harvest stump is smashed so tree can coppice many trunks. Manual harvest is undertaken in Malaysia, Cambodia, etc.
Basil, *Ocimum basilicum and sub-species.*	Plants usually flower at 50-60 cm height after 3-6 months.	Plants are cut immediately upon flowering, either manually or mechanically. Basil should be replanted after harvest.
Black Pepper, *Piper nigrum*		Harvested when plants fruit, just when they start to ripen. This is usually a manual operation and occurs several times during the season.
Calamus Oil, *Acorus calamus*	Usually can be harvested 6-10 months after planting	Rhizomes must be dug up by spade or plough, washed and dried before distillation.
Cananga/Ylang Ylang *Cananga odoratum*	Usually in 2nd year, peak after 5th year.	Manual picking: Flowers should be picked when early in the morning to maximize oil content, only after they have turned yellow. Ropes are sometimes attached to the branches so pickers can pull them down to pick off the flowers without having to climb the tree.
Cassia Bark, various *Cinnamomum* species	*C. cassia:* First harvest approximately 5-7 years when trees coppiced at 3 m height. *C. verum:* first harvest 2-3 years after planting	*C. cassia:* Trees coppiced and pruned by hand to strip leaves and bark for oil production. *C. verum:* Tree coppiced at 3 m height after 2 years for bark by hand.
Citronella, *Cymbopogon nardus*	Usually first harvest can be undertaken between 4-5 months after initial planting, with subsequent harvests every 3-4 months.	Small holders will manually harvest with a sickle and carry to the still for distillation. Foliage harvesters are used on larger fields, which chop and collect the material. Most oil is in the leaves so cutting distance set to where the bulk of the leaves are (18-28 cm). This also allows faster regrowth. Crop can have a commercial life of 4-10 years.

Table 9.28. Continued

Common Name	Time from initial planting to first harvest	Method of Harvesting
Coriander seed, *Coriandrum sativum*	Usually after 6 months with coordinated spring planting and autumn harvest.	When the plant is 50-70 cm in height and fruit is 5-7 mm in size
Geranium, many species and hybrids of *Pelargonium*	Crop usually grows enough foliage for first harvesting 6-9 months after planting.	Usually mowed around 10-15 cm above the ground as little oil in the stems [144] and to allow for re-growth.
Ginger, *Zingiber officinale and other species*	Harvest can occur anywhere between 150-300 days after planting, depending upon temperature conditions.	It is important to determine the optimal level of oil and oleoresin content in the rhizomes before harvesting. Harvesting can be manual or mechanized, as whole plant is pulled out, which must be without damage.
Jasmine, *various Jasminum species.*	Jasmine may take 4-5 years before productive.	In warm humid areas, flowers can be continually harvested for around 6-9 months per year. Flowers should be picked before sun rises 20% above the horizon and a daily basis to avoid loss of volatiles. This is a manually process, although combing and suction systems have been experimented with. Plants are usually pruned after each flowering season to promote growth.
Lemon scented gum, *Eucalyptus citriodora*	First harvest 6-12 months after planting. After 2nd year tree can be felled for re-growth.	If grown solely for oil production, trees should be regularly topped and coppiced to maintain growth. A height of around 2.5 m maintained. Alternatively trees can be felled, leaving the main stem for re-growth of a coppice of young shoots, which can be re-harvested every 6-12 months.
Lemon Scented Tea Tree, *Leptospermum petersonii*	First harvest after 2-3 years, subsequent harvests each year.	A foliage harvester can coppice the tree when re-growth warrants it.
Lemongrass, *Cymbopogon flexuosus*	Usually first harvest can be undertaken between 4-7 months after initial planting with subsequent harvests every 3-5 months.	Small holders will manually harvest with a sickle and carry to the still for distillation. Foliage harvesters are used on larger fields, which chop and collect the material. Most oil is in the leaves so cutting distance set to where the bulk of the leaves are (15-20 cm). This also allows faster regrowth. Crop can have a commercial life of 4-5 years.
Nutmeg, *Myristica fragrans*	Trees from seed bear fruit between 6-10 years, vegetative propagated trees 5-7 years. Fruit ripens around 6-9 months after flowering. Reach maximum yields	Fruit is allowed to split and either picked or allowed to fall to the ground and collected on a daily basis. Nets can also be used to catch the falling fruits. Long poles with cutters also used.

	after 20 years.	
Palmarosa, *Cymbopogon martini, var. motia* and *sofia.*	First harvest around 6 months after planting Further harvests when flowering occurs every 6 months.	Plants should be mechanically or manually harvested about 10 cm from the ground, when flowering begins, around 6 months after planting.
Patchouli, *Pogostemon cablin*	Can be harvested 4-8 months after planting and subsequent harvests at 3-6 month intervals for a 2 to 6 year period.	Usually the leaves are cut manually or mechanically, dried and stored to allow some fermentation, before distillation at a later time.
Peppermint, *Mentha piperita*	Planted in early spring and harvested mid to late summer.	The crop is usually mowed, allowed to wilt and them scooped up into bins for distillation. This is usually an automated process.
Rose. *Rosa species (usually R. centifolia and damascene)*		Flowers picked manually between 5-10 am in the morning, while flowers still open.
Sage, *Salvia officinalis*	Trees can be trimmed after first year for around 6 years.	Trees can be trimmed for leaves each year and dried.
Sandalwood, *Santalum album and S. spicatum*	30-50 years after planting	The oil is contained primarily in the heartwood and large roots, thus the tree must be felled and pulverized.
Tasmanian Blue Gum, *Eucalyptus globulus*	Trees can be lopped after 6-12 months, upon reaching around 3 m height. Trees then allowed to coppice for lopping and coppicing every 9-15 months.	Trees either coppiced and lopped when dedicated to oil production manually or through mechanized lopper. If trees cultivated for timber, harvest after tree felled around 5-8 years of age.
Vertivert, *Vetiveria zizanioides*	First harvest usually 18 months after planting to allow rhizomes time to mature.	Usually the foliage is cut and slashed prior to the lifting of rhizomes (sometimes burning used). Roots either dug up manually or dug up with the aid of a mechanical digger. As much vetiver is planted on hill slopes, harvesting is a very difficult process to mechanise.

Equipment too large for the job will bring larger capital costs requiring higher taxes, insurance, maintenance, loan and hire purchase repayments and fuel charges to be paid, which lead to higher than necessary overheads. Equipment too small for the job will lead to lower yields due to the slower time to complete critical tasks and also possibly lead to greater wear on the machinery, leading to high repair costs and quicker replacement. Machinery size should be selected where the total machinery costs – ownership costs, operating costs, task window lapses, and labour costs - are at the lowest point, as is shown in Figure 9.19. As machinery size increases, the probability that task windows will be kept too without lapses will improve, labour costs will decrease and operating costs will decrease as they are spread against a larger number of hectares, until increased size leads to increased costs. Ownership costs (taxes, insurance, repairs and maintenance, hire purchase and loan repayments) will steadily increase, thus at a certain machinery size, total costs will begin to increase.

HARVESTING

The method and timing of harvesting crops will depend upon the part of the plant required, the pre-processing preparation required before extraction, the re-growth characteristics of the crop, the changes of chemical constituents in the plant during growth, the diurnal variance of chemical constituents in the plant, the characteristics of the field and the type of enterprise in terms of size, scale and socio-economic environment it operates within.

As essential oils can be sourced from leaves, steams, flowers, bark, wood, fruits, rhizomes or seeds, the nature of the plant material required will have great bearing on the mode of harvesting required.

Flowers are more delicate than other plant tissues and mechanization may damage them. Thus many flowers like rose and cananga must be picked manually. Some jasmine and boronia are mechanically harvested through combing arrays, although the effectiveness of this is unknown. Bark can be scrapped off from trees or collected as a by-product of the timber industry. However many bark products come from remote areas in tropical countries and are still collected manually by collectors from both the wild and plantations. Woods have to be cut in a similar manner to how the timber industry would harvest a tree. Fruits are usually utilized for other products like citrus juices, and the peels which contain oil are processed as a by-product. Rhizomes must be collected from underground, either manually or through mechanical upturning of the earth. Seeds are either directly collected from the ground or plant when mature via manual or mechanically combing them from branches in some instances.

With trees like eucalyptus and lemon myrtle, a portion of the leaves are usually lopped off for distillation, leaving the bulk of the tree intact for growth. These trees, if mature in the wild, will have difficulty re-growing if completely chopped down. However under plantation cultivation the whole tree is coppiced at an early stage, where it will usually re-grow increasing leaf bio-mass for future harvests. This is also the case with tea tree *(Melaleuca alternifolia)* where initial growth from a seedling will have a singular trunk where coppicing after the first year and breaking up the trunk butt at ground level, will promote multiple stem re-growth, promoting more bio-mass (see Figure 9.20.). Table 9.28. shows the length of the first harvest time from planting and method of harvest.

Some crops like peppermint have a distinct harvest window where phyto-chemicals within the leaves synthesize and convert into desirable constituents that give the oil its commercial value. These processes depend upon seasonal factors and temperature conditions, *i.e., in the case of peppermint daylight hours and night time temperatures.* Plants like *Artemisia* vulgaris change in constituent levels throughout their growth cycle, so it is important to determine the optimal harvest time based on maturity [145]. Determining the optimal harvest time requires sampling and graphing of the leaf oil constituents over the crop lifecycle. Figure 9.21. shows the harvest window applicable to the Victorian and Tasmania mint industry in Australia [146].

Figure 9.20. Broken up tea tree trunk to promote coppice growth (photo courtesy of Mr. John Bax).

Some flowers exhibit diurnal variations in constituents and the daily timing of harvest is critical. This is the case for rose and jasmine which may have to be harvested in the very early hours of the morning to obtain the optimum constituents in the flowers for extraction. Other flowers where this issue is important include *Hoya carnosa*, *Stephanotis floribunda* [147], *Syringa vulgaris* [148], *Narcissus tazetta* and *Osmanthus fragrans* [149].

Harvesting methods and timing is effected by the physical state of the fields. Hilly fields restrict the degree of mechanization during harvesting, particularly if the gradients are high. The weather, particularly rain will degrade field compactness and can lead to delays in harvesting as conventional harvest equipment may have trouble operating on waterlogged fields, particularly in tropical areas. Mechanised harvesting equipment can be adapted to waterlogged fields through paddle arrangements connected to the wheels of tractors and bins. This method is successfully used in rice paddies throughout South-East Asia.

The harvesting system should ideally be integrated with the extraction system for maximum efficiency. This is restricted by any pre-extraction wilting and/or comminution required before extraction, as any pre-processes increase the time lag between harvest and extraction, such as is in the case of patchouli where it must be stored for a few months before distillation.

An important consideration in the design of any harvesting system is the potential damage on the plant material. Some plant material is very easily bruised or damaged, which would restrict mechanization options. This is why some traditional harvesting methods are still widely used for a number of essential oil crops.

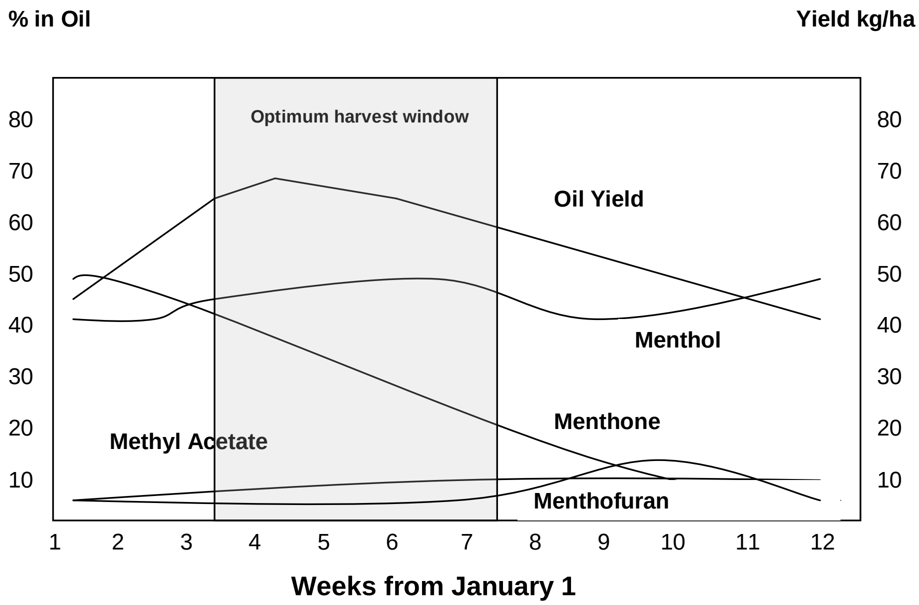


Figure 9.21. The Harvest Window Applicable to the Victorian and Tasmanian Mint Industries.

Figure 9.22. Paddle arrangement connected to tractor wheel for 'boggy' conditions.

The most efficient method of harvesting is to cut the material in the field and load it directly into a container that will also act as the charge vessel during distillation. This causes some loss of oil and inefficiency in yields due to non oil bearing plant material also being harvested, *i.e., twigs and branches in tree crops*. But overall this is much more economic than selective harvesting of plant parts. If crops are mechanically harvested, row planting must be coordinated with the distance between the tires of the harvesting equipment, so that the crop can be effectively harvested.

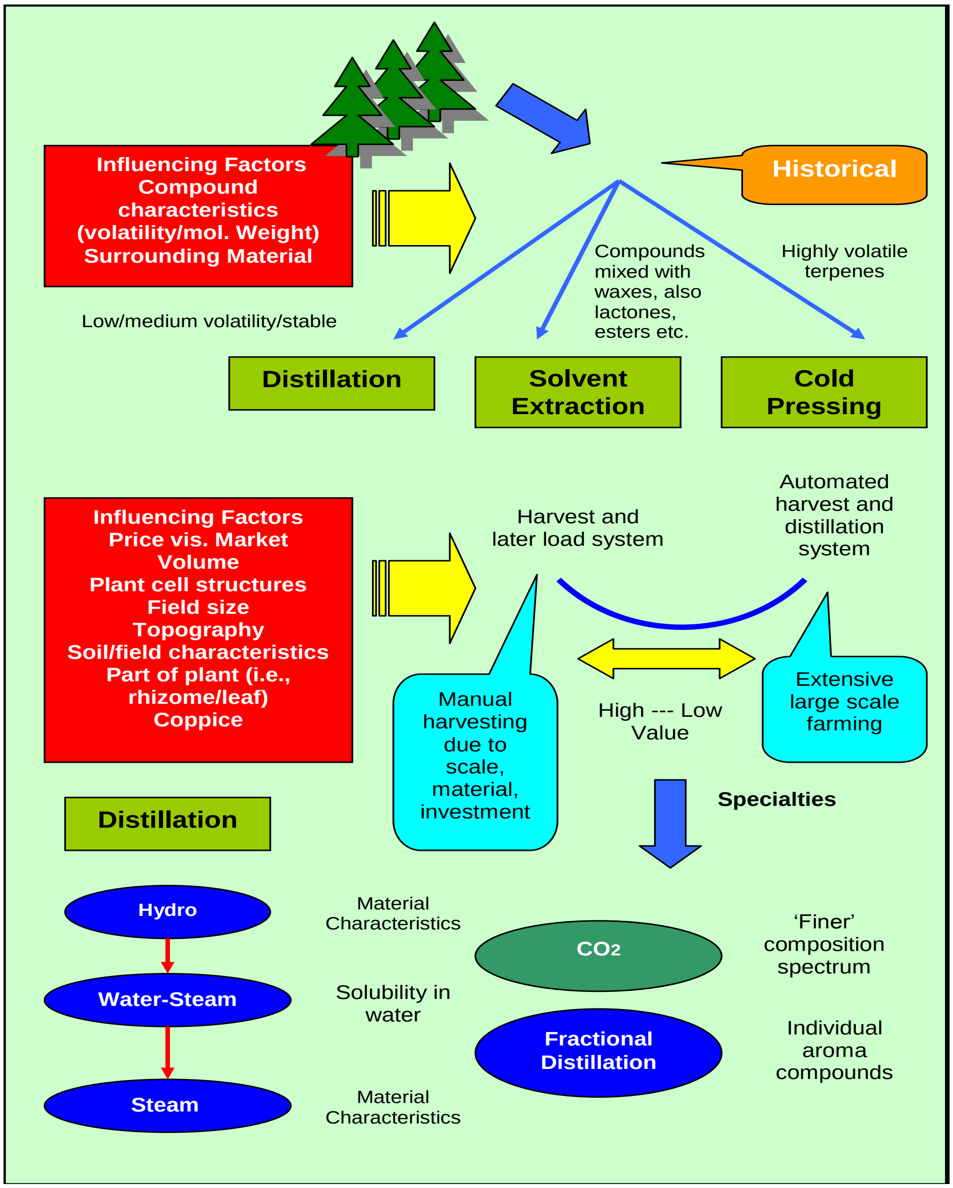


Figure 9.23. An Overview of Some of the Factors Influencing the Mode of Extraction of Essential Oils from Plants.

Planning of the harvest is of paramount importance as it must be synchronized with the capacity of the distillery to ensure there is no undesired backlog of unprocessed material waiting to be distilled. Ideally, harvest should be followed by almost immediate distillation, where appropriate. The distance of the field from the distillery is also a consideration and harvest times over a diverse region utilizing a central facility, requires very careful logistical planning. Where crops like mint require some time to wilt after being mowed before being picked up by a forage harvester and deposited into buns, delays in the two operations can lead to excessive wilting, which will greatly reduce oil yields. Wilting times may be heavily influenced by daily wind and temperature conditions, requiring great flexibility in the time lag between mowing and picking up the foliage for distillation.

Still today a large amount of harvesting is undertaken either manually as is the case in Indonesia, Cambodia and Vietnam by small holders. "Outback" stills are still used in Australia for tea tree, where the farmer collects wild or small scale plantation material with a tractor and trailer, to be loaded into the still upon returning from the field. Although some companies offer state of the art harvesting equipment, many producers fabricate their own specialized equipment, utilizing standard agricultural machinery available. Over a period of years during the winter months, this equipment is rebuilt and modified to suit their small to medium scale operations. Large scale operations in the mint, citrus, eucalyptus and tea tree industries utilize equipment that brings the most efficiency to the operation, as a low production cost is of great importance to survival.

Good management of the harvesting procedure requires;

- The determination of the optimal harvest time,
- Precise mowing or harvesting of the herb with minimal damage to the crop,
- Consistent and precise wilting, if required before extraction,
- Efficient collection of the material in the field and delivery to the distillery,
- Minimization of backlogs in material to be distilled, and
- Minimal delays in harvest to distillation times, according to requirements.

SELECTION AND DESIGN OF EXTRACTION SYSTEM

The choice of method for essential oil extraction will depend upon;

a) the sensitivity of the aromatic constituents in the plant to heat,
b) the sensitivity of the aromatic constituents in the plant to moisture,
c) the volatility of various constituents within the plant,
d) the physical nature of the plant tissue, and
e) the solubility in water of the aromatic constituents within the plant.

An overview of some of the issues involved in selecting an extraction process can be seen in Figure 9.23.

A summary of the extraction methods used for a number of essential oils is listed in Table 9.29.

The comments in the rest of this section are primarily related to distillation. Some mention was made of other extraction methods in Chapter Five. A great number of distilleries tend to be locally built and designed from what information people have in the hope that these systems will fulfill their requirements. Fabricated *'turnkey systems'* are offered by some suppliers, however, they account only for a small percentage of actual working field stills in the industry. Most stills are locally fabricated with local materials taking advantage of the local topography and energy sources, usually fitting in with the socio-cultural way cultivation is undertaken in their geographical location. This would include the majority of small holder production, cultivating small plots or collecting from the wild in Indonesia and Vietnam. Similarly boutique farms producing specialty essential oils like lavender, tea tree, manuka and lemon myrtle in Australia and New Zealand would also in the majority of cases employ simple designs. Only large extensive farms producing large tonnage oil like mint and the larger Australian tea tree plantations would develop capital intensive *'integrated production systems'*.

A number of factors must be taken into consideration in designing a distillation system for the project;

1. *The nature of the plant material:* This would lead to considerations such as; What are the absorption characteristics of the material? What would the most important distillation fundamentals that would apply to this material? What would be the effect of steam and/or water on the physical state of the material? *i.e., will it congeal or tend to form steam channels?* Will the material have to be pre-processed before distillation*? i.e., cut up, ground or some other form of comminution.* Is the material sensitive to delay in distillation? Does it have to be wilted? Are the volatile constituents subject to damage at prolonged high temperatures? Are there low and high boiling constituents? What considerations must be given to this? How do others distill this material?

   These questions would assist in identifying the most suitable type of distillation method and the general practices that will be applied during distillation, such as what type of steam, for how long should it be distilled, etc.
2. *The harvest method and logistics:* The harvest methods used will depend upon the scale of the project, the nature of the herb, the local traditions and practices of farming, the capital investment made into the venture and the amount of the particular herb that requires handling and processing. Harvest methods can vary from manual harvesting, mowing and wilting before being picked up from the field by another vehicle, to a fully integrated system where the material is harvesting, mulched and spread directly into a cartridge or box array, behind the tractor/harvester. Another consideration is the potential damage that could occur to the plant material through harvesting, as in the example of rose petals which must be picked by hand to prevent any damage which could promote hydrolysis, oxidation and resinisation before distillation. Time between harvest and distillation is another factor that needs consideration. In the case of rose petals, distillation time after harvest is very crucial, where time is not as critical for eucalyptus and tea tree oil distillation. Basically a *'time and motion'* flowchart of the logistical aspect of harvest to distillation can be undertaken, which can assist in determining the amount of integration between harvesting and distillation systems. This needs to be quantified

with expected volumes on a daily basis to assist in determining the required still capacity, steam requirements and overall still design. A flowchart for mint is shown in Figure 9.23.

Table 9.29. Methods of Extraction Utilised for a Number of Essential Oils

Essential Oil	Botanical Name	Part of Plant Used for Extraction	Usual Method(s) of extraction
Star Anise Oil	*Illicium verum*	Seeds	Steam distillation after seeds are comminuted
Artemisia Oil	*Artemisia vulgaris*	All the herb	Steam distilled after drying
Basil Oil	*Ocimum basilicum*	All the herb	Steam distilled after drying
Bergamot Oil	*Citrus bergamia*	Fruit Peels	Cold expression of nearly ripe fruits
Broom Absolute	*Spartium junceum*	Flower Blossoms	Solvent extraction
Cajuput Oil	*Various Melaleuca species*	Leaves and twigs	Steam distillation of fresh material
Calamus Oil	*Acorus calamus*	Roots	Steam distillation of fresh or dried material
Cananga Oil	*Cananga odorata*	Flowers	Steam distillation of fresh material
Cedarwood oil	*Juniperus virginiana*	Wood chips, sawdust	Steam distillation
Celery Seed Oil	*Apium graveolens*	Seeds	Steam distillation of crushed seeds
Citronella Oil	*Cymbopogon nardus*	grass	Steam distillation of dried material
Coriander Seed Oil	*Coriandrum sativum*	Seeds	Steam distillation fo crushed dried seeds
Fennel Oil	*Foeniculum vulgarie*	Seeds (in fruits)	Steam distillation of the crushed seeds
Ginger Oil	*Zingiber officinale*	Rhizomes	Steam distillation of freshly ground rhizomes
Jasmine Absolute	*Jasminum grandifloram and other*	Flowers	Solvent extraction of the fresh flowers
Lavender Oil	*Lavandula officinalis and others*	Flowering tops and stalks	Steam distillation of fresh material
Lemon Oil	*Citrus medica*	Peel	Cold expression
Lemongrass Oil	*Cymbopogon flexuous and citratus*	Grass	Steam distillation of fresh or mildly wilted grass
Lime Oil	*Citrus aurantifolia*	Peels	Steam distilled or cold pressing
Litsea Cubeba	*Litsea cubeba tree*	Ripe fruit	Steam distillation

Oil			
Patchouli Oil	*Pogostemon cablin*	Leaves	Steam distillation of dried and fermented leaves under pressure
Rose Oil	*Rosa centifolia, damascena and others*	Flowers	Water distillation of fresh flowers
Sandalwood Oil	*Santalum album*	Wood	Steam distillation of chipped and powdered wood
Thyme Oil	*Thymus vulgaris*	Flowering herb	Steam distillation

3. *Available cooling water for condenser:* An important factor in condenser design is the temperature of the available water for cooling. This will greatly influence the size of the condenser along with vapour throughput. Ignoring the condensate water temperature issue when designing the condenser could lead to expensive re-fabrication and modification at a later date or restriction on the steam flow, temperature and pressure that can be used in distillery operation. Some distillation systems in remote areas of Australia and Indonesia utilize a near by pond to run a pipe through where exiting vapours from the charge vessel are condensed and collected on the other side of the pond, away from the distillery. This can be designed when one side of a pond is elevated from the other. Other 'field' or 'bush' stills utilize a large single water tank with stationary water inside to run a condenser pipe through for the same effect. These methods save substantially on the cost of constructing a dedicated condenser.
4. *Potential energy source:* One of the major challenges facing the essential oil industry today is final economical energy sources to produce steam. Stills in remote areas were directly fired using firewood collected from surrounding areas. However due to the decline in logging in most places, a premium has been put on the cost of fire wood and for many places it is not free anymore. Plant refuse from the still can be used for distillation, but it is only a supplement to firewood, as there is not enough volume in its own right to maintain a distillery operation. Further there are alternative uses for plant refuse in mulching and composts which if applied correctly can save more on labour for weeding and maintaining moisture in soils.

   Larger distilleries have employed diesel, bunker fuel or natural gas to power their boilers. With the crude oil price going above USD 100 per barrel at the time of writing, up from just USD 16 per barrel a few years ago, the cost of running a distillery in terms of fuel has risen fivefold. Given that the market expects the price of crude oil to rise even further, perhaps close to the USD 200 per barrel mark, this is a critical issue for the existing industry and any potential new venture.

   At the present, no specific alternative sources of energy stand out as a solution. Bio-diesel as an alternative to fossil fuels has gained a lot of attention at late, from either ethanol or a fixed oil feedstock, but pricing is still according to market forces, usually around 70-90% of fossil fuels. The economics of jatropha cultivation and extraction is questionable. The logistics of producing your own is enormous due to the plant and land required and this type of venture would attract regulation, licensing and even excise in many legal jurisdictions [150]. However possibilities exist for the recycling of used cooking and engine oils for diesel fuels. However in these cases collection and processing become issues. Various pilot schemes exist in the region producing bio-fuels based on plastics, spent sugarcanes and other crops like palm oil wastes, but most of these remain pilot projects and may be too far away to consider.

Another alternative is solar distillation. Solar distillation involves using solar energy to supply a heat source to produce steam through a Scheffler mirror reflector to concentrate UV light onto a focal point to convert water into steam [151]. This method is used to clean drinking water and is being used experimentally to distill essential oils [152]. The system doesn't work on cloudy days where a back up system is required.

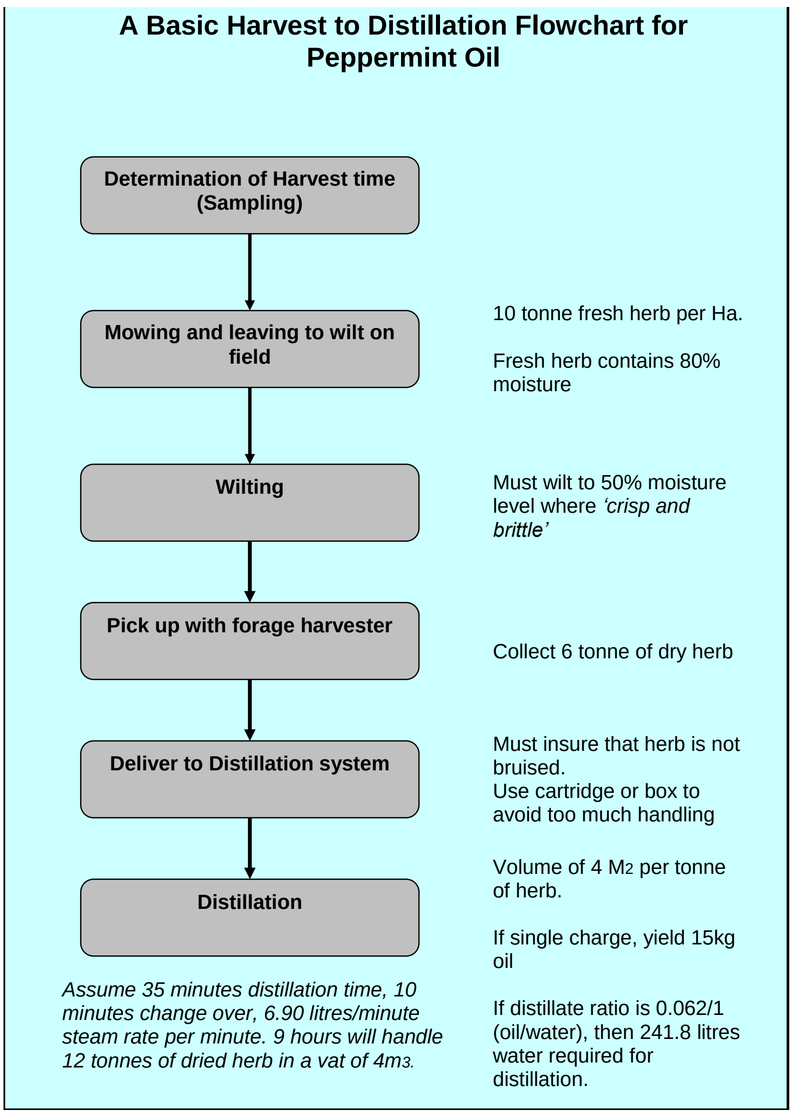


Figure 9.24. A Basic Harvest to Distillation Flowchart for Peppermint oil.

5. *Required plant material throughput (Scale):* The required size of a distillery will depend upon the required throughput of bio-mass per annum and whether it will be a continuous or seasonal operation. The factors which should be considered in deciding upon the scale of the distillery would include;
   a) Whether the harvest would be seasonal or staggered over the year,
   b) The actual size of the plantation, *i.e., tonnage of bio-mass to be processed each year.*
   c) Whether labour is an important factor in the cost of production (operating cost),
   d) The value of the crop, and
   e) The overall capital cost of the distillery.

If harvesting needs to be undertaken within a short season, as would be the case for peppermint, a large distillery to cope for the bio-mass within the period would be necessary. The number of operating hours distillation is carried out in a day, *i.e., single or double shift or around the clock would also influence the required size.* Crops with less critical harvest times, where harvesting can be staggered would require a smaller distillery.

The design of efficient working stills usually comes with experimental trial and error, and the testing of smaller prototype stills in field operation where they can be scaled up. Field results will differ from laboratory results because; laboratory distillations will be exhaustive and field distillations will be guided by shut down times. A laboratory distillation will utilize selected parts of the plant, where the field distillation may also incorporate branches and twigs because of the economics of harvesting them. Plant material in laboratory distillations will be packed differently, milder steam will be used in laboratory distillations and hydrophilic and oxygenated compounds will be less in scaled up distillations [153].

Figure 9.25. A small plant designed and built by The Author to convert used cooking oil to bio-diesel.

Figure 9.26. A glassware still is usually more efficient than a commercial still.

During the working life of each prototype still, a number of design parameters, operating procedures and plant characteristics should be tried and tested to determine their influence on results. These are shown in Figure 9.27. below.

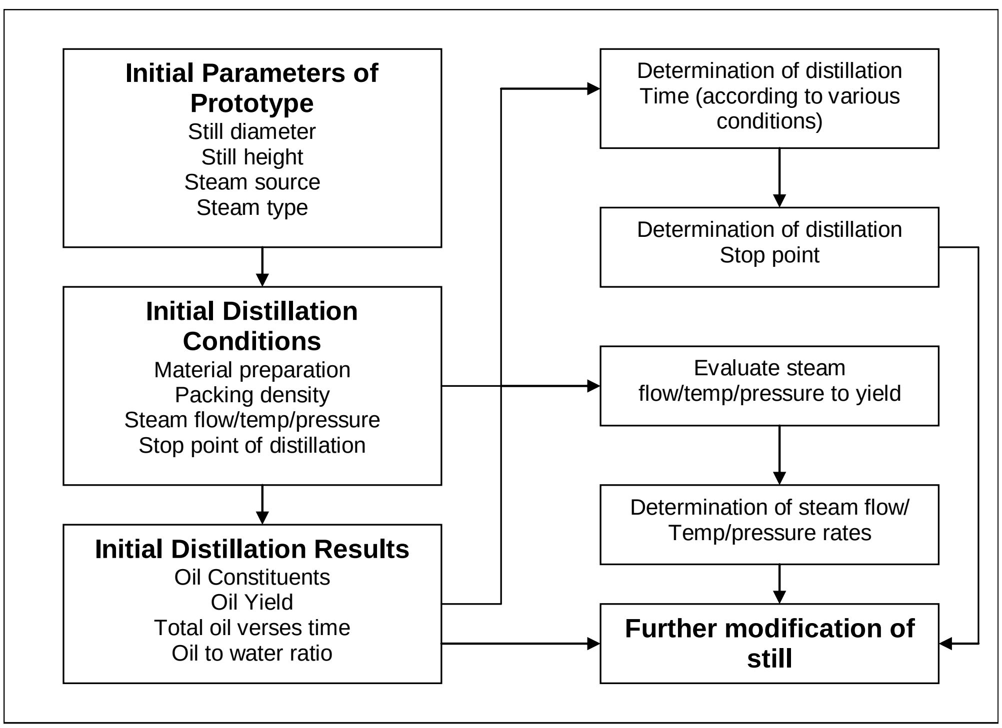


Figure 9.27. Testing procedure for prototype stills.

Figure 9.28. Manual harvesting and mulching before Loading into fixed still arrangement at Author's property In Perlis, Malaysia..

Still scale varies from plantation to plantation, with different ideas and philosophies about the optimum size. Some systems distil small batches at a time within a cartridge or bin system, usually handling multiple units at a time. Other systems distil a large charge at a time. System design appears to be more influenced by the logistic flow than the technical issues of distillation. Most designs in larger scale operations are more concerned about continuous operational flows, minimizing labour and handling. No widespread conclusions have been made about this issue. In plantations of medium size, one of three types of systems are usually employed; a fixed still operation which requires manual loading and unloading, a cartridge system or a box system.

Fixed stills are ideal for operations that require water distillation. They are also suitable for plant material where heavy comminution is required and this cannot be undertaken in the field. Most fixed stills exist in smaller to medium plantations and in operations where plant material is collected from the wild. They are also used in situations where the cost of labour is not of paramount importance to the economics of the operation, so many family farms in Australia utilize this method as they are owner operated. However, it should be noted that due to rapidly rising living standards in many parts of South East Asia, these operations could face challenges to their economic viability.

Most fixed stills consist of an open topped tank, usually constructed of mild steel or other locally available scrap metals. The lid is usually sealed with cork or mud, which is not heat sensitive and clamped during distillation. The foliage is usually loaded and unloaded manually or with the assistance of a block and tackle pulley, connected to a tractor. Compact packing of the charge into the still is vital in achieving good yields. The charge must be packed efficiently to prevent steam from channeling through the plant material. Steam is usually generated through an adjacent boiler, which can produce some pressure. Steam is introduced into the charge vessel through a pipe arrangement or vapour coils to distribute the steam evenly. Others utilise a direct fire under the still, built up upon a three sided brick wall. A direct fire will only produce steam at atmospheric pressure. Such stills usually utilize water-steam distillation. Condensers are either specially built or the natural topography around a pond or dam is used as a cooling reservoir with the separator positioned on the other side of the dam. Alternatively a stationary tank is used to house cooling water for the condenser pipe. Figure 9.29. shows a simple design diagram of a fixed still.

Cartridge distillation systems were developed as a labour saving process over fixed stills which have to be loaded and unloaded manually. This system can exist in two basic forms. One is where plant material is brought in from the field and loaded into the cartridges at the distillery and loaded into the still, once the previous cartridge has completed its distillation. The other is where the cartridge is actually taken into the field behind the harvester and loaded directly during the harvest.

These systems greatly improve the logistics of distillation, where cartridges can be positioned ready for exchange with the previously distilled cartridge, almost immediately without having to wait for the spent plant material to cool. Distilled cartridges are lifted to a refuse area where the spent foliage is tipped into a compost heap, before the cartridge is returned to the field. In some systems, the cartridges themselves form the still, where the steam inlet pipe and vapour outlet are connected directly to the steam boiler and condenser respectively, for immediate distillation.

These designs greatly improve daily production throughput, as loading, cooling and unloading times between distillations are saved. Still heights range between 1.3-2.0 metres with a suitable diameter for handling. Still design is greatly influenced by handling convenience. The steam supply should be sufficient to handle multiple charges at one time for best efficiency.

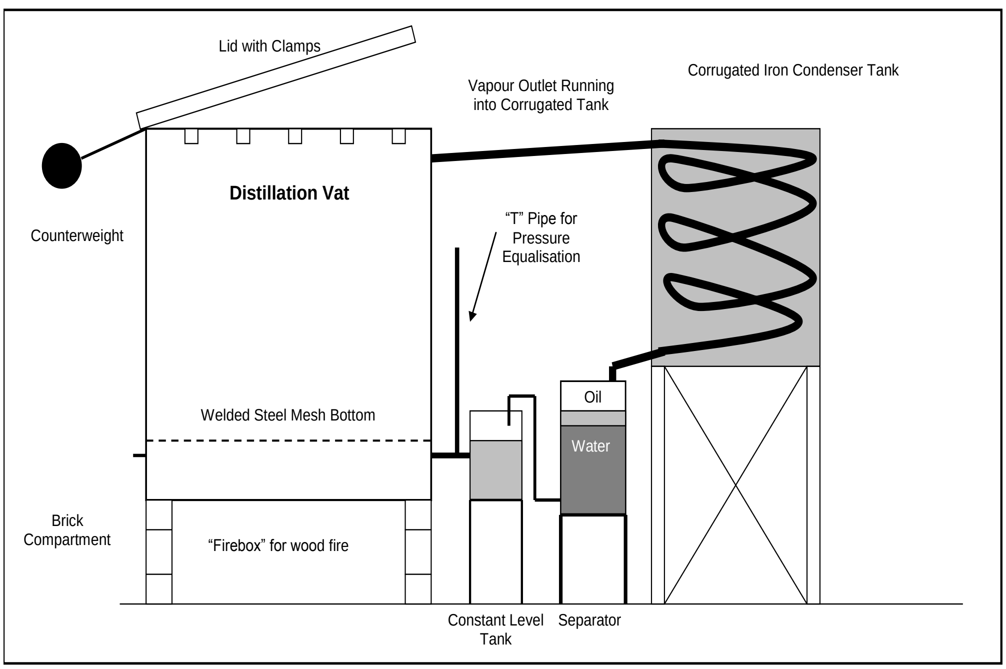


Figure 9.29. Simple Design Layout of a Fixed Still.

Figure 9.30. A cartridge distillation system at theFormer ‘Maincamp’ property in Australia. (Photo courtesy Mr. John Bax).

Box distillation systems are usually used for extensive high bio-mass crops like mint and fennel, where a number of growers over a particular area may share the facilities. A central distillery is made up of a steam boiler and a station to park and connect up boxes to the steam and condenser. The box is mobile on a trailer that can be carted behind the harvester in the field for direct filling of the harvested plant material. The box will have a lid that can be elevated towards the harvester, so the harvested material can be deposited or with no lid, where a suspended lid at the distillery will be lowered onto the box during the actual distillation. Once the box is full of plant material, it is disconnected from the harvester and attached to a truck or tractor (depending on the distance) for transport to the distillery. At the distillery, a steam inlet pipe is connected at the bottom of the box and another pipe (or lid) connected at the top flowing to the condenser system. Once the distillation has been completed, the box is pulled out of the distillation station and through hydraulics, tips out the spent plant material into a designated refuse area, before being returned to the field.

Some producers use small compact boxes which are easier to use on fields, especially during rainy conditions. Smaller boxes can be distilled quicker and are lighter in weight for handling and most suitable when the distillery is nearby. Smaller boxes also create less pressure at the beginning of a distillation when the massive air volume in the top of box heats up and is expelled through the condenser system. Larger boxes, although more difficult to handle on the field, lend themselves to longer distance hauls to a central distillery.

Figure 9.31. Box coupled to the steam source at the distillery for peppermint Distillation at Myrtleford, Victoria (Photo courtesy of Mr. Fred Bienvenu).

The box must be designed so that steam will circulate throughout the space inside the box. Design of the internal piping array to inlet the steam is critical. The herb material rests on a false mess bottom above the steam inlets to prevent any burning of foliage that could create unpleasant odours and assist in even distribution of the steam vapour throughout the internal space of the box. Box still are suitable for logistic situations where crops are grown in distributed areas, as transport of herb material is a crucial issue. Box systems are also very efficient from the labour point of view, requiring only one person to drive the harvester, one person to drive the transporter, one person to operate the steam and one person to couple and uncouple the boxes and pipes during the operation.

Distillation Effluent

A distillation plant will have two types of polluting effluent, smoke from a steam generator (unless electrically powdered) and the water distillate from the charge bin. These effluents fall under the jurisdiction of local environmental protection authorities. Smoke discharges may require filters to trap excess carbon emissions and distillation effluent may require aerobic or anaerobic treatment in a pond before discharge into the environment.

Potential By-Products from the Distillation Process

The production of any possible by-products from the waste products of distillation, not only assists in the handling of wastes, but in adding value to the process through either savings or extra revenue gained.

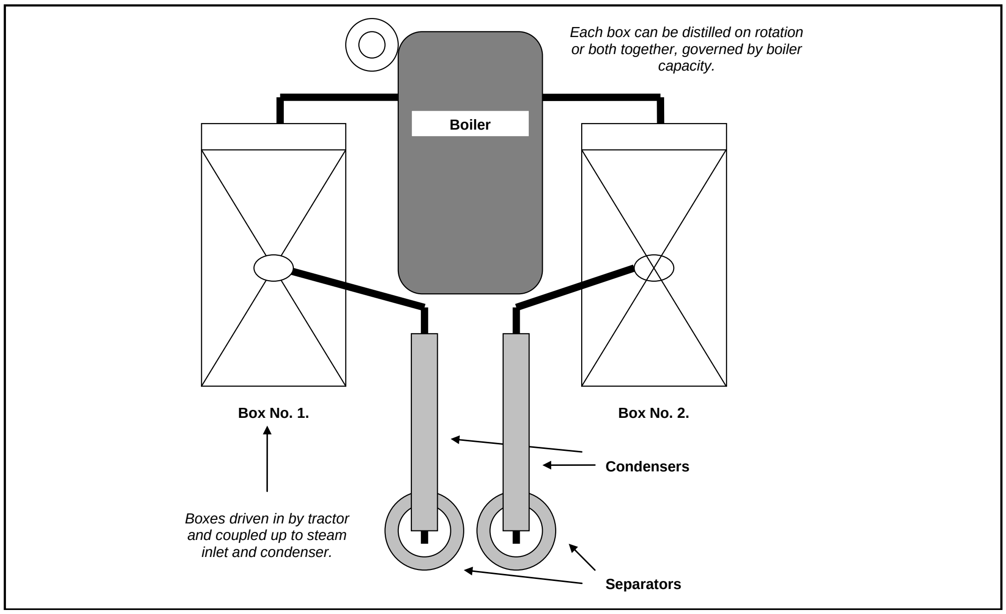


Figure 9.32. Layout Plan for a Box System Distillery.

The spent foliage of many plants after distillation can by utilized as mulch. Mulch is very beneficial in weed control and maintaining moisture in the soil after rain or irrigation. Using spent foliage as mulch is also part of a sustainable farming system and encouraged. Spent foliage after oil extraction usually makes good mulch as it has been sterilized during distillation. The farm enterprise has the option of either using the mulch back on its own fields or selling it as a commercial product. There is usually high demand for good mulches in the horticulture, agriculture and home gardening sectors.

Other potential by-products from distillation wastes include hydrosols from certain distillate waters, although these are limited to a few crops like lavender, rose, and other florals. Spent foliage can be used as cattle feed base, ferro-cement filler for green bricks and buildings, and as a source of fuel for steam production in the distillation plant.

STORAGE FACILITIES

Essential oils are stored before they are sold to customers and sent off to users. Storage facilities can range from an area where individual “180 Kg” stored to an elaborate bulk tank facility (see Figure 9.33.). How elaborate a storage facility is will depend upon the amount of oil the producer must handle each harvest season, how long the oil is stored before sale and shipment and whether any blending is required.

Figure 9.33. The 'tank farm' at the former 'Maincamp' Property (Photo courtesy of Mr. John Bax).

Sometimes oil is just bulked, *i.e., each distilled batch is added to each other,* or stored in separate containers until the quality of each batch is checked and assessed. Where different distilled batches vary from field to field in chemical constituent levels, they can be blended together to create a uniform product. For example if a batch of tea tree oil from one field contains 48% terpenin-4-ol and another batch from another field contains 44% terpenin-4-ol, if in equal quantities, they can be blended together to form a blended oil of 46% terpenin-4-ol. This procedure is not uncommon for a number of essential oils produced.

Throughout the bulking, blending and storage process, information should be recorded and logged, so that oil can be tracked through an audit trail, required by a number of certification processes (these are discussed in chapter 11). Blending and storage facilities should be built according to fire and hazard requirements due to flammability. This will most likely require drums and tanks to be positioned away from other buildings or with a firebreak between buildings, with all electrical equipment and tanks earthed to prevent any sparks igniting any oil.

If any essential oil produced is sold to the pharmaceutical industry as *"pharmaceutical grade"*, blending and storage facilities should meet Good Manufacturing Practice (GMP) guidelines discussed in chapter 11. Shipping containers, if glass, should be dark to prevent UV light spoiling them.

Steel drums that have resin or plastic lining are not suitable for a large number of essential oils, particularly those containing terpenes. Some essential oils are packed with a layer of nitrogen to prevent any oxidization. Essential oils should be kept away from extreme heat.

GOOD AGRICULTURAL PRACTICE (GAP)

Good Agricultural Practice (GAP) originated around a decade ago as consumers developed a concern for safety issues, environmental and labour standards along the supply chain, by European Retailers, and standards bodies [154]. This led to the formation of EurepGAP, which is a private sector body comprising of retailers, farmers, and relevant people from the service side of agriculture, in what is espoused as a partnership of agricultural producers and retailers for the setting of voluntary standards for the certification of agricultural products.

GAP is basically a number of agreed principals set in agreed and certifiable terms applying to farm production processes that result in safe and healthy food and non-food agricultural products. These principals take into account economic, social and environmental sustainability, as well as social and community cultural practices, with the objective of developing natural resources. These principals set out a framework understanding production issues from a sustainability viewpoint, planning, reviewing, monitoring, and record keeping for each stage of the production process. This framework should provide farmers with the ability to identify problems and issues and modify practices, according to changes in conditions.

There are now a number of certification programs for GAP, with some placing emphasis on different issues. The USDA certification is more like HACCP (discussed in chapter 11). However generally, GAP certifications cover integrated crop management, fertilizer use, irrigation, weed control, pest and disease control and harvesting. The general GAP guidelines set by The European Herb Growers Association (Europam) are [155];

1. General Provisions
    a. GAP guidelines apply both to conventional and organic agricultural practices,
    b. All farm production should avoid harmful environmental disturbances, which involves good crop rotation, developing buffers and hedge zones, avoidance of damage to existing wildlife habitats, and within the framework of enhancing the biodiversity of the farm.
    c. Required to follow the critical steps that are needed to comply with good quality, with good hygiene,
    d. Reduce potential microbiological contamination to a minimum during the production process,
    e. Documentation should be kept to allow traceability of the entire production process, and
    f. Encourage their suppliers to comply with GAP guidelines.
2. Personnel and Facilities
    a. Personnel should be fully trained and educated in what is required in the cultivation, harvesting, processing, drying and conservation processes, as a way to ensure the best quality.
    b. The education process should be documented,
    c. Personnel involved in the production process should have a high degree of personal hygiene, and understand their hygiene responsibilities.

   d. People with infectious diseases or open wounds and cuts should not be involved in the production process (complying with EU-Guidelines on food hygiene and European Directive on Good Manufacturing Practice).
3. Seeds and Propagation Materials
   a. Seed and other propagation materials must be identified botanically, indicating plant variety, cultivar, chemotype and origin. The material should be traceable.
   b. Starting materials used in organic production should be certified as organic.
   c. Starting materials should be pure and free of any pests and diseases and contaminating plants controlled during the cultivation, harvesting and packaging processes.
   d. Seed and plant materials of or derived from genetically modified organisms (GMO) must be in accordance with National and European regulations.
4. Cultivation, Soil and Fertilization, Irrigation
   a. Plants should not be grown in soils that are contaminated by sludge, heavy metals and residues of plant protection products and other synthetically derived chemicals.
   b. Farms should aim for effective minimum input of chemicals, and comply with European Union minimum residue limits.
   c. Manure should be free of human faeces and thoroughly composted before application
   d. Irrigation should be minimized as much as possible, according to the needs of the plant.
   e. Irrigation water should comply with quality standards and free of contaminants such as faeces, heavy metals, pesticides, herbicides and other toxicologically hazardous substances.
   f. Tillage should be adapted to plant growth and requirements.
5. Harvest
   a. Harvests should take place when plants are of the best quality and take place under the best conditions i.e., in terms of soil, field and weather conditions).
   b. Harvest equipment should be in the best order and should be clean.
   c. Care should be taken during harvest not to collect contaminating weeds.
   d. Time between harvests, drying and/or processing should be very short and in accordance with the methods that will result in the best quality.
6. Primary Processing
   a. All primary steps of processing whether for food or medicinal use should conform with the relevant National and European regulations.
   b. Buildings used in the processing of harvested crops should be clean, thoroughly aerated, dedicated and protect the crop from birds, insects, rodents, and domestic animals, etc.
   c. In the case where drying is required, the crop must be spread out in a thin layer to secure unlimited air circulation and all attempts made to prevent mould formation. Where heat is used, correct temperatures should be adhered to, according to the requirements of the specific plant.
7. Packaging

   a. After control and elimination of low quality and contaminating materials, the product should be packaged in clean and dry conditions with the label fixed clearly and permanently.
   b. Re-useable containers should be thoroughly cleaned and dry before reuse.
8. Storage and Transport
   a. Stored materials and products should be stored in dry, clean locations where daily temperature does not fluctuate and good aeration is available.
   b. Essential oil storage must conform to the appropriate chemical storage and transport standards concerning risks and labelling requirements with national regulations and EU Council Directive 94/55/EEC.
   c. Storage area must be protected from pests, birds, rodents, domestic animals through windows and door openings.
   d. Organic products must be stored with national organic regulations and EU Directive 209/91.
9. Equipment
   a. Equipment used in plant cultivation should be easy to clean to assist in the elimination of contamination.
   b. All equipment should be in continual good order and calibrated.
   c. Preferably non-wooden equipment should be used unless traditional methods require this.
10. Documentation
    Documentation required to enable traceability, includes;
    a. field records
    b. pesticide, herbicide, fertilizer usage
    c. Special situations due to weather, etc.
    d. Product batch numbering, and
    e. Any processes that can affect the quality of the product.
11. Quality Assurance
    a. Active ingredient levels, optical and sensoric properties, limit values of germ numbers, chemical residues and heavy metals must be based on internationally recognized specifications.
12. Self Inspection
    a. Should be conducted to monitor the implementation and compliance with Good Agricultural Practice principals and identify corrective measures required
    b. Documents should be examined periodically to ensure adherence to quality assurance principals, and
    c. Self inspections should be recorded.

As mentioned, there are a number of certification schemes in operation. The Food and Agricultural Organisation of the United Nations (FAO) adopted a set of GAP principals in 2002 [156].Good Agricultural Practice (GAP) is growing in countries like Australia [157], New Zealand, Vietnam [158] and especially in Thailand [159], where it is claimed some 60% of rice production is under GAP standards [160]. In countries like Indonesia and Malaysia, GAP is still in its infancy of awareness by producers [161], although schemes exist [162].

FINANCIAL MODELLING, FEASIBILITY AND EVALUATION

The development of an essential oil plantation requires long term financial commitment. In normal circumstances revenue will not come to the venture for a long period of time. Plans, objectives and strategies must be financially modelled, so that the viability and financial sustainability of the venture can be assessed. Many projects have failed because they have not been financially modelled properly. Others have fallen short on financial resources before creating enough revenue to become financially sustainable. Some were not financially viable in the first place. Thus development requires commitment, patience and confidence in strategy implementation. The management of the project will be much more confident with a solid financial model behind the project.

A financial model is a reflection of the project objectives, chosen strategies and scale. The first step is to determine what infrastructure development is needed on the site and what capital expenditure is required. This involves making cost estimates of land preparation and development in relation to drainage and irrigation, buildings, fencing and roads, machinery and equipment. These estimates also should include the costs of administrative development, research and quality control facilities.

Evaluating all the potential costs will result in the development of a cost schedule. The example used in this book is for a 200 hectare tea tree plantation in Northern Malaysia during 2001-2003 time period *(reflected in costing)*. Malaysia is a mid range cost country in the Asia-Pacific region where countries like Thailand would be cheaper to develop infrastructure (except land) and countries like Australia and New Zealand more expensive, where issues of water management and EPA compliance may add substantially to costs. Countries like Cambodia and Laos mat have higher cost bases than Malaysia because of their special infrastructure needs and remoteness from potential supplies*, i.e., tractors and other specialized equipment may have to be shipped from suppliers in from Bangkok*. Table 9.30. shows the potential capital costs for a 200 Ha. tea tree plantation in Northern Malaysia.

Every location is a unique one and will have its own specific cost issues. Land may require road access, have specific costs for utility connection or require electricity generation and water self-sufficiency. Some land may be totally deprived of top soils and require extensive land regeneration. Cost will also depend upon whether the site is already part of an existing farm where field infrastructure already exists. There situation requires much less capital commitment in creating a new project on an existing plantation site, compared to starting from scratch where everything has to be developed and purpose built for the venture.

The same venture can be modelled many different ways, with many different capital cost figures. For example, an already operational farm with suitable fields, dams, fencing, irrigation, internal roads, utilities, farm machinery and equipment, electricity generators, pick up trucks and business structure may only require a capital investment of RM1,475,000 instead of RM5,549,500, saving RM4,074,500, on the above example. A distillery will be required if the existing venture is not already producing essential oils, but much of the existing equipment with little or no modification can be utilized and existing nurseries used. Capital costs will also greatly depend upon the chosen crop.

Table 9.30. Capital Costs for a 200 Ha. Tea Tree Plantation in Northern Malaysia

Item Description	Cost (RM)	% Total
Infrastructure Development		
1. Land Clearing	1,000,000	18.02%
2. Fencing	250,000	4.50%
3. Drainage Work	250,000	4.50%
4. Buildings	450,000	8.11%
5. Dams	250,000	4.50%
6. Internal Roads	300,000	5.41%
7. Utility Access	50,000	0.90%
8. Distillery	750,000	13.51%
9. Farm machinery & Equipment	750,000	13.51%
10. Harvester	450,000	8.11%
10. Laboratory Equipment	350,000	6.31%
12. Other	350,000	6.31%
	5,200,000	**93.70%**
Equipment		
1. Pumps	25,000	0.45%
2. Small Distillation Unit	25,000	0.45%
3. Electricity Generators	25,000	0.45%
4. Pick-up Truck	150,000	2.70%
5. Misc. Farm Equipment	50,000	0.90%
6. Nursery Equipment	20,000	0.36%
7. Other	20,000	0.36%
	315,000	**5.68%**
Administration Issues		
1. Business Registration	2,500	0.05%
2. Legal Fees	5,000	0.09%
3. Labour Permits and Costs	10,000	0.18%
4. Water & electricity Deposits	5,000	0.09%
5. Insurances	12,000	0.22%
	34,500	**0.62%**
Total:	**5,549,500**	

The next stage of the financial model involves the estimation of all required nursery activities. If a small pilot project has been carried out or similar operations on other farms visited and evaluated, making these estimations will be straight forward. The total nursery aspect should be broken down into individual time-based activities, so a material, labour and time estimate can be made for each activity. Ways to streamline and make these activities efficient, *i.e., are polybags necessary, can the seedlings be field planted directly from trays? Can an overhead watering system be developed rather than manual watering?* These are all task design issues to consider at this point. Each task can be plotted of a *Gantt* chart as in Table 9.31.

Estimates are required of the potential output from the nursery operation so that seedling costs can be determined. This requires an estimation of the germination rate of the seeds and the attrition rates of seedlings whilst in nursery care. This will assist in any evaluation of *'in-house'* verses *'outsourcing'* decisions. Table 9.32. shows an estimate of nursery production costs for planting material for approximately 9 hectares. In this case, 1 gram of seed material represents approximately 20,000 seeds where a 10% germination rate is assumed. Another 10% loss is assumed during the nursery process, yielding a total of 270,000 seedlings.

Table 9.31. A Simple Gantt Chart Summarizing Each Nursery Activity for Costing Purposes

Activity	Staff Required	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Materials Required
1. Seed Germination *(bed preparation, sowing, maintenance)*	8	→						Sterile media, growth fertiliser, polytrays for germination
2. Sowing bed maintence	3	→						
3. Transfer Seedlings to trays	6		→					Composted media, trays
4. Tray Maintenance	3			→				
5. Transfer Seedlings to polybags	6				→			Compost media, polybags
6. Maintence of polybags	3					→	→	
7. Transfer to seedlings	Field team						→	

Table 9.32. Nursery Cost Estimates

Item	Qty	Cost (RM)
Materials		
Seeds (purchased or collected)	150 gram @ RM12,000/kg	1,800
Bed Soil Media	2 Tonne @ RM 1,000 Tn	2,000
Compost & sand	5 Tonne @ RM200 Tn	1,000
Polybags & Trays	300000 @ RM6/1000	1,800
Fertiliser	500 Kg @ RM5 kg.	2,500
Other		2,000
		11,100
Labour		
Sowing & transfer to trays	200 man days @ RM25 per person	5,000
Transfer to polybags	300 man days @ RM25 per person	7,500
Maintenance	180 man days @ RM25 per person	4,500
		17,000
Total Cost:		28,100
Estimated Yield in Plantable Seedlings:	90% 270,000	
Cost per Seedling		0.10

Estimates of field costs require calculation. This involves defining the various activities that are required in the field, and calculating the labour and material costs. This will be different in the first and subsequent years, as the first year involves planting. These estimates will be greatly influenced by the level of technology used in the venture. If the plantation is extensive, it may utilize high mechanization where costs like fuel, machine time, maintenance will be important, rather than man-hours shown in the examples in Table 9.33. and Table 9.34.

Table 9.33. One Hectare Field Cost for First Year Tea Tree Cultivation in Malaysia

Item	Qty	Cost (RM)
Planting	20 man days @ RM25 per person	500
Maintenance	10 man days @ RM25 per person	250
Harvesting	40 man days @ RM25 per person	1,000
Irrigation	5 man days @ RM25 per person	125
Fertiliser	250 kg @ RM5 per kg	1,250
		3125

Table 9.34. One Hectare Field Cost for Subsequent Year Tea Tree Cultivation in Malaysia

Item	Qty	Cost (RM)
Maintenance	10 man days @ RM25 per person	250
Harvesting	40 man days @ RM25 per person	1,000
Irrigation	5 man days @ RM25 per person	125
Fertiliser	250 kg @ RM5 per kg	1,250
		2625

To fully estimate operational costs, field foliage (biomass) yields, oil yields and distillation costs are required. If field trials have been conducted, this information is readily available for incorporation into the financial model. The following table shows various foliage yields per hectare, distillation yields, diesel and other extraction costs and a calculated distillation cost per kilogram of essential oil produced. The cost of diesel per kilogram of essential oil produced is independent of the amount of biomass harvested (not diesel used in the harvest vehicles), but affected by the percentage oil yielded per unit of biomass, as the table shows.

From all the preceding information, a cash-flow projection can be prepared. The cash-flow projection will show the following information;

- Total and periodic funds required,
- For what purpose funds will be required and when,
- Total and periodic expenditures,
- Total and periodic revenue,
- The aggregate expenditure situation of the venture (infrastructure and working capital),
- The overall cash surplus and/or deficit the venture is projected to have at any time (i.e., profitability/loss trends).

Thus the cash-flow projection will show sources of funds and eventual expenditure in the form of a budget projection. This should become an actual operational document so that during implementation, costs and revenues can be compared against projections to monitor adherence to the predetermined objectives and strategies. Any financial deviations would be the source of management inquiry. A cash-flow projection prepared from the above information is presented in Table 9.36.

Table 9.35. Calculated Distillation Cost per kilogram Essential Oil

Foliage Harvested Hectare	Yield 0.80%	Distillation Cost/Kg	Yield 1.00%	Distillation Cost/Kg	Yield 1.20%	Distillation Cost/Kg	Diesel Qty	Diesel Cost	Other	Total
10000 Kg	80	↓	100	↓	120	↓	150 kg	RM450	RM 180	RM 630
15000 Kg	120		150		180		225 Kg	RM675	RM 270	RM 945
20000 Kg	160		200		240		300 Kg	RM 900	RM 360	RM1,260
25000 Kg	200	RM 7.88	250	RM 6.30	300	RM 5.25	375 Kg	RM1,125	RM 450	RM 1,575
30000 Kg	240		300		360		450 Kg	RM 1,250	RM 540	RM 1,790
35000 Kg	280		350		420		525 Kg	RM 1,575	RM 630	RM 2,205
40000 Kg	320		400		480		600 Kg	RM 1,800	RM 720	RM 2,520
45000 Kg	360	↑	450	↑	540	↑	725 Kg	RM 2,175	RM 810	RM 2,985

Table 9.36. A Cash-flow Projection for A Tea Tree Plantation in Northern Malaysia

Item	Year 1	Year 2	Year 3	Year 4	Year 5
Cash at Beginning	0	-6,062,000	-6,251,440	-5,819,740	-4,769,380
Revenue		445500	1188000	1930500	2673000
Oil Produced		**3 tonnes**	**8 Tonnes**	**13 Tonnes**	**18 Tonnes**
Expenses and Costs					
Capital and Infrastructure Costs	5,515,000				
Nursery Costs	60000	60000	60000	60000	60000
Packaging Materials		2040	5400	8640	12000
Direct land costs	25000	25000	25000	25000	25000
Salaries	200000	200000	200000	200000	200000
Other Salary costs	25000	25000	25000	25000	25000
Fuel and vehicle costs	40000	44000	48000	52000	56000
Administrative costs	34500	25000	25000	25000	25000
Cultivation & maintenance costs	62500	115000	167500	220000	272500
Distillation costs		18900	50400	94500	144900
Marketing Costs	100000	120000	150000	170000	190000
Total Costs	6,062,000	634940	756300	880140	1010400
Cash at Year End	-6,062,000	-6,251,440	-5,819,740	-4,769,380	-3,106,780

Finally a sensitivity or breakeven analysis should be undertaken to determine potential profit and loss contribution, as well as finding out where the venture break-even points are. This analysis can examine both technical and business variables. For example technical variables usually examined would include biomass/foliage yields and business variables may include price and/or percentage of oil produced that is sold to customers. Examining these variables which are critical to the venture is very important, as even the most carefully researched and prepared plans and forecasts will have assumption errors. In addition, unforeseen or extraordinary things can happen at both the business and technical levels. An examination of variables, particularly at their lower levels will determine the critical points where the venture may perform below break-even level and present critical survival threats. The sensitivity analysis in Table 9.37. examines the effects of changes in price and yield per hectare on venture profitability.

As can be seen in this example, even at a price of USD 10 per kilogram there is little threat to venture viability, except at biomass yields under 25 tonnes per hectare. However this would drastically lower the return on investment ratio, which could influence perceptions of venture viability in terms of comparative return to the shareholders. The probability of low prices and/or biomass yields may require an analysis of percentage of oil sold on profitability, as is shown in Table 9.38.

Table 9.37. Sensitivity Analysis for Tea Tree Oil Project[1]

Foliage Yield (Ha.)	% Rev. Received	Net Revenue	Costs	Net Profit/Loss
15 Tonne	100%	495000	960000	*-465000*
	90%	445500		*-514500*
	80%	396000		*-564000*
	70%	346500		*-613500*
	60%	297000		*-663000*
25 Tonne	100%	825000	1023000	*-198000*
	90%	742500		*-280500*
	80%	660000		*-363000*
	70%	577500		*-445500*
	60%	495000		*-528000*
35 Tonne	100%	1155000	1086000	69000
	90%	1039500		*-46500*
	80%	924000		*-162000*
	70%	808500		*-277500*
	60%	693000		*-393000*
45 Tonne	100%	1485000	1164000	321000
	90%	1336500		172500
	80%	1188000		24000
	70%	1039500		*-124500*
	60%	891000		*-273000*

Table 9.38. A Further Sensitivity Analysis at Price USD 10/Kg Showing Percentage of Tea tree Oil Sold

Price (USD)	Foliage Yield (Ha.)	Revenue (RM)	Fixed Costs (RM)	Variable Costs (RM)	Total Cost (RM)	Operational Profit/Loss
USD 10	15 Tonne	495000	865500	94500	960000	-465000
	25 Tonne	825000		157500	1023000	-198000
	35 Tonne	1155000		220500	1086000	69000
	45 Tonne	1485000		298500	1164000	321000
USD 15	15 Tonne	742500	865500	94500	960000	-217500
	25 Tonne	1237500		157500	1023000	214500
	35 Tonne	1732500		220500	1086000	646500
	45 Tonne	2227500		298500	1164000	1063500
USD 20	15 Tonne	990000	865500	94500	960000	30000
	25 Tonne	1650000		157500	1023000	627000
	35 Tonne	2310000		220500	1086000	1224000
	45 Tonne	2970000		298500	1164000	1806000
USD 25	15 Tonne	1237500	865500	94500	960000	277500
	25 Tonne	2062500		157500	1023000	1039500
	35 Tonne	2887500		220500	1086000	1801500
	45 Tonne	3712500		298500	1164000	2548500

[1] Assumptions: Yield of oil at 1.0%, Size 100 Ha with all planting completed, USD/RM exchange rate 3.30.

USD 30	15 Tonne	1485000	865500	94500	960000	525000
	25 Tonne	2475000		157500	1023000	1452000
	35 Tonne	3465000		220500	1086000	2379000
	45 Tonne	4455000		298500	1164000	3291000
USD 35	15 Tonne	1732500	865500	94500	960000	772500
	25 Tonne	2887500		157500	1023000	1864500
	35 Tonne	4042500		220500	1086000	2956500
	45 Tonne	5197500		298500	1164000	4033500
USD 40	15 Tonne	1980000	865500	94500	960000	1020000
	25 Tonne	3300000		157500	1023000	2277000
	35 Tonne	4620000		220500	1086000	3534000
	45 Tonne	5940000		298500	1164000	4776000
USD 45	15 Tonne	2227500	865500	94500	960000	1267500
	25 Tonne	3712500		157500	1023000	2689500
	35 Tonne	5197500		220500	1086000	4111500
	45 Tonne	6682500		298500	1164000	5518500
USD 50	15 Tonne	2475000	865500	94500	960000	1515000
	25 Tonne	4125000		157500	1023000	3102000
	35 Tonne	5775000		220500	1086000	4689000
	45 Tonne	7425000		298500	1164000	6261000
USD 55	15 Tonne	2722500	865500	94500	960000	1762500
	25 Tonne	4537500		157500	1023000	3514500
	35 Tonne	6352500		220500	1086000	5266500
	45 Tonne	6682500		298500	1164000	5518500
USD 60	15 Tonne	2970000	865500	94500	960000	2010000
	25 Tonne	4950000		157500	1023000	3927000
	35 Tonne	6930000		220500	1086000	5844000
	45 Tonne	8910000		298500	1164000	7746000

The sensitivity analysis shows that the venture will only be profitable at four points where a price of USD 10 exists, at 35 tonne per hectare biomass yield, where 100% of the crop is sold, and where 80-100% of the crop is sold at 45 tonne per hectare yield.

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Chapter 10

THE ORGANIC PRODUCTION OF ESSENTIAL OILS

Organic farming involves crop cultivation to produce uncontaminated products free of pesticides, herbicides and heavy metals according to ecological principals while maintaining sustainability. There is remarkable growth for organic products today with organic orientated supply chains developing throughout mainstream markets. Organic farming is considered by a number of people to be a viable alternative to conventional farming. A great number of essential oils are produced organically around the world although not certified as such. This chapter looks at the place of organic farming within the continuum of farming systems and discusses the basic principals of organic farming which include crop rotation, cover crops and green manures, animal manures, intercropping, composting, mulching, crop diversity, natural fertilizers, minerals and supplements, insect and disease control, weed control, tillage and farmscaping. The chapter concludes with a look at the planning and certification process and the extent of organic farming in the Asia-Pacific Region today.

INTRODUCTION

Until the 'green revolution' took place in the late 1940s agriculture relied primarily on traditional methods of production, based on preventative measures and local inputs. Through technological advances during the Second World War in many fields including agriculture, farm productivity improved dramatically. This was achieved through chemical based fertilizers, pesticides and herbicides, ironically 'spin-offs' from chemical warfare programs. In addition, a number of labour saving and automation inventions and innovations, such as tractor plough arrays and automatic harvesters enabled the development of extensive farming on much larger scales than ever before.

The 'green revolution' dramatically increased farm productivity and it took some time for people to become aware of a number of undesirable consequences. Doubts eventually developed about the long term viability and sustainability of these new agricultural practices [1].

These doubts fell in two broad areas;

Firstly, conventional agriculture has degraded natural resources like rivers, lakes and underground water tables, through chemical residuals from fertilizers, pesticides and herbicides leaking from the system. Mono-cropping and constant tillage had worn down soil nutrients contributing to the erosion and disappearance of humus and tops soils. Conventional agriculture was seen as very disruptive on eco-systems, contributing to the demise of biodiversity within farming areas. These undesirable effects from conventional agriculture contributed to the general degradation of the environment.

The second doubt arose of the need to utilize public funds to subsidise non-sustainable practices. Farm inputs like chemical fertilizers, pesticides and herbicides are usually manufactured long distances away and need to be transported to farms. These chemical inputs are manufactured using non-renewable resources and energies leading to CO2 emissions, thus having negative effects to both the economy and environment [2].

From the scientific point of view, organic farming practices are seen by some as a solution to many problems. Eliminating the use of pesticide assists in opening up degraded eco-systems for re-diversification [3]. Organic farming can assist in reclaiming, rehabilitating and restoring biological diversity [4]. Organic farming practices generally reduce nutrient leaching of the soil [5], and arrest the degradation caused by conventional farming, hence the term given to organic farming by some; regenerative agriculture. Organic farming philosophy sees agriculture as part of a complex eco-system, which if approached with the correct practices to manage functional relationships, would increase productivity. Organic agriculture is seen as a way to reduce dependence on chemicals [6] through practicing agriculture in a coordinated way within existing eco-system cycles.

From the consumer perspective, organic foods have been associated with health, safety, social responsibility, ethical issues [7] and cleanliness. Many consumers believe that organic products are superior in quality to conventional products, safe and socially responsible [8]. This is certainly the view of many aromatherapists, natural herbalists and pharmacists [9]. This has been reinforced by food scares and the debate over ‘genetically modified’ foods. Major retailers now promote organic lines and multinational processed food manufacturers are launching organic products which contribute to increasing consumer attention to the sector and promote growth in the World market [10]. In 2008, the worldwide market for organic products was approximately USD 36.5 Billion, including the fast growing organic cosmetics market (see Figure 10.1). The general organic market is growing approximately 10-15% per annum, while the organic cosmetic market is said to be growing somewhere between 20-30% per annum [11]. However, even with this growth, only 1-2% of total agricultural land is under organic cultivation today [12].

The organic cosmetics segment is still considered a niche market. Although still very small compared to the conventional market, a number of corporate strategic moves have taken place in recent times to indicate that this market niche will continue to dramatically grow in size over the next few years. L’Oreal, often cited as the World’s largest cosmetic company, purchased The Body Shop in 2006 [13]. Colgate-Palmolive and Clorox have also made large purchases of companies producing “green” and “organic” products, the following year. A recent report states that both Unilever and S.C. Johnsons are also looking for strategic purchases in this area [14].

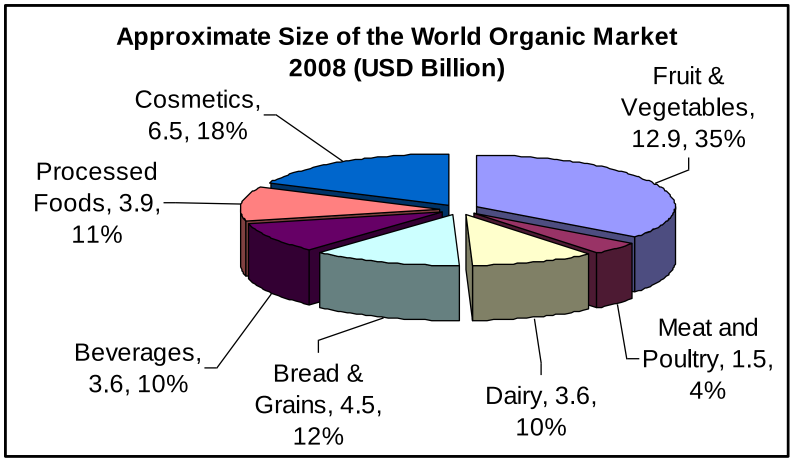

Figure 10.1. Approximate Worldwide Market for Organic Products 2008.

Aiding in the development of the 'green' and 'organic' markets is the growth of the ethical market. The ethical market began to emerge with changing social thought during the 1960s, triggered by a number of watershed opinions published in the 1960s and 1970s. The publishing of the Rachel Carson's book Silent Spring, criticized the chemical industry of spreading disinformation about the effects of pesticides [15]. In the 1970s, The Limits to Growth questioned the Earth's ability to feed itself with rapid population growth and warned of grave environmental consequences [16]. E.F. Schumacher in 1974 published Small is Beautiful which radically questioned the way we organize ourselves, criticising economic growth without personal fulfillment and quality of life [17]. Schumacher was also the president of the UK Soil Association, where the issues of social responsibility and fulfillment found their way into organic farming sustainability philosophies. Consequently, these issues have become somewhat fused together, where the Fairtrade movement has become very closely associated with the organic movement [18]. Like organic cosmetics, ethical cosmetics are still only a niche market. However, there were more than 2,260 product launches in Europe alone during 2007, five times as many in the previous year [19].

Organic essential oils include, a) those produced by traditional means which are not usually certified, b) specially organically cultivated and usually certified, and, c) those collected from the wild, existing in a natural eco-system and also not certified. Examples of essential oils produced by traditional means would normally include patchouli, citronella, and vetiver oils in Indonesia and Vietnam. These oils although produced organically, are usually not certified as such, and carry no price premium in the market. Specially cultivated organic essential oils would include those like lavender and other herbs cultivated on hobby and agro-tourism farms, usually for small local markets, such as tourists visiting the farm. By definition, essential oils produced from materials collected from the wild are also organic, as they have grown in an untouched natural eco-system, although they may not be certified organic.

Even with all the attention that has been given to organics and fair-trade, the actual production of organic essential oils is very low in terms of volume. In terms of value, organic essential oil production is presently little more than 2-3% of total production. This excludes essential oils that have been wild harvested or produced by traditional methods. Table 10.1.

lists some organically produced essential oils and their production locations, offered to the market as organic oils today.

Table 10.1. Some Organic Essential Oils and Their Production Locations Offered to the Market Today

Oil	Scientific Name	Location	Cultivated/Wild Harvested
Allspice Berry Oil	*Pimenta officinallis*	West Indies	Wild Harvested
Angelica Root Oil	*Angelica archangelica*	France, Canada, Hungary	Cultivated
Angelica Seed Oil	*Angelica archangelica*	France	Cultivated
Anise Seed Oil	*Pimpinella anisum*	France, Spain	Cultivated
Artemisia Oil	*Artemisia absinthium*	China, Morocco	Wild Harvested
Bay Oil	*Pimenta racemosa*	West Indies	Wild Harvested
Basil Oil	*Ocimum basililcum*	Comoros Islands, Madagascar, United States	Cultivated
Bergamot Oil	*Citrus bergamia*	Italy	Cultivated
Cajuput Oil	*Melaleuca cajuputii*	Vietnam	Cultivated
Camphor Oil	*Cinnamomum camphora*	Madagascar	Cultivated
Caraway Oil	*Carum carvi*	India	Cultivated
Cardamom Seed Oil	*Elattaria cardamomum*	Guatemala, Hungary	Cultivated
Carrot Seed Oil	*Daucus carota*	France, Hungary	Wild Harvested
Catnip Oil	*Nepata cataria*	France	Cultivated
Cedarwood Oil, Atlas	*Cedrus atlantica*	United States	Cultivated
Cedarwood, Virginia	*Juniperus virginiana*	United States	Wild Harvested
Chamomile Oil	*Matricaria chamomilla*	Morocco, France, United Kingdom	Cultivated
Cinnamon Bark Oil	*Cinnamomum zeylanicum*	Sri Lanka	Cultivated
Cinnamon Leaf Oil	*Cinnamomum zeylanicum*	Sri Lanka	Cultivated
Citronella Oil	*Cymbopogon nardus*	Brazil, Vietnam	Cultivated
Clary Sage Oil	*Salvia sclarea*	France, United States	Cultivated
Clove Bud Oil	*Eugenia caryopyllata*	Comoros Islands, Indonesia, Madagascar, Tanzania	Cultivated
Coriander Seed Oil	*Coriandrum sativum*	Egypt, France, Hungary, Russia	Cultivated
Cumin Oil	*Cumimum cymimum*	India	Cultivated

Cypress Oil	*Cypressus sempervirens*	France	Wild Harvested
Dill Seed Oil	*Anethum graveolens*	Bulgaria, France, United States	Cultivated
Eucalyptus Oil	*Eucalyptus globules/radiata*	Australia, Portugal	Cultivated/Wild Harvested
Sweet Fennel Oil	*Foeniculum vulgae*	Australia, France, Italy	Cultivated
Galangal Oil	*Alpinia galangal, officinalis*	Indonesia, Thailand	Wild Harvested
Geranium Oil	*Pelargonium graveolens*	China, Egypt, Kenya, Malawi, South Africa, Zambia	Cultivated
Ginger Oil	*Zingiber officinale*	China, Indonesia	Cultivated
Grapefruit Oil	*Citrus paradisi*	Argentina	Cultivated
Juniper Berry Oil	*Juniperus communis*	France, Nepal	Cultivated
Lavener Oil	*Lavendula angustifolia*	Australia, France, South Africa, Spain	Cultivated
Lemon Oil	*Citrus Limon*	Argentina, Italy, United States	Cultivated
Lemongrass Oil	*Cymbopogon citratus*	India, Madagascar, Malawi, Nepal, Sri Lanka, Tanzania, Zambia	Cultivated
Lime Oil	*Citrus aurantium*	Mexico	Cultivated
Litsea cubeba Oil	*Litsea cubeba*	China	Wild Harvested
Lovage	*Levisticum officinalis*	France	Cultivated
Mandarin	*Citrus reticulata*	Italy	Cultivated
Manuka Oil	*Leptospermum scoparium*	New Zealand	Wild Harvested
Marjoram Oil	*Marjorana hortensis*	France, Hungary, Spain	Cultivated
Neroli Oil	*Citrus aurentium*	Comoros islands, France	Cultivated
Niaouli Oil	*Melaleuca quinquinervia*	Australia, Madagascar	Cultivated
Nutmeg Oil	*Myristica fragrans*	India	Cultivated
Oregano Oil	*Oreganum vulgare*	France, Hungary, United States	Cultivated
Palmarosa Oil	*Cymbopogon martini*	India, Madagascar, Nepal	Cultivated
Parsley Seed Oil	*Petroselinum sativum*	Australia, France, Hungary	Cultivated
Patchouli Oil	*Pogostemon cablin*	Indonesia, Madagascar	Cultivated
Pennyroyal Oil	*Mentha Pulegium*	Morocco	Cultivated
Pepper Oil	*Piper Nigrum*	India, Madagascar, Sri Lanka	Cultivated
Peppermint Oil	*Mentha piperita*	France, India, United States	Cultivated

Table 10.1. Continued

Oil	Scientific Name	Location	Cultivated/Wild Harvested
Petitgrain Oil	*Citrus aurantium*	Egypt, Paraguay	Cultivated
Rose Oil	*Rosa damascena*	Bulgaria, Iran	Cultivated
Rosemary Oil	*Rosmarinus officinalis*	France, Malawi, Morocco, South Africa, Spain, Tunisia, Zambia	Cultivated
Rosewood Oil	*Aniba roseaodora*	Brazil	Wild Harvested
Spearmint Oil	*Mentha spicata*	United States	Cultivated
Spruce Oil	*Tsuga Canadensis*	Canada	Wild Harvested
Tarragon Oil	*Artemisia dracunculus*	South America	Cultivated
Tea Tree Oil	*Melaleuca alternifolia*	Australia	Cultivated/Wild Harvested
Thyme Oil	*Thymus vulgaris*	France	Cultivated
Vanilla Extract	*Vanilla plantifolia*	Madagascar	Cultivated
Verbena Oil	*Lippia citriodora*	France, India	Cultivated
Vetivert Oil	*Vetiveria zizanoides*	Haiti, Madagascar	Cultivated
Ylang Ylang Oil	*Cananga odorata*	Comoro Islands, Madagascar	Cultivated

Only essential oils extracted through physical processes can be correctly called organic. Concretes, absolutes and oleo resins that have utilized a hydrocarbon solvent (except organically produced ethanol) cannot be called organic. Most of these materials would contain traces of solvent from the extraction process. However CO2 extraction (an inert gas), which doesn't leave any residual traces in the end product is an allowable method of extraction for organic oils, along with steam distillation.

The growth of organic essential oil production has been slower than other organic segments. This may be the case for a number of reasons;

7. The price difference between organic and conventional essential oils is much wider than other organic categories. Organic essential oil prices are usually 3 or 4 times the conventional price. This restricts the purchase of organic essential oils to only the most discerning consumers, usually for aromatherapy purposes. These high prices discourage greater demand for organic products [20].
8. On the supply side, high prices are perpetuated by the lack of reliable producers.
9. Consumers tend to see essential oils as 'natural' products, *and 'more or less organic anyway'*. Thus there is little incentive to producers to undergo the organic certification process, which is both time consuming and expensive [21].
10. There are organic cosmetic certification abnormalities, where synthetic materials can still be used as fragrances in organic cosmetics. This inhibits the growth of organic essential oil production, and
11. Current EU organic product certifications that allow non-organic 'natural' materials in a product, as long as they are under 5% of the total formula.

Should natural material requirements become more stringent in the future, demand for organic essential oils will dramatically increase.

Organic products are usually distinguished from conventionally produced products by the way in which the product is produced rather than the physical properties and attributes of the product. This does not guarantee organic products are superior in quality to products produced by conventional means. While some producers take great pride in organic production and some consumers are interested in ecologically sustainable production systems, the majority are interested in the product itself and what it can offer relative to competitors [22].

There is also great consumer confusion over the meanings and significance of terms, logos, labels, certifications, trademarks, certainty of supply, quality and price [23]. Labeling laws differ between countries. There is little, if any empirical evidence of the environmental and health advantages of organic agriculture. Chemically, there is no difference between organic and conventionally produced essential oils. However many claims are made that organic oils are superior. The only physical advantages are that an organic essential oil will not contain any pesticide residuals and people involved in the production will not be exposed to any pesticides [24].

Before exploring the concepts and principals of organic production further, it is important to briefly mention the some of the issues that bring confusion to this topic. Most people believe that organic products are produced without artificial fertilizers and pesticides and have been produced with a high degree of environmental awareness [25]. Many consumers have the image that organic farming is monolithic in concept and practices, and is a guarantee of sustainability.

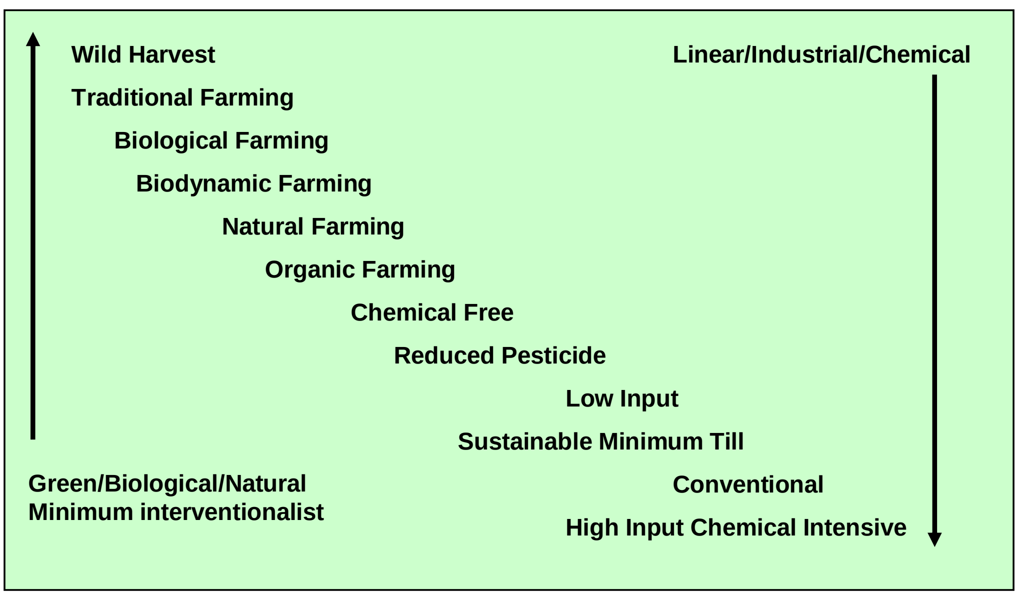

Figure 10.2. The Continuum of Farming Techniques.

Table 10.2. Definitions of the Spectrum of Farming Systems

Farming Paradigm	Brief Explanation
Wild Harvest	Hunting and gathering of foods still remains an important activity in semi-arid, humid and tropical areas, and mountainous areas around the world. Wild collection areas are usually associated with undisturbed systems of the ecological diversity and thus receive no inputs from the gatherers. For various reasons *(i.e., very large trees with long gestation period for harvesting)* many wild plants are not domesticated and thus wild harvesting is required. Over exploitation of many species has lead to endangerment of these species.
Traditional Farming	The term Traditional agriculture is usually associated with primitive agricultural systems or pre-industrial peasant agriculture [27]. Traditional farming methods developed over long periods of time through trial and error according to the requirements of site specific soil, climate, weather and social conditions. This knowledge slowly evolved and improved as new information was discovered and passed down from one generation to another. Much of this information has never been formally recorded. As indigenous communities were usually isolated, only locally available inputs could be utilized, which generally made for sustainable agriculture practices. Traditional systems usually cultivated indigenous crops which have partly been replaced by introduced crops over the last few decades. This has led to the disappearance of a number of indigenous plants like aromatic rice and herbs.
Biological Farming	Biological farming is based on balancing the general microbial activity of the soil on a farm. When microbial activity is balanced, livestock, plant nutrition will be healthy; insects, diseases and weeds will be in harmony with the farm. Excessive pests, diseases and/or weeds are seen as symptoms of a larger problem with microbial activity and balance. A number of diagnostic instruments are utilized to measure various soil parameters. A range of microbial nutrients are used to assist the soil maintain its microbial balance.
Biodynamic Farming	Biodynamic farming evolved from the doctrines and philosophies of the Austrian anthropologist Rudolf Steiner in the 1920s. Biodynamic farming aims to produce a closed nutrient cycle that is regenerative, utilizing the integration of animals, carefully chosen crop planting times and an awareness of life processes in nature in a holistic manner. Eight specific preparations are used to maintain balance on the farm. These include cow manure, silica and herbal composts to treat specific soil imbalances.
Nature Farming	Nature farming (mostly practiced as Kyusei Nature Farming) was developed out of a philosophy based on both nature and humanity by Mokichi Okada in Japan during the 1930s. Although many principals are similar to organic farming, the guiding philosophy specifies pre-treatment of organic materials with EM (effective micro-organisms) to sanitize, purify and convert for farm use. This and most other principals have both a spiritual and practical basis [28].

Organic Farming	Organic farming is a production system which excludes the use of synthetically compounded fertilizers, pesticides, growth regulators and livestock feed additives. Organic farming systems rely on crop rotations, crop residues, animal manures, legumes, green manures, off farm organic wastes, mechanical cultivation, mineral bearing rocks, and biological pest control to maintain soil fertility, to supply nutrients, and to control insects, weeds, and other pests [29]. Some modern definitions include clauses relating to social justice and the environment. These methods are tailored to site specific conditions.
Chemical Free Farming	A very similar method to organic farming, except chemical free farming does not use any chemical pesticides or insecticides on crops, in contrast to organic farming which allows a number of products to be used. Often referred to the *"third world"* version of organic farming, where farmers cannot afford chemicals [30].
Reduced Pesticide Farming	Reduced pesticide farming developed as a result in the United States following concerns about health, environment, food security and operating costs [31]. The driver of these programs was primarily the high direct operational costs of using industrial pesticides and their affect on yields [32]. Some form of Integrated Pest Management (IPM) is utilized as a way to optimize and manage pesticide usage [33].
Low Input Farming	Low input farming is based on reducing chemical fertilizers, insecticides and herbicides to a minimum usage in farm production. Biological farm practices are utilized in their place. These practices are usually developed as cost saving measures and to make minimum impact on the environment.
Sustainable Minimum Till Farming	Sustainable minimum tillage farming is a conservation farming method, utilized in semi arid and drought effected areas to reduce the effects of soil erosion and soil structural decline through maintaining organic matter in the soil to promote the growth of soil organisms [34]. Minimum tillage assists in conserving soil moisture. Sustainable minimum tillage can encompass reduced tillage, direct drilling or zero tillage.
Conventional Farming	Conventional agriculture is an industrialized agricultural system characterized by mechanization, mono-cropping, and the use of synthetic inputs like chemical fertilizers, pesticides and herbicides. Emphasis is on maximizing yields, productivity and hence financial profitability through linear thinking and operational approaches. This is a relatively recent form of agriculture enabled by the 'green revolution' after World War II.
High Input Chemical Intensive Farming	High input chemical intensive farming is an intensive farming system utilizing high levels of fertilizers, growth regulators, pesticides and herbicides to obtain the highest possible yields and productivity. These systems are usually accompanied with high rates of mechanization to save labour. These systems usually involve factory farming, aeroponics, fertigation, hydroponics systems, rice paddy, aquaculture, some urban agriculture, and vertical agriculture, etc.

There are a large number of farming concepts each with different production systems developed from various origins and philosophies in existence. These systems range from wild collection and harvesting with zero crop intervention to high input chemical intensive *(i.e., fertigation)*, which represent techniques that are highly interventional in the farming process as shown in Figure 10.2 [26] and Table 10.2.

There is little consensus as to the precise meaning of sustainability in agriculture [35]. One view by Ikerd, which summarizes much of the current thinking is that the general elements of any system of practice must be capable of maintaining usefulness and productivity to society, be environmentally resource wise, socially supportive and economically viable and competitive [36]. Organic farming practices are only part of sustainable agriculture. It is no guarantee of sustainability.

It is uncertain what practices actually bring about sustainability due to the complex nature of interrelationships between agricultural production and the environment [37]. Poor environmental practices like leaching of nitrates from the soil and diminishing nutrient levels in the soil could still occur during organic agriculture [38]. Developing an organic system of practices will take some time to create through research, trial, error and transition, with some degree of uniqueness in each farm site. Achieving sustainability is reliant on the farmers understanding and knowledge of the cause and effect relationships and linkages between various parts of the farm and the surrounding eco-system [39]. Acquiring this knowledge on a site specific basis can take a number of years of trial and error.

Another issue to consider, increasing the difficulty of developing sustainability is the declining capacity of land due to salinity, rising water tables, soil acidification, nutrient and soil structure depletion, erosion, and loss of biodiversity. Some estimates put this decline at 10% of useful land, per annum [40].

Sustainability is an overall objective rather than a mandatory fulfillment of organic farming. Sustainability is very much a site specific concept, multi-faceted and thus complex; requiring not just attention to environmental issues, but economic and social as well. Organic certification requirements reflect this and are not uniform, differing from body to body around the World. Thus organic standards are diverse.

Organic agriculture originally developed from knowledge fused together from traditional and indigenous systems, enhanced with insights from modern agro-ecological ideas [41]. These concepts and practices were further influenced by a number of different schools of thought, which have tended to blend together over time, which is reflected in their specific practices. The methods employed will also greatly differ according to climate, geography and particular site requirements. Site specific solutions may be heavily influenced by traditional farming methods used in the farmer's particular region. Organic farming practices on a specific farm will most likely employ a *uniquely site specific* approach developed through personal experience and knowledge gained by the farmer over many years of working a particular piece of land.

BASIC ORGANIC FARMING CONCEPTS AND PRACTICES

Organic agriculture can be described as a method of farming a selected piece of land within it's biological and ecological processes and cycles, with focus on maintaining a closed and renewable system of inputs, minimizing waste, maximizing recycling, and reducing reliance on external farm inputs. With the need to maintain a closed biological and ecological system, farming methods must enhance and manipulate existing natural processes. Farm management must therefore be biologically cyclic and place heavy emphasis on creating a sustainable local eco-system and soil nutrient system. Organic farming should be undertaken with an aim where practices should not deplete resources, be non-polluting to the environment and practiced within accepted social values. For these reasons, organic farm management is very different from conventional farm management (see Table 10.3.).

Organic agriculture requires a holistic management system that utilizes practices to benefit from biological cycles rather than intervene through chemical and other off-farm inputs. An organic system according to the Codex standards should;

"a) enhance biological diversity within the whole system;
b) increase soil biological activity;
c) maintain long-term soil fertility;
d) recycle wastes of plant and animal origin in order to return nutrients to the land, thus minimizing the use of non-renewable resources;
e) rely on renewable resources in locally organized agricultural systems;
f) promote the healthy use of soil, water and air as well as minimize all forms of pollution thereto that may result from agricultural practices;
g) handle agricultural products with emphasis on careful processing methods in order to maintain the organic integrity and vital qualities of the product at all stages;
h) become established on any existing farm through a period of conversion, the appropriate length of which is determined by site specific factors such as the history of the land, and the type of crops and livestock to be produced" [43].

Table 10.3. Comparison of Organic and Conventional Farming Models [42]

Organic Farming Model	Conventional Farming Model
Requires knowledge development	Energy Intensive (both direct and indirect)
Cyclical Processes	Linear Process
Farm as an Ecosystem	Farm as a Factory
Enterprise Integration	Enterprise Separation
Many Enterprises (product & Venture diversity)	Single Enterprise
Diversity of Plants and Animals	Monoculture
Higher-Value Products	Low Value Products
Multiple Use Equipment	Single Use Equipment
Active Marketing	Passive Marketing

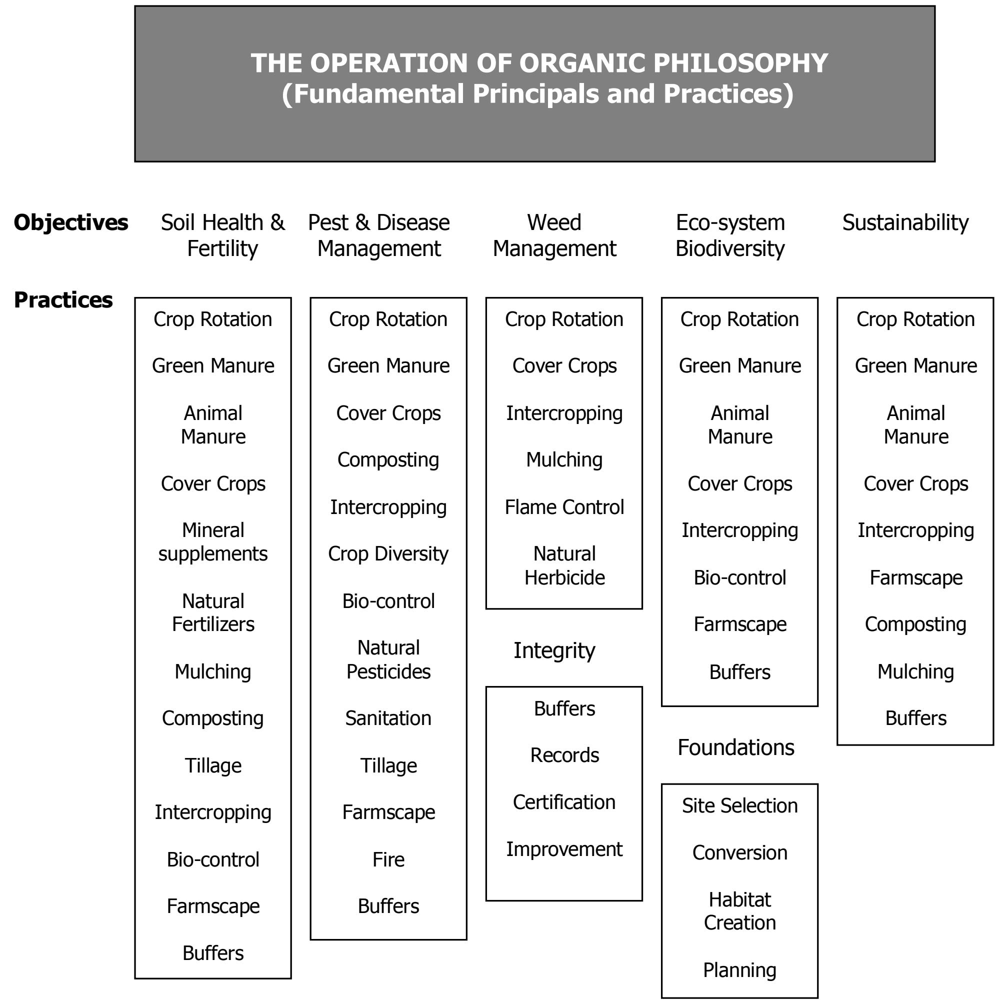

Figure 10.3. The Operation of Organic Philosophy: Fundamental Principals and Practices of Organic Farming.

Achieving sustainability within the context of organic agriculture at any site will require some time to learn and experiment with ideas and concepts. Most often these ideas and concepts will need enhancement and modification during experimentation to achieve desired outcomes. Farming concept experiments must be coordinated with cycle times, so the learning period can often take some years to acquire sufficient knowledge to develop proven sustainable practices for any specific farm site.

As mentioned, organic farming had its origins in traditional and indigenous farming systems. Since traditional farming times, many contributions by organic farming pioneers have helped to develop a set of organic principals. Sir Albert Howard, while working on an agricultural research station in India during the early 1920s emulated many concepts from the indigenous farmers to develop the *Indore Process* of composting [44]. Howard's ideas about soil management [45] were enhanced by J. J. Rodale in the United States who added crop rotation and mulching concepts [46]. Steiner's work on biodynamic farming in the 1920s and

Okada's work in the 1930s further enhanced the concepts of what was first called organic agriculture in 1940 by Northbourne, who presented the concept in an integrated manner in his book *Look of the Land* [47].

Others who made contributions include Lady Eva Balfour who compared organic and conventional farming in farming trials in the UK in the 1940s. Hans and Maria Mueller in Switzerland developed pioneering techniques during the 1950s. Hans-Peter Rusch in his book *Bodenfruchtbarkeit,* was one of the first to make strong scientific links between soil fertility and microbiology of the soil [48], where all schools of organic thought agree upon. The formation of the International Federation of Organic Movements (IFOAM) in 1972 and the development of the Codex Alimentarius organic farming principals have contributed to the development of a farming concept where practices can be assessed for compliance and validated with a certification certificate. These principals and corresponding practices are shown in Figure 10.3. which sets out the objectives and operational principals of organic farming.

Crop Rotation

Crop rotation is a method where crops are planted within the same field on a rotational basis over a certain period of time. Selected crops are usually sequenced according to their effect on the soil, the existing state of the soil, climate and precipitation to replenish soil nitrogen and other nutrients, reinvigorate soil structure, and break up pest and weed cycles in a field. Crop rotation is important within an organic farming system for soil health and fertility, pest and disease management *(both airborne and in the soil)*, weed management, eco-system diversity and sustainability. Crop rotation systems were first practiced in Roman times throughout Europe and the Middle East. It was also practiced on the African and Asian Continents. The practice all but disappeared in the West with the advent of the *'green revolution',* where artificial fertilizers and soil pH adjustment chemicals where used to allow crop specialization *(mono-cropping)* all year round.

Utilising crop rotation to improve soil fertility can be skillfully undertaken with a selection of legumes and other crops to assist nitrogen and other nutrient replenishment in the soil. This is a great advantage with crops that exhaust nitrogen in the soil and are dependent on specific levels of nitrogen for yield optimization [49] like peppermint [50]. Crop rotation is an advantageous practice in bringing up pre-planting levels of nitrates. Similarly, patchouli rapidly exhausts nitrates from the soil and crop rotation is often practiced [51].

Crop rotation is effective for perennial herb crops such as chamomile, calendula and coriander, but not possible for annual and permanent aromatic tree crops like lemon myrtle and tea tree. For annual and permanent crops, cover crops and green manures can be utilized.

Cover Crops and Green Manures

Cover crops are annual, biannual or perennial plants grown in a pasture either as a mono or complementary crop to assist in the production of the primary crop. Cover crops include green manures which are crops usually ploughed into the field during flowering, living mulches to assist in weed suppression, catch crops to prevent soil erosion after harvesting of the primary crop or a forage crop for incorporation into the soil [52]. Cover crops can be legumes, cereals or grasses depending upon their intended field application. Cover crops are utilized in organic agriculture for the following purposes;

- To prevent soil erosion

  One of the most important functions of a cover crop is to prevent soil erosion and preserve field top soils. Correctly chosen cover crops can greatly lesson the impact of rainfall on the soil and slow down the rate of natural water channeling, which carries top soil away with it. This allows more time for the soil to soak in the rain and reduces the amount of water that drains off the field.
- As a source of soil nitrogen

  Organic farmers utilize green manures from legume crops *(Fabaceae or pea family)* which contain nitrogen fixing symbiotic bacteria inside nodules of the root systems that can convert atmospheric nitrogen into nitrates that can remain fixed in the soil. Killed off leguminous cover crop can contribute between 10 to 50Kg of nitrogen per Hectare depending on the particular crop and cultivation conditions [53]. This is usually done as a forage crop after a harvest to replenish the soil nitrates as part of a crop rotation plan. In temperate climates lentils, alfalfa, acacias, cowpeas, soybeans and various types of clover are examples of commonly utilized as cover crops for this purpose. *Mucuna pruriens* [54], *Canavalia ensifrmis* [55] and *Crotalaria ochroleuca* [56] are all used in semi arid regions and *Calapogonium mucunoides, Centrosema pubescens, Indigofera tintoria, Mucuna cochinchinensis, Vigna radiate* and *Pueraria javanica* are widely used in tropical countries like Malaysia [57].
- To improve soil fertility with organic matter

  Cover crops and green manures increase the percentage of organic matter in the soil. This has a number of benefits in assisting in the release of necessary nutrients and elements beneficial for plant growth. Besides nitrogen, green manures also release phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S) and other nutrients into the soil upon decomposition. The breakdown of green manure in the soil promotes the growth of micro-organisms which assist in releasing the above elements into the soil. Additionally, the breakdown of green manure also produces organic (carbonic) acids which help to breakdown insoluble minerals and phosphates from rocks and rock based soils [58]. Through extra organic matter, soil structure improves its capacity to hold moisture and nutrients. The root systems of some cover crops can loosen and aerate compacted soil with similar effects to deep tillage [59].
- Weed Control

  Cover crops have become a very popular method of weed control, especially in tropical climates over recent years. Cover crops and green manures can suppress weed growth through a number of methods. Most non-legume green manure crops are primarily utilized for weed control purposes. They suppress the ability of weeds to establish themselves through providing competition. When the cover crop is mowed or cut and left on the ground it forms fairly impenetrable mat structured mulch that protects the covered area through hindering the ability of weeds to germinate by cutting out light [60] and smother any existing weeds [61]. When these matted mulches are tilled into the soil, they add organic matter to the soil. Some cover crops also prevent weed growth through allelopathy methods by releasing compounds that suppress weed seed germination [62]. Potential cover crops that have allelopathy properties include *Secale* cereale or rye, *Vicia* villosa or hairy vetch, *Trifolium pretense* or red clover, *Sorghum bicolor*, and mustards of the *Brassicaceae* family [63]. Finally, deep rooting cover crops that break up and loosen the soil tend to hinder the establishment of weeds that tend to thrive on compacted soils.

- Pest Control

  Cover crops are increasingly utilized as part of integrated pest management programs. They can form part of a *'trap crop'* strategy to produce an environment that will appear more favourable to predatory insects [64]. When this strategy is successful, most predatory insects will inhabit the cover crop where they can be vacuumed up by a high power specially designed vacuum system from the cover crop [65]. Alternatively the cover crop selected may provide a favourable habitat for other beneficial insects, which are predators of the pests that the primary crop need to be protected from [66].

- Disease Management

  Research has shown that cover crops can be utilized for reducing fungal diseases in crops [67] and parasitic nematodes [68] through the allelopathic release of glucosinolade artifacts from plant cell tissues [69].

- As a method to reduce *greenhouse gases*

  Carbon sequestration in soil can be enhanced through no-till farming, residue mulching, cover cropping and crop rotation [70], which has been promoted by some scientists as a strategy to help offset the rise in atmospheric CO_2 levels [71].

Table 10.4. A List of Some Potential Cover Crops

Botanical Name	**Comments**
Alysicarpus vaginalis	Good for clay type soils, regenerates through seeds to maintain cover
Calopogonium mucunoides	Introduced into S.E. Asia. Shade suppresses growth, but cattle don't eat it.
Canavalia ensiformis and *gladiata*	Introduced into S.E. Asia, good source of nitrogen, short term (seasonal) cover.
Cassia pumila	Good for erosion prevention.
Dolichos hosei	Indigenous in Borneo, creeping plant for weed suppression. Grows well under shade.
Glycine max	As a high nitrogen cover crop, which can be ploughed in.
Indigofera sumatrana	Has good nitrogen value.
Mimosa invisa	A wide sprawling cover crop with a life of around 1.5 years. Good weed suppressant.
Mucuna deeringiana	Good as a supporting cover crop.
Passiflora laurifolia	Produces hydrocyanic acid.
Phaseolus lunatus	Short duration cover crop with good nitrogen value. Good weed suppressant.
Tephrosa vogelii	Hardy regenerating plant, with some insecticide properties.

There are a number of limitations of cover crops and green manures. Although the retention ability of soils under cover crops is great, cover crops during growth also absorb water which can become an issue of concern in drought situations and semi arid areas like Australia, particularly in Spring when growth conditions are good. In these situations there will most likely bring the need for a tradeoff between reduced soil moisture due to the cover crop and available moisture for the newly planted or flush growth from dormant winter crops. The economics of investing in a cover crop verses the benefits needs to be assessed and some trial and error may be required in finding which cover crops may be the most suitable for the aromatic crops grown. Nevertheless, if integrated into the farming system successfully, cover crops and green manures are one more potential labour saving field management tool.

Finally, the factors to consider when selecting a green manure/cover crop include;

d) The sowing times that best meet the specific purpose of the green manure/cover crop,
e) The root system of the cover crop and its effect on the soil, *i.e., deep roots will loosen the soil, while a fibrous system will add organic matter to the soil*,
f) The average biomass generated by the cover crop and amount of N it will contribute to the soil,
g) The types of weeds, pests and diseases the green manure/cover crop will suppress,
h) Any allelopathy produced by the green manure/cover crop,
i) What types of pests and diseases the green manure/cover crop will host,
j) What beneficial insects will the green manure/cover crop host, and
k) What potential synergies can be achieved between the green manure/cover crop and the primary crop [72].

A list of potential cover crops is shown in Table 10.4

ANIMAL MANURES

Most animal manure is made up of the excrement of plant eating animals like cattle, goats, sheep, and poultry. Animal manures contain nitrogen and a large number of elements necessary for plant health. These include phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S). Animal manure also contains organic matter, which can improve soil structure, water holding capacity, improve aeration, promote beneficial organisms and tilth of the soil. The nutrient value of animal manure varies according to the type of animal, the type of feed the animal consumes, the geographical location and climate. The potential single animal production quantity per year and range of manure nutrient values from various animals are indicated in Table 10.5. [73].

Basically, most meat eating animals are not suitable as a source of manure. Although a large number of other animals provide sources of manure, hog manure is not advisable due to its strong odour. Dog and cat manure should be avoided because of the potential for parasites [74]. A recent study has shown that livestock antibiotics and hormones can be taken up into organic crops through the soil system. If non-organic manure is used, the integrity of farm inputs will be compromised [75].

Table 10.5. Potential Single animal Manure production per year and Nutrient Value Range

Poultry (Chicken)	**Goat**	**Sheep**	**Cattle**	**Manure Source**
9.0-13.5	5.0-7.9	5.0-7.5	7.0-15.0	Single Animal Tonnes/Year
1.2-3.8%	1.2-3.2%	1.4-2.7%	0.6-3.0%	N
1.0-3.0%	0.4-1.2%	0.5-2.0%	0.2-1.2%	P
1.0-3.2%	0.2-3.0%	0.5-3.4%	0.6-3.4%	K
4.8-17.0%	1.0-3.0%	1.0-3.8%	5.0-15.0%	Ca
0.4-1.4%	0.1-0.8%	0.4-1.0%	0.5-1.5%	Mg
0.035-0.09%	0.018-0.08%	0.04-0.06%	0.014-0.13%	Mn
0.13-0.48%	0.166-0.4%	0.8-1.0%	0.07-0.5%	Fe
0.004-0.25%	0.001-0.014%	0.001-0.003%	0.001-0.015%	Cu
0.002-0.067%	0.01-0.045%	0.009-0.07%	0.006-0.07%	Zn
0.002-0.005%	0.001-0.006%	0.005-0.02%	0-0.006%	B

Animal manures can be utilized directly as a fertilizer for a crop. It can also be incorporated into a compost or natural fertilizer mixture, manufactured at farm level for field application. Animal manures can also be used for improving soil nutrient and element content at a pre-planting stage. It is advisable to specifically analyse the source of animal manure for its nutrient values as well as existing soil fertility levels so correct field application calculations according to crop nutrient requirements can be made.

INTERCROPPING

Intercropping is a way of planting crops to emulate the diversity of nature through the creation of a multi-crop regime within the same area in the field at the same time, with a crop selection that will create some sort of mutual benefit to assist in improving productivity. Intercropping can be considered part of farmscapping crop layouts which should be designed to take advantage of natural interaction between two or more crops. This is in contrast to the mono-cropping alternative which is primarily designed to facilitate the use of farm machinery and chemical applications on the field over a production cycle in an extensive manner.

The primary benefits of intercropping are;

a) to create greater yields and productivity on a given piece of land through total utilization of space, which may not occur through mono-cropping, i.e., growing tall and short crops in a canopy arrangement or deep and shallow rooted crop mixes,
b) to utilize other crops to protect the field through windbreak arrays, double or multi tier shade arrays and for pest management,

c) to assist in enterprise diversification, which leads to both risk aversion and the evening out of income inflows over the year, and
d) to encourage maximum biodiversity of the farm habitat, which will assist in limiting and reducing pest and disease outbreaks [76].

Intercropping can be considered a major strategy for pest and disease control, eco-system management and sustainability.

The primary principal behind intercropping is that a diverse system containing a number of plants, animals, birds, insects and microorganisms will have a much lower propensity to have pest and disease outbreaks than a less diverse environment like mono-cropping [77]. Pest and disease outbreaks occur much more frequently in less dense habitats [78]. Mono-crop situations are much more attractive to insect herbivores because under this type of crop regime food resources more concentrated food than would exist in a mixed environment [79].

A well thought out and designed intercropping environment can greatly enhance field resistance to pest and disease infestation, through a variety of methods. The intercrop environment if well designed will disrupt the ability of insects to search and find useful plants to infest through its diversity. Through the selection of certain plants, insect olfactory and sight senses can be confused to assist in camouflaging potential host plants [80]. Crop diversity also attracts natural enemies due to the availability of foods like nectar and pollen, and favourable shelter and micro-climates [81].

In addition to developing an intercrop situation into a camouflaged environment, plants can be selected to perform the role of a trap, repellent or companion crop.

Companion crops are plants that discourage insects from feeding on the primary crop. Companion crops also assist in providing nutrients to the primary crop in a similar manner to cover crops discussed above. Any plant that acts in a beneficiary manner with another such as assisting to repel or trap insects, providing protection from wind as a windbreak, etc., can be considered a companion crop. Table 10.6. shows a number of aromatic plants that can be utilized as companion crops.

Repellent plants employ a strategy to avoid, deter and/or repel insect pests. Very often, plants utilize more than one method to repel insect pests. Plants through the metabolic system produce a number of chemicals in their roots, leaves, stems, flowers, barks and fruits, which through odour, toxicity, blocking biological functions or mimicking, can disturb the lifecycle habits of insect pests. Aromatic herbs can deter insects in one of three ways; by masking, repelling or killing [83]. Examples of masking plants would include thyme (Thymus spp.) and Sage (Salvia officinalis), repelling citronella (Cymbopogon nardus), clove (Eugenia aromaticum), and peppermint (Mentha piperita), and killing, pyrethrum (Tanacetum cinerariifolium). Some plants block insect biological processes. One such case is substance produced by Ageratum houstonianum or blue billygoat weed that blocks insect juvenile hormones which kills off insect larvae by forcing them to molt prematurely [84]. Finally, some plants can produce mimic natural hormones to confuse insects. The wild potato (Solanum berthaulthii) produces a mimicking hormone that is similar to the alarm pheromone of aphids, which confuses and causes them to disperse [85].

Table 10.6. Some Aromatic Plants that can be Utilised as a Companion Crop.

Plant	**Botanical Name**	**Potential Use as a Companion Crop**
Basil	*Ocimum basilicum*	Helps to repel flies and mosquitoes
Catnip	*Nepeta curviflora*	Repels fleas, ants and rodents
Caraway	*Carum carvi*	Helps break down heavy soils
Chamomile	*Matricaria recutita*	Deters flies and mosquitoes. Assists in strengthening nearby plants.
Dill	*Anethum graveolens*	Attracts predator wasps
Fennel	*Foeniculum vulgare*	Repels Flies, fleas and ants
Garlic	*Allium sativum*	Said to enhance the production of essential oils and deter pests [82].
Geranium	*Pelargonium spp.*	Deters insects and encourages bees
Peppermint	*Mentha piperita*	Repels cabbage white moth keeping brassicas free from infestation
Oregano	*Origanum vulgarie*	Provides ground cover and humidity for plants.
Parsley		Beters some beetles, improves some plant growth
Rosemary	*Rosmannus officinalis*	Deters some mothsw and beetles
Rue	*Ruta graveolens*	Keeps cats and dogs off garden beds if planted around borders
Sage	*Salvia officinalis*	Repels moths
Spearming	*Mentha spicata*	Helps control ants and aphids
Tansy	*Tanacetum vulgare*	Repels moths, flies and ants. Toxic to animals.
Thyme	*Thymus pulegioides*	General insect repellent, improves growth of some plants.
Wormwood	*Artemisia spp.*	Can inhibit the growth of other plants near it. Also repels insects and keeps away animals.

Figure 10.4. Basil intercropped with Chili.

Trap crops are plants that protect the primary crop from pests by attracting and retaining them. The trap crop releases an odour that attracts herbivorous pests to establish their habitat. Pests establishing themselves on the trap crop will emit aggregation pheromone to attract more to colonise the trap crop. Trap crops are either planted around the perimeter or in rows through the primary crop.

Intercropping is also used to assist in managing plant disease in reducing the potential for fungal, bacterial or viral infections. Row separation is effective in creating barriers to prevent spores from diseased plants traveling to populations of healthy plants and potentially infecting them. Mixed cropping also reduces the potential population that is adverse to any infection from any fungus, bacteria or virus.

The extent of crop integration and overlap of two crops in intercropping techniques varies. Some of the basic types of intercropping include;

- Mixed intercropping is where more than one crop is planted in the same land at the same time,
- Row cropping is where crops are arranged in selected rows. Sometimes this is undertaken in alternating strips of two or more crops,
- Relay cropping is where a fast growing crop is planted along side a slower growing crop, where the fast growing crop will be harvested before the slow growing crop is mature. Usually this method allows more growing area for the slower moving crop once the faster growing crop has been removed providing some beneficial effects of residual moisture from the area the fast growing crop occupied.
- Canopy cropping is practiced in many tropical areas where there are two or three canopy tiers within a cropping system. The top canopy will be trees that protect the other crops from the sun, wind and weather [86]. This allows more delicate plants to be planted below. An example of a multi tier tropical canopy system would be where coconut and cashew nut trees provide a protective upper tier, banana trees the middle tier creating a cooler micro-climate below where a number of crops like ginger, medicinal and aromatic crops can occupy.

Intercropping concepts and practices have developed through centuries of practice through tropical traditional farming. These concepts were taken up by contemporary researchers over the last couple of decades in efforts to develop intercropping as an integrated pest management and overall field management strategy. Determining the relationship between two crops within any intercropping system is extremely complex due to the large number of environmental and eco-system variables [87]. Some of the primary variables requiring consideration in planning an intercropping model include;

- *Allelopathy compatibility:* Do any of the intended intercrops emit any allelopathic compounds that would in any way inhibit the other crop?
- *Shading:* Will there be any advantage to the crop from shading?
- *Root Systems:* Will the root systems compete or complement each other?
- *Nutrients:* Will any of the intended crops assist in supplying nutrients to the other crop(s)?

- *Role in pest and disease control:* What role will the intended crop play in pest and disease management?
- *Competition:* Will the two intended crops compete or complement each other?

Understanding the above relationships will assist in determining spatial arrangements *(i.e., row, strip, mixed, relay or canopy intercropping)*, planting densities and planting times. A few examples of successful intercropping research with aromatic plants are shown in Table 10.7.

Table 10.7. Some Successful Intercropping Research with Aromatic Plants

Aromatic Plant	Nature of Intercropping
Palmarosa *(Cymbopogon martini Stapf.)*	Palmarosa and basil intercropped resulted in 17% increase in land use efficiency. Also palmarosa and soyabean + maize showed yield increases [88].
Citronella *(Cymbopogon wintereanus),* Lemongrass *(cymbopogon flexuosus),* Palmarosa *(Cymbopogon martini Stapf.),* Patchouli *(Pogostemon patchouli)*	All crops grown under teak *(Tectona grandis)* showed increase in herbage [89].
Patchouli *(Pogostemon patchouli)*	Successfully cultivated under sesbania plantations in India [90].
Peppermint *(Mentha piperita L.),* Basil *(Ocimum basilicum L.),* Oregano *(Origanum vulgarie L.)* and Sage *(Salvia officinalis)*	Successfully cultivated with coffee in Mexico. Caffeine, rather than inhibit growth, stimulated growth of the aromatic herbs [91].
Ginger *(Zingiber officinale Roscoe)*	Reported to be grown as an intercrop with coffee. Also grown mixed with banana or other shade giving plants, eg., pigeon-pea, cluster bean (guar) under coconut [92].

COMPOSTING

Composting is widely used in organic farming as a primary method to condition and improve soil fertility. Through the breakdown of a wide variety of materials, compost helps increase the diversity of soil nutrients and organic matter. It is particularly useful for clay and compact soils to improve texture so that air can flow between the spaces. Composting also helps with improving the moisture and nutrient holding abilities of sandy soils. Increased soil biodiversity usually correlates with improved soil regeneration and disease suppression [93]. Composting is a valuable tool to use in conjunction with green manures and cover crops, forming part of integrated soil management programs. Composting makes a valuable contribution to farm sustainability and should be made from materials available on the farm site, or if necessary within the nearby surrounding area.

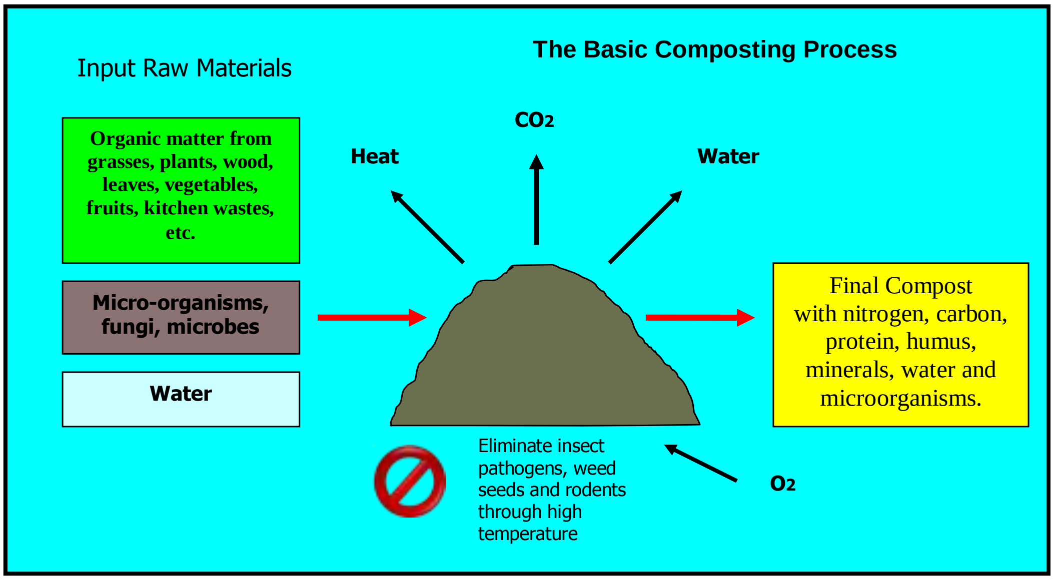

Figure 10.5. The Basic Composting Process.

Composting involves breaking down biodegradable organic matter through a heat generating oxidative process where the materials within the biomass pass through a hemophilic phase leading to the temporary release of phytotoxins before producing carbon dioxide, water minerals and stabilised organic matter, called compost [94]. Composting is a necessary process in the preparation of organic matter before being applied to the field. This is necessary, principally for sanitary purposes although composting also assists in breaking down the material into particle size so that can easily mix with the soil soon after field application. Heat generated from the process should be enough to kill off pathogens, dormant weed seeds and deter any vermin. The process of composting is shown in Figure 10.5.

Through the introduction of microorganisms, fungi or bacteria and the generation of heat through energy-nutrient exchanges, composting speeds up the decomposition process to return organic materials back to the beginning of the food chain; the soil. The composting process goes through three distinct stages. During the first stage *(mesophilic stage)*, simple structured materials degrade as the temperature of the compost heap rises to 30-50°C. During the second stage *(thermophilic stage)*, where the temperature of the compost heap rises to 45-65°C, cellulose structures begin to decompose and pathogens, weed seeds and microorganisms are killed. During the final stage *(Curing stage)*, the compost heap begins to cure as the temperature decreases, humus begins to form and some beneficial organisms establish themselves within the compost [95]. Composting time is influenced by the density of materials used and the speed that they can be broken down organically. Therefore heavy woods can take some time, even up to years to decompose. Grasses and cellulose materials can usually compost within 7-12 weeks.

The quantity of nutrients within the final compost material depends upon the quality of the organic raw material inputs. High nutrient organic inputs will produce high nutrient values in the compost and visa versa. The use of legumes in the compost will increase final compost nitrogen levels. Incorrect compost processing can lead to a heap that either fails to decompose of becomes foul smelling and full of pathogens. Failure to decompose usually signals an absence of aeration and moisture, while foul smelling heaps result from too much moisture and not enough oxygen. Pathogens and rodents are usually attracted through using materials like meat, cooking oil, bones, or cooked waste foods.

Some of the major factors that influence the effectiveness of the composting process are summarized as follows [96];

- *Microorganisms:* are responsible for the commencement of the degradation process. These can consist of various bacteria, fungi, actinomycetes, sometimes enhanced by enzymes.
- *C:N (Carbon/nitrogen) ratio:* Microorganisms need approximately 25 times more carbon than nitrogen for growth and reproduction. A compost heap should have the correct balance of carbon and nitrogen so that microorganisms will ingest carbon for energy and nitrogen for protein. The ratio of carbon to nitrogen is called the C:N ratio. Optimum C:N ratios for microbial activity range between 19-30:1 [97]. To make effective compost heaps, materials with high C:N ratios like straws must be mixed with materials with lower C:N ratios like manures. When composts have low C:N ratios, the carbon materials will be fully utilized by the microorganisms leaving free nitrogen which will be lost to the atmosphere [98]. Higher C:N ratios will take longer to decompose and require extra nitrogen from the surroundings. Too high a C:N ratio may prevent the compost heap from heating up and decomposing. In general the nitrogen content of the compost decreases as the composting process advances. Finished composts with high C:N ratios if added to the soil could immobilize nitrogen in the soil, suppressing plant nutrient uptake.
- *Particle Size:* Organic materials should be ground into small particle size so that microorganisms can react with them. Large particle size will take much longer to decompose.
- *Aeration:* As the composting process is aerobic the compost heap must have access to aeration, so oxygen can enter in order for the microbes to decompose the organic materials. Most often compost heaps must be regularly turned over so that aeration can be maximized. Poor aeration can lead to anaerobic microbes starting anaerobic digestion which may create foul rancid rotten egg type odours and promote the growth of pathogenic microbes that will decrease the quality of the heap.
- *Temperature:* The compost heap must reach the correct temperature ranges during the three phases of decomposition to create high quality finished material. It is important that the compost heap reach a plateau temperature for a specified period (usually a few days to a couple of weeks) to stabilize the compost and certification requirements [99]. This process is important for sanitation and the killing of pathogens and weed seeds within the compost.
- *Moisture:* Moisture is necessary to allow metabolic microbial processes within the compost. Without this the organic material will fail to decompose. A compost heap should contain between 55-65% moisture to ensure effective microbial activity. Excessively high moisture can restrict aeration and prevent aerobic processes. Due to natural evaporation, the moisture content of the compost heap must be continually checked and more moisture added if necessary.

- *Size:* The compost heap must be of optimal size to maintain enough moisture and keep in heat during decomposition.

Compost quality and organic integrity is directly related to the input raw materials. When collecting materials from waste sources outside the farm, it is very important to collect manures from animals that have not been treated with anti-biotics and hormones, and woods and sawdust that have not been chemically treated. Nitrogen, phosphorus and potassium contents will vary according to different materials used. The pH of composts during the composting period will be acidic, but after curing it should become slightly alkaline. The general properties of a good compost should be;

pH 6.0-8.0
<0.05 ppm ammonia
0.2 to 3.0 ppm ammonium
<1.0 ppm nitrites
>1.0% CO_2
Moisture content 30-35%
> 25.0% organic matter [100]
N 0.9-3.5%
P 0.5-3.5%
K 1.0-3.8% [101]

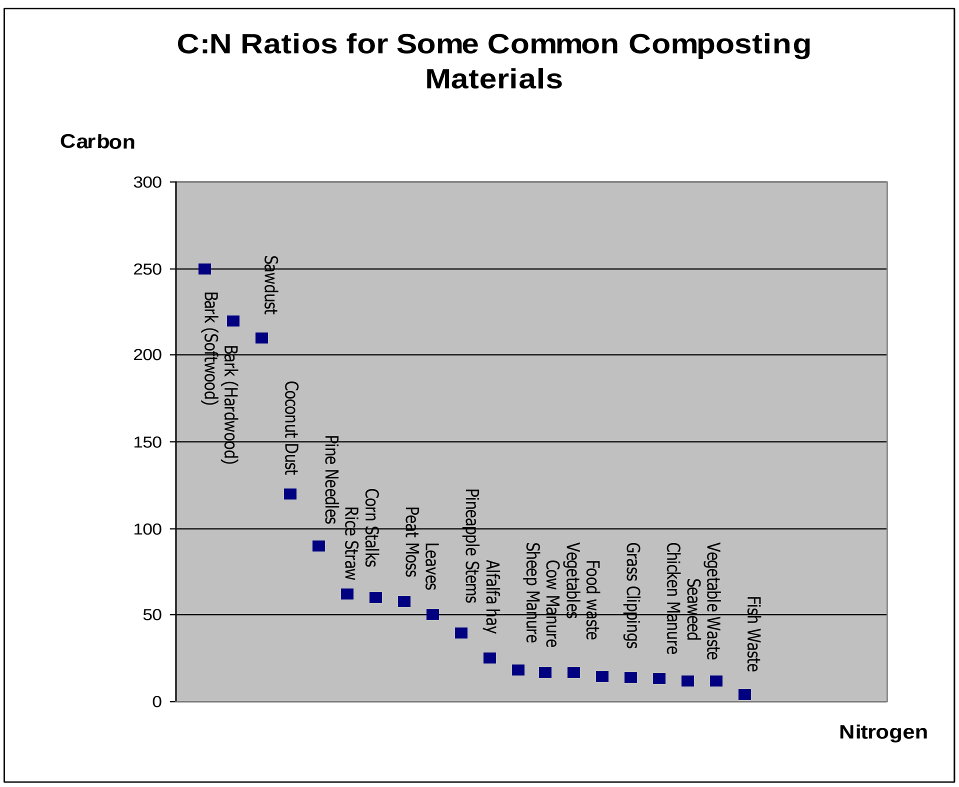

Figure 10.6. C:N Ratios for Some Common Composting Materials.

Some variations on the practice of producing compost are also in wide use. *Bokashi* is a method of introducing a starter culture *(called 'EM' effective microorganisms)* to organic matter to induce a fermentation process. Microbes usually introduced into organic matter convert oxygen into carbon dioxide, which is used by anaerobes to commence anaerobic fermentation of the organic matter [102]. This occurs at much lower temperatures than conventional composting. Molasses is usually added as an energy source with rice bran, oil cake fish meal, water and other organic materials. Fermentation through this process takes around 2 to 3 months and the *bokashi* is mixed with 2-3 parts of peat soil before application as a fertilizer or use as a potting mix. Usually an 'EM' culture is obtained and used to inoculate the organic materials. However 'EM' cultures can be developed through selecting microorganisms from the forest *(indigenous micro-organisms)* and/or yeasts and cultivating them under controlled conditions [103]. A similar method utilizing cooked rice, molasses and water with inoculation by airborne microbes called IMO to ferment organic materials in composts is widely used in East Asia [104]. Finally vermicompost, is a method that utilizes worms certain species of worms, (usually *Eisenia foetida* and *Lumbricus rubellus)* to create the compost in rotting organic matters such as manure, green leaves, sawdust, rice straw, banana stems, etc. This method is popular in India and also utilized in Thailand, Philippines and Malaysia. Several commercial producers exist in the US and Australia.

MULCHING

Mulch is a protective cover, usually consisting of organic materials, which is placed over the soil to assist in crop cultivation in some way or another. Mulching involves the wide spreading of the mulch material over the field, especially around crop plants. Some of the benefits of mulching are;

- Assisting in maintaining even temperatures by slowing down earth cooling at night and holding in heat through the protective mulch layer,
- Decrease temperature fluctuation which leads to less plant stress [105],
- To improve soil moisture retention by slowing up evaporation,
- To help control weed growth through blocking sunlight,
- To help in erosion control through preventing direct rainfall reaching the soil surface,
- To increase organic soil matter which will help soil moisture absorbency, and decrease soil density and compactness,
- To increase soil biodiversity through adding beneficial fungi to the soil upon decomposition, and
- To increase soil nutrients through mulch decomposition into the soil.

Mulch is usually applied to the soil at the beginning of a growing season to warm and protect the soil, maintain moisture and later assist in controlling weeds and eventually contribute to increasing soil fertility upon decomposition. This greatly assists in the economic use of irrigation, minimal herbicide application and long term soil fertility.

Mulch can be produced from a number of on or off farm organic sources such as manures, grass clippings, leaves, hay, straw, shredded bark, sawdust, sea shells, shredded newspaper, disused fabrics or compost. Other materials that are often used include chopped up or shredded car tires and plastic sheets laid over raised field beds. Waste materials that can develop foul odours should be avoided due to their potential to attract insect pests and rodents.

Mulching is important in overall strategies to develop soil fertility. Mulch decomposition is part of the process of plant recycling through organic material breakdown. Mulch decomposition increases the level of nitrogen and other nutrient levels in the soil. The long term use of mulch through increasing the organic content of tops soils should dramatically increase moisture absorbency capacity. This can greatly benefit sandy soil types. The increasing organic matter in the soil also increases the ability of air circulation within the soil, root penetration and growth. This can be of benefit to clay type soils. Mulch application generally increases enzyme and microbial activity in the soil [106], and reduces the incidence of surface diseases [107]. Mulch promotes an increase of worm activity with the right moisture conditions in the soil [108].

Mulching is also a major strategy component in integrated weed management. The level of protection a mulch can provide a crop will depend upon the thickness of the mulch, the coarseness of the mulch and how well external sources of weed seeds are managed. A well prepared mulch can provide 10-18 months protection from weeds from when it is applied [109].

Mulches should be optimized to be;

- Weed (and seed) free
- Pathogen free
- Biologically stable
- Of coarse particle size
- Non-toxic to the environment
- Reasonably dense
- Provide fair to good longevity
- Have good moisture absorbency
- Be easy to apply to the field
- Able to support beneficial organisms
- Be free of unpleasant and foul odours,
- Have readily available raw materials for production and
- Be of reasonable cost to produce [110].

As a result, some composting of mulches are required to meet the desired mulch characteristics above, *i.e., killing of weed seeds and pathogens through heat, fermenting the material to reduce potential toxic root compounds and providing a material capable of hosting beneficial microorganisms.*

Mulch longevity can be controlled through the type of organic materials used in its production. High carbon content materials like hay and straw will increase longevity, while high nitrogen containing material like manures will shorten mulch longevity. The ideal C:N ratio for a mulch would be between 25-30:1.

Figure 10.7. Mulched Lemongrass Cultivation using Sugarcane Waste.

The extent of mulching that takes place on a farm will depend upon the availability of organic raw materials, the cost to prepare and apply the mulch and the benefits mulching provides the farm in the particular site specific situation. Mulching is widely used in intensive operations where high value seasonal and annual crops are produced. It is also used where high value tree crops are cultivated.

The spent biomass from tea tree oil distillation has become a popular commercial mulch. Due to the high carbon content of tea tree stems and leaves, tea tree mulch is relatively long lasting. After chopping the foliage at harvest tea tree mulch forms a woven and highly absorbent mat that retains soil moisture, inhibits weed growth and lasts around 12 months on the field [111]. Distillation acts as a sterilization process on the material [112] which makes it completely free of weed seeds and pathogens. A number of brands now exist on the Australian market with raw material supplied from tea tree plantation producers [113].

CROP DIVERSITY

Crop diversity has greatly diminished over the last 50 years leading to a narrower range of plants that farmers plant as crops today. Diminished crop diversity has brought with it increasing problems of airborne pathogens, increased herbivores insect pests and increased numbers of viruses into agriculture [114]. Increasing crop diversity through mixed cropping within a farm eco-system is a method to dilute the concentration of airborne pathogens, herbivores insect pests and viruses [115]. Crop diversity is a useful tool in pest and disease management.

NATURAL FERTILIZERS, MINERALS AND SUPPLEMENTS

Ideally, if organic farming was fully sustainable, supplemental fertilizers from external sources would not be necessary. Farms, however due to soil, land and resources can only be sustainable to a certain degree where some outside inputs may be required. Purchasing external outputs is also a way of bringing in nutrients that may not necessarily be available (or be too costly to gather) within the farm eco-system. Natural fertilizer, mineral and supplement categories include;

a) Basic, semi and processed meals like fish meal, alfalfa meal, kelp meal, blood meal, crustacean meal, fortified compost blends, poultry manures, yard-waste composts, spent mushroom wastes, etc
b) Proprietary meal and organic fertilizer blends in various forms (compost teas, liquid compost extracts, effective microorganism blends, bacterial blends, fungal inoculants, seaweed extracts), including fish and other emulsions, biological fertilizers, blended organic composts and fertilizers,
c) Basic sustainable mined minerals, rock phosphates, gypsum, rock dusts, etc.
d) Bioactivators, humates, humic acids, enzymes, microbial teas, and catalyst waters, and
e) Proprietary minerals.

Basic and semi processed meals like bone, blood, kelp, fish and seaweed were the principal fertilizers used by many farmers before the advent of the 'green revolution'. Manures can be used as soil conditioners, especially with clay soils. Composts, which have been discussed above are very versatile. Some basic and semi process fertilizers are listed in Table 10.8.

Table 10.8. Some Basic and Semi Processed Fertilizers

Material	Application
Bone Meal	An animal based source of nitrogen, calcium and phosphorous that assists in building strong root systems.
Blood Meal	An animal based slow release nitrogen source for top growth. Blood meal does not contain salts like inorganic fertilizers, so can be used anytime on a crop.
Fish Meal	An animal based fertilizer which contains important trace elements.
Crustacean Meal	Contains nitrogen, of which some is slow released. Also contains P and K and chitin as a natural nematicide.
Seaweed/Kelp Extract	A marine based extract which contains important trace elements and other plant nutrients.
Animal Manures	Chicken manure is nitrogen rich, cow manure for potassium.
Mushroom Meal	Completely neutral pH with many plant nutrients.

Many basic meals are further processed into other forms such as pellets to enhance material handling and increase its residual effect during field use. These products may be generic or include some form of proprietary materials and come in different grades. *Complete fertilizers* containing nitrogen, phosphorus and potassium, as well as other nutrients in many cases, can be prepared on the farm, or purchased from a manufacturer. Compete fertilizers are general purpose and often contain seaweed concentrates, blood and bone, fish and chicken manures. However not all are organically certifiable.

A number of farm made and commercial products are used as compost teas, liquid composts, ‘EM’, bacterial and fungal blends. A number of compost by-products are useful for nutrient sources and crop fertilization. These include compost leachates, which are a dark coloured liquid that leaches out of a compost heap and compost extracts, which are prepared watery solutions of compost leachates. Compost teas are aerobically brewed mixtures of compost extract with molasses and other nutrient materials like seaweeds through oxygen aeration through the liquid for a period of 24 to 48 hours to promote the growth of beneficial microorganisms [116]. Compost teas, although not very stable in sunlight interact extremely well with organic matter in the soil as well as providing nutrients to the plant. Compost teas are reported to play some role in preventing disease through reducing non-beneficial fungi [117].

Over the last 15 years EM-*bokashi* type composting has been gaining popularity in countries like the Philippines and Thailand. The economic downturn in 1996 encouraged conversion from conventional fertilizer to EM because of the savings to ‘cash-strapped’ farmers. Environmental concerns over the last couple of years have sustained interest in EM. In Thailand, some farmers have formed cooperatives to produce EM based fertilizers and a large number of rural based SMEs have gone into the fertilizer production business throughout South-East Asia.

Figure 10.8. Preparing vegetable material for fermentation in Sabah.

Effective microorganisms consist of *Lactobacillus plantarum, Rhodopseudomonas palustris, Sacchararomyces cerevisiae* and other bacteria which exist naturally in the environment. This mixture of bacteria is usually purchased or given out to farmers (by Thai Dept. Agriculture) to inoculate compost to produce both liquid and soil based composts and fertilizers. A general recipe for an EM base liquid fertilizer used in Thai agriculture is as follows;

6 Kilograms	Banana, pineapple, papaya, other fruit and vegetable wastes according to what is available.
2 Kilograms	Molasses or raw sugar
20 Litres	Water
3 Kilograms	Chicken or cow manure
100 Grams	Effective Microorganisms

Procedure: Place all the ingredients together in a place them into a dark sealed tank. Place tank in a dark cool place for 90 days. Use the liquid 1:50 with water as a fertilizer [118].

Numerous biological products for agriculture are commercially manufactured as organic products. These products, either through micro-biological activity in someway enhance the soil, or contain fixed nutrients which upon application to the soil release these nutrients. This category contains a broad spectrum of products on the market, which begin with biological fertilizers based on organic nutrients. A number of specialist products like biological activators that promote microorganism growth and proprietary liquid humates (humic acids) are offered for specialist functions. The next group of products include enzyme plant activators, which enhance plant growth through "*bring(ing) out the life energy that is inherent in plants"* [119] and into the esoteric [120] with cosmic fertilizers. Many organic products are developed and marketed with some form of innovative media and/or delivery system to make the product more convenient to use by the consumer.

Table 10.9. Some Generally Allowable Minerals in Organic Farming

Mineral	**Application**
Natural Phosphates	Important nutrient for root growth and flowering. Good for seedling transplanting. Helps to bind sandy soil.
Mineral Potassium	To promote flowering and fruiting or potassium deficiencies (i.e., reduced growth, browning of leaf edges, etc) occurs.
Calcareous and Magnesium Amendments	Control of pH (decrease acidity)
Clay (bentonite, perlite, zeolite)	Soil conditioner, to absorb moisture
Magnesium rock, Kieserite and magnesium sulphate	To overcome Mg deficiency symptoms in plants. Also helps to break up soil.
Gypsum (Calcium Sulphate)	To help break up the soil and provide calcium for high calcium requiring crops.
Sodium Chloride	Disease prevention [122]
Sulfur	To provide high sulfur requiring plants.
Trace Elements (boron, copper, iron, manganese, zinc)	Important nutrients

In poorer soils, mineral deficiencies will exist that will require attention. Several natural inorganic rock materials are allowed in organic farming for the purpose of addressing important mineral imbalances. Mineral source materials must not be chemically treated and contain no heavy metals or substances that will contaminate the soils [121]. These inorganic minerals are extremely rich in specific nutrients and can provide benefits to deficient soils. A list of some generally allowable minerals are shown in Table 10.9. These are most often applied as ground or powdered forms.

Many companies are producing proprietary products based on rock minerals for organic agriculture. An example is AZOMITE® mined from volcanic ash, rich in minerals and trace elements and certified organic in both the United States and Australia [123].

Many commercial organic fertilizers are sold as soil conditioners or soil amendments and don't display a nutrient rating on the label. As most organic products are low on one or more major nutrients, caution is needed in purchasing these products to solve specific crop fertility issues. One of the greatest advantages of organic agriculture is the lower cost of inputs, replacing purchased fertilisers through *on-farm production* of nutrients. Purchasing outside products *(especially considering more organic fertilizer is needed over inorganic due to lower concentrations)* could negate some of the cost savings organic practices bring to a farming system.

INSECT AND DISEASE CONTROL

Insect control within an organic farming regime is primarily concerned with managing relationships within the farm eco-system with the objective of achieving balanced insect populations, which do not pose a major threat to crops. Emphasis is placed on preventative practices and measures. Curative or reactionary measures are only used if insect populations break out of control. Managing insect control within a *bio-intensive integrated pest management (Bio-IPM)* framework is driven by forecasting and monitoring. These plans are implemented through preventative practices through three major categories. Cultural and biological controls manipulate the environment according to a farmscapping plan. Mechanical controls are used to supplement cultural and biological practices. Curative measures utilizing biological and organic pesticides are used if other methods fail to control insects and they become pests. An overview of organic insect management is shown in figure 10.9.

Within a bio-intensive integrated pest management framework insects are not considered pests until the population levels increase to a point where they can cause economic damage to a crop. Thus an insect could be considered a pest during one period but not during another period. The level at which pests cause economic damage is called the *economic injury level (EIL)*. The *economic threshold level (ETL)* is where curative measures should begin to be taken to prevent insect population from reaching the economic injury level. Below the economic threshold level only preventative practices are undertaken to assist in maintaining insects around an *equilibrium population (EP)*, which will normally vary according to season. Therefore if population build-ups occur, the farmer must understand whether this build-up is a natural variation from the equilibrium population or a potential 'pest' outbreak. In a balanced eco-system, insect population increases will usually be countered by an insect enemy or predator, which will normally bring the population back down without outside intervention. If the increase of insect population is not brought under control by a natural predator, then outside intervention through biological and organic pesticides will be necessary. Figure 10.10. shows the intervention limits within the insect cycle.

The successful control of pests begins with a thorough understanding of pests and pathogens within the site specific and crop context of the farm. The important basic aspects of knowledge that support the planning process include;

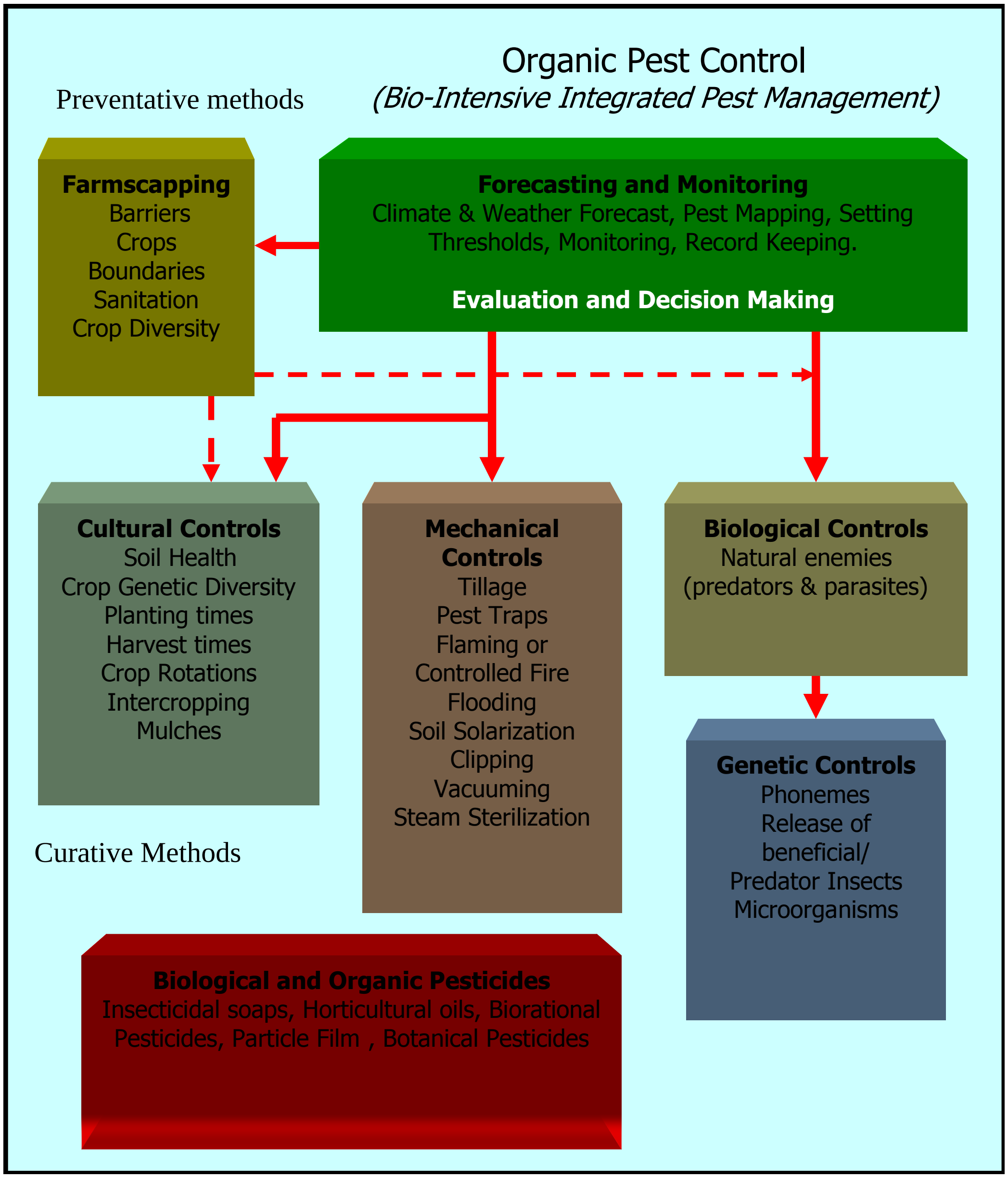

Figure 10.9. An Overview of Organic Insect Pest Control System.

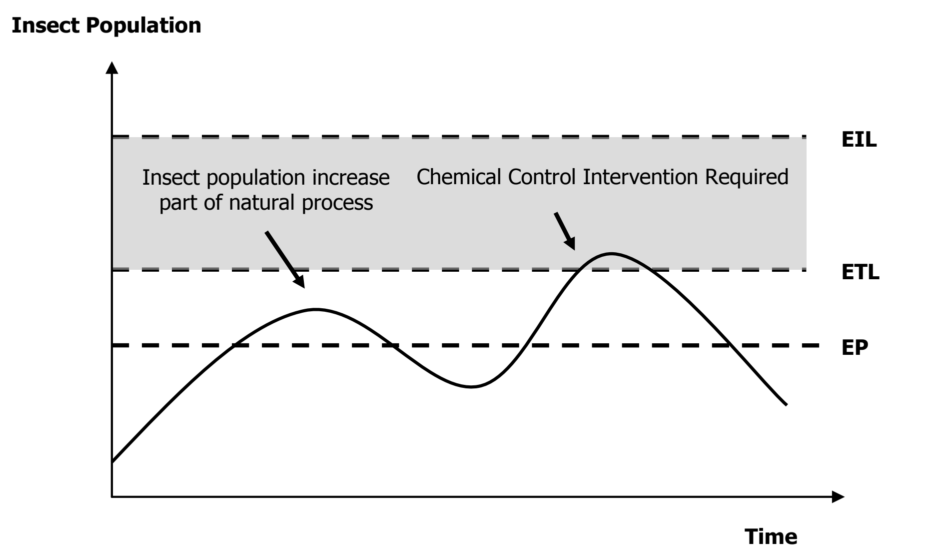

Figure 10.10. The Intervention Levels within the Pest Cycle.

- *The historical status of the farm*, e.g., past pest severity and crops grown will provide some ideas to assist in anticipating potential pest problems,
- *The location of the farm*, is important in terms of soil fertility and conditions (drainage, water supply, etc.) and proximity of the farm to other farms and features that will influence pest incidence,
- *The types of crops planted*, will influence the types of pests and pathogens attracted to the site,
- *The design of the farm*, and cropping systems that incorporate pest prevention philosophies such as crop diversity and intercropping,
- *Knowledge about pests and their natural enemies* and
- *Knowledge about bio-intensive integrated pest management practices* [124].

The basic knowledge accumulated above, together with experience (and no doubt some advice) will enable the development of a farmscape designed around the preventative parameters *(i.e., crop diversity, intercropping, barriers, etc)* which serve as a platform to practice integrated pest management on the farm.

Before planting any crops, it is necessary to consider all the issues that contribute to pest and pathogen development on the farm. Information would include historical farm information, the latest weather and climate predictions for the next season, latest pest mapping information [125], the types of insects attracted by proposed crops, how these insects would arrive?, will they be followed by any potential predators? Finally, what farming methods would be the most appropriate given the potential pest risks?

The analysis taking into consideration all available information will enable the determination of *economic threshold level (ETL)* and *economic injury level (EIL)* for each identified pest and a total planned approach to pest management for the coming season. This should also be transformed into a specific monitoring and record keeping program to assess potential threats during the season.

Cultural controls involve the utilization of cropping practices that discourage habitation of the crop by unfriendly pest populations. Soil health and biodiversity is important for eco-system balance, which includes pathogen populations. Soil health and biodiversity is directly influenced by the amount of organic matter, pH, nutrient balances, moisture contents, and the basic soil type. Approximately 75% of insects spent some of their life-cycle in the soil [126]. Research has found that soils rich in organic matter tend to suppress pathogens [127], while imbalances in soil nutrient ratios affect insect responses to plants [128].

Biologically diverse fields are more effective in repelling insects than mono-cropped fields [129]. Genetically diverse crops have a much higher resistance to pathogens than a genetically uniform crop [130]. Planning planting and harvest times can avoid the seasonal incidence of insect hatchings and migrations. Crop rotations can radically change the farmscape disadvantaging target insects. Companion and trap crops can be used to enhance protection against pests, as discussed previously. Mulching can help minimize the spread of soil borne pests. Experimentation with different coloured/synthetic based mulching materials has been successful in repelling a number of specific insect pests [131]. Table 10.10. provides a summary of cultural controls.

Table 10.10. A Summary of Potential Cultural Control Strategies

Strategy	Use/Benefit
Crop diversity (farmwide)	Maintain maximum plant biodiversity on the farm is the primary strategy of cultural control [132]. Decreased biodiversity leads to an unstable system, which will become prone to pest problems.
Crop Genetic diversity (single crop)	Genetically diverse crops show a higher resistance to pest and diseases than cloned crops [133].
Provide plants with a good start	Healthy and strong crops from the nursery planted in the field are less susceptible to insect attacks. This is particularly important during the transplanting stage.
Soil Health	Fertile and soils rich in organic matter and balanced nutrients contain less pathogens than unbalanced soils.
Planting and harvest timing	Can be used to avoid specific insect periods.
Intercropping/crop rotation	Change the environment that pathogens perceive and can be used to interfere with insect life cycles, through the disguising of crops. Crop rotation can eliminate pests associated with the previous crop. Multi cropping can provide natural barriers
Mulching	Can be used to provide habitat for enemies, *i.e.*, *spiders*. Synthetic mulches can repel potential insects.
Cover crops	Certain cover crops can repel insects.
Sanitation	Removing potential breeding sites for potential insect pests, eg., nematodes.
Companion and trap plants	Used to attract away or repel insects from the primary crop.
Tillage	Tillage can dry out organic matter to ensure it doesn’t attract potential pests.

Biological controls are primarily concerned with the use of living organisms to maintain balance within the insect population at equilibrium population levels. Ideally this occurs naturally where mammals, birds, insects, fungi, microorganisms and viruses act on each other within the natural eco-system food chain without any intervention. But situations often arise where some part of the chain is absent within the farm eco-system, requiring intervention. This occurs with the introduction of a mammals, birds, insects, fungi, or microorganisms to become parasites or predators within the eco-system. This requires careful study within the planning stage to determine which insects are threats at what population levels, where in the food chain they exist and what are their predators and enemies.

Traps with synthetic pheromones are increasingly used in farming with great success in some industries. According to the Australian CSIRO, 90% of chemical insecticides have been eliminated in the orchard industry in Australia with the use of chemical sex attractants [134]. Pheromone traps confuse the male insect, which disrupts the mating cycle. Pheromone traps can be used either for detection and monitoring and/or eradication of insects.

Mechanical controls assist as supplemental practices to assist cultural and biological controls. A number of mechanical methods exist which can be utilized to suppress insect population growth as follows;

- As many insects inhabit the upper area of the soil, tillage can expose and kill insect eggs and larvae by bringing them to the surface to dry out under the sun's radiation.
- Coloured pest traps covered with non-drying glue attract and trap insects within the crop itself. This is useful against a variety of insects and can also be used as a monitoring as well as a control tool [135].
- Flaming and controlled fire are primarily weed control methods, but they destroy potential insect habitats.
- Flooding of crops is sometimes used to control certain pests, where there is ample supply of water in tropical areas [136]. However this method should be used sparingly due to crop and soil damage potential from flooding.
- Water pressure during irrigation is sometimes enough to remove some pests like aphids from crops. This may have to be done repeatedly to prevent them re-attaching themselves.
- Soil Solarization involves covering the soil with a plastic cover for a period of 4-6 weeks during periods of hot weather. This will heat up the top 15 cm of soil, killing a wide range of insects, fungi and weed seeds. This is an especially effective method for killing insects which inhabit the root systems of crops, e.g., fungi and nematodes.
- Row covers are flexible, semi transparent woven or plastic materials that cover the crop to exclude insect pests. Row covers also enhance crop growth through increasing soil temperature, reduce wind damage. Row covers are effective for airborne pests, but totally ineffective for soil borne pests.
- Using vacuums to remove insects from plants is becoming more popular. Trees and mulches are directly vacuumed with the insects traveling into a disposable cartridge lined with sticky gel to trap them. Vacuums can be hand held or attached to a tractor.
- Steam treatment on soils has been used in greenhouses and small fields in the United States for a number of years. This method has also been used effectively on larger fields through a steam rake attached to a tractor [137]. Steam effectively kills

pathogens through heating of the soil to levels that cause protein coagulation or enzyme inactivation [138]. Although this method is effective, there are a number of practical problems associated with it over large acreages.

Some methods like pest traps are widely accepted. Many of the other methods, although suitable for small areas, have limited application on large farms, *i.e., netted greenhouses*. However, through innovative engineering developments, some of these methods are gaining popularity and coming into wider farm use as pest control strategies.

Cultural, biological and mechanical controls are the prime management methods of pests and diseases within a bio-intensive integrated pest management system. This pro-active approach is intended to avoid the outbreak of pests with the aim of minimizing inputs through reducing the need for intervention agents and chemicals [139], thus reducing field overhead costs. However, bio-intensive integrated pest management requires a deep ecological knowledge to adopt a holistic approach [140], which is extremely difficult, if not nearly impossible to practice flawlessly according to Altieri [141]. Bio-intensive integrated pest management changed the paradigm from total eradication of pests to managing populations of insects within a farm eco-system where curative measures should be used as an option of last resort to prevent economic losses [142]. This recognized the dangers that pesticides had to the environment and also the non-selectivity in many chemicals on beneficial insects as well as pests.

Organic certification systems allow the use of a number of pesticides. Bio-pesticides used in organic farming fall under the categories of;

Figure 10.11. Netted Greenhouses are Popular for Insect Protection.

- Biorational, derived naturally from microorganisms,
- Particle film barriers, comprised of natural materials that create a barrier between crop on insect,
- Insecticidal soaps and plant oils,
- Botanical pesticides, and
- Other organically acceptable concepts.

Bio-pesticides are not only used by organic farms, but also by some conventional producers due to consumer pressure over food health, security and pesticide exposure. The bio-pesticide market is one of the fastest growing chemical industries with an estimated global value of USD 260 million in 2005, projected to be around USD 1.0 Billion by 2015 [143]. This still represents less than 2.0% of World pesticide usage [144].

The general advantages of bio-pesticides over conventional pesticides is that they have multiple modes of activity against pests, low restricted entry intervals between 0-4 hours and generally exempt from maximum residue limits [145]. Cost and immediate efficacy are bio-pesticide disadvantages, restricting wider use. Also the increasing selectivity of synthetic pesticides is another factor restricting the future growth of bio-based products [146].

Biorational Pesticides

Biorational pesticides are a rather loosely defined group of pesticides that are generally derived from naturally occurring compounds or are formulations utilizing microorganisms. These include a wide range of microorganism based products, plant and pathogen mimicking compounds, composts and ‘EM’ based pesticides (compost teas, etc).

Microbial insecticides can be derived from viruses, bacteria, fungi, protozoa or nematodes, or toxins produced by these organisms, formulated into a conventional pesticide form as a spray, powder or liquid. Most of these microorganisms are found in soils and produced into pesticides through fermentation [147]. Many microbial insecticides are selectively toxic to a single species or closely related group of species [148] and present very low toxicity threats to other plant or animal species, including humans.

One of the most common commercially produced microbial insecticides is one that contains the spores and protein crystals (endotoxin) of the bacteria *Bacillus thuringiensis (Bt)*. *Bt* is not a contact poison and must be ingested by insects to be effective. The spectrum of effectiveness against various insects depends upon the nature of the *Bacillus* strain, the product contains. The discovery of new *Bacillus* strains in the 1980s greatly widened the effectiveness of *Bt* against much wider ranges of insects. A second group of *Bt* bacteria isolated from the *Bacillus thuringiensis* variant *israelensis* enabled the killing of fly and mosquito larvae. *Bt* products are applied to crops in a similar way to conventional pesticides. However efficacy drops back rapidly in the environment, which often necessitates a number of sprays.

As each *Bt* insecticide controls only specific types of insects, it is necessary to correctly identify the target pests before making pesticide selections. Treatments must be directed towards the parts of the plants that insects will eat. *Bt* insecticides have a slow knock down effect, compared to many conventional pesticides, as it will take over a day for insects to drop off sprayed plants once they have ingested the *Bt. Bt* also has a much shorter *half life* than conventional insecticides and should be sprayed on cloudy days to minimize UV radiation exposure.

Viruses, fungi, protozoa, and nematodes can all be used to produce microbial pesticides, but to date most of these processes are limited. For example, viruses must be produced in live insects, which is expensive and time consuming [149]. However, through further advances in biotechnology more products from these sources will eventually come onto the market, utilizing much more efficient routes of production.

Many compost teas are made on-farm, utilizing microorganisms to develop fermentation for pest and disease control. The products are manufactured as liquid composts with a number of materials that will create insecticide properties, such as neem, tobacco, galangal, citronella, etc, and applied as sprays. A simple formula for a liquid compost pesticide utilized in Thailand consists of;

5 Kilograms	Neem fruits and leaves (fruits preferred)
1 Kilogram	Tobacco Leaves
6 Kilograms	Banana, pineapple, papaya, other fruit and vegetable wastes according to what is available.
3 Kilograms	Molasses or raw sugar
20 Litres	Water
100 Grams	Effective Microorganisms

Particle Film Barriers

Diatomaceous earth is a naturally occurring chalk like rock consisting of the fossilized silica shell remains of diatoms. Diatomaceous earth absorbs lipids and moisture from insect exoskeletons, causing them to dehydrate and die upon contact. It is effective as a barrier against a number of insects and also as a soil additive. It is effect in arid-dry low rainfall regions, rather than tropical humid regions.

Particle film barrier concepts, based on natural mineral materials were developed in the late 1990s [150] and are an early example of the many new IP protected, organically certified agricultural products appearing on the market. Modified kaolin was applied to crops as a fine particle solution which left a residual protective coat that deterred insect contract through agitating the insects and preventing egg-laying [151]. The light colour of kaolin also makes the plant less recognizable as a host. This product is manufactured under the trademark SURROUND [152].

Insecticidal Soaps and Plant Oils

Insecticidal soaps have been popular in the nursery, horticultural and market garden sector in Australia and New Zealand for a number of decades because of the non-residual properties and low toxicity of the product. Insecticidal soaps are usually manufactured from fixed (non-volatile) plant oils (palm, coconut, olive, cottonseed, etc.), saponified with potassium salts to neutralize the acidity and making the emulsion alkaline. Usually additives like ammonia and an essential oil like citronella, eucalyptus, nutmeg, rosemary, pennyroyal, clove, or tea tree oil would be added to enhance product efficacy. How insecticidal soaps actually work is still not fully understood. It is thought that the soap physically disrupts the insect cuticle or outer skin, causing toxic paralysis [153]. Another theory believes that the insects are suffocated during spraying and the irritation from the product forces insects to abandon the host plants [154]. It is important that insecticidal soaps sprayed onto plants must directly contact insects to be effective. Insecticidal soaps are effective against a number of soft bodied insects like aphids, scales, psyllids, whiteflies, mealy bugs, thrips, and spider mites. Hard bodied insects have the protection of their hard chitinous bodies. Insecticidal soaps are quite effective in intensive and confined areas, but of limited use in extensive farming due to the number of repeated applications required to maintain a zero insect infection. Insecticidal soaps due to their high pH tend to burn hairy leaved plants but usually safe to use on smooth leaved plants.

This type of formulation could be considered the 'grandfather' of a number of new *organic pesticides and fungicides* utilizing essential oils and encapsulation technologies, discussed in the next section.

White or horticultural oils are a name given to oils, sometimes emulsified in a soap base to control diseases and insects. Any number of oils including paraffin, mineral oil, canola, caster, sunflower, are used. These products are generally used to remove various fungi and scales from plants and trees and to control insects like aphids and spider mites. Some people manufacturing their own on-farm emulsions add either ammonia or vinegar to enhance insect repellency efficacy. In general these emulsions are sprayed directly over plants to coat and suffocate insects, or used as a rubbing agent for disease infected plants. Commercially, there are various products on the market with many variations of the product based on different philosophies and approaches. However traditional oils like paraffin are declining in use due to the long number of CH2 chains which brings up phototoxicity issues [155], which can be potentially fatal to the plant. In addition, these long chain oils may carry sulphur residuals and the film created by these oils can block the stomata (intake apparatus of the plant), preventing nutrients being taken up. White oils now tend to be light vegetable oil soaps with various additives to assist in killing fungi and spores and remove scales.

Botanical Pesticides

Botanical pesticides are a wide group, which utilize a variety of plants and their parts. Production processes are also widely varied, ranging from soaking of leaves and fruits in the case of neem, leading to mixtures of variable quality, to the steam distillation of essential oils and solvent extraction of pyrethrum from pyrethrum daises, in a standardized form. Botanical pesticides include both products that can be manufactured on the farm and commercially produced branded products. Generally, botanical pesticides are less harmful than other pesticides, breaking down easily and quickly in the environment.

Neem *(Azadirachta indica A.* Juss) is considered by many to be one of the wonder trees in our global bio-diversity. A native of India, neem is also found throughout South-East Asia and is also cultivated in Australia. Numerous applications of the tree have been practiced by indigenous communities over the centuries, which include as an insecticidal, antifeedant, acaricidal, insect growth regulator, nematocidal, fungicidal and antiviral agent [156]. Neem contains a number of active compounds, of which two *azadirachtin* and *salanin* [157] exhibit very potent insect intervention properties. They are present in most parts of the tree, but concentrated in the fruits. Neem does not knock down insects like conventional pesticides, but rather interferes with the feeding and reproductive lifecycles, confusing them until they are unable to reproduce and thus disappear [157].

Neem oil is not a true oil in the real sense, but a tincture that can either be extracted through solvents on a commercial scale or obtained through soaking out the active ingredients from the fruits and leaves in a bin or tank. Neem is a major input in the production of natural insecticides at the farm level in Thai agriculture. The resulting tincture is very unstable and will lose activity within a very short period of time. Although a number of commercial products are in the market, standardization problems have stood in the way of neem gaining further acceptance as a major agricultural pesticide. Neem's efficacy as a human contraceptive [158] is considered by some authorities as a health and safety issue. Another variety of neem, *Azadirachta excelsa* is also used as a pesticide.

Pyrethrum based products are also rapidly growing in demand as a pesticide in agriculture. Pyrethrum has one of the broadest insect killing spectrums, of products on the market. Pyrethrum is solvent extracted from the flowers of *Chrysantemum cinerariifolium*, a highland or temperate climate plant. Natural pyrethrum was once the major ingredient for household insecticides before the advent of synthetic pyrethroids, which had a much longer residual efficacy. Natural pyrethrums are of low toxicity to mammals and one of the safest pesticides in use. One of its advantages is that it has a very quick knock down effect on insects through attacking the nervous system. However the substance is very unstable in UV radiation, breaking down very quickly. Pyrethrum is usually applied as a spray on crops during growth and maintenance periods.

As discussed in chapter 4, plants produce volatile and non-volatile metabolites that deter insects and other herbivores from feeding on the plant in a number of ways. More than 2000 plants have been investigated and found to posses these characteristics [159]. Much more interest has been taken in essential oil based insecticides over the last few decades [160], resulting in a number of products in the marketplace for pesticide applications. Table 10.11. provides a summary of some of them.

A number of relatively young, specialized small companies are expanding in the area of organic agricultural products. EcoSMART [161] utilizes essential oils of rosemary, clove, thyme, nutmeg and cinnamon as neural blocks to insect nervous systems in their range of new generation botanical pesticides. Biomor, a company in Israel has utilized tea tree oil in a range of fungicides, effective against a broad number of diseases in plants with no residuals or phytotoxicity [162].

Garden dusts are multipurpose insecticide/fungicides made up of a synthetic or natural plant derivative with a bulking agent. Garden dust is used against plant diseases like powdery mildews, bacterial blights, early blights, fire blight, anthracnose, alternaria blight, leaf spot diseases, brown rot, apple cedar rot, peach leaf curl, peach canker, stem blight, shothole, leafscorch, black rot, scabs and botrytis [163].

Table 10.11. Summary of Plant Extract/Essential Oil Based Insecticides

Plant Extract/Essential Oil	**Application**
Basil Oil *(Ocimum spp.)*	*Wide spectrum*
Citronella *(Cymbopogon nardus)*	*Wide spectrum*
Citrus Oils	*Wide spectrum*
Clove Oil *(Syzygium spp.)*	*Sitophilus zeamais, Tribolium castaneum*
Eucalyptus *(Eucalyptus spp.)*	*Wide spectrum*
Garlic Oil or extract *(Allium sativum)*	*Worms, aphids and beetles, also antifungal*
Lavender *(Lavendula spp.)*	*Acanthoscelides obtectus, Cydia pomonella*
Mint Oils *(Mentha spp.)*	*Wide spectrum, ants*
Nutmeg Oil *(Myristica fragrans)*	*Wide spectrum*
Pennyroyal oil *(Mentha pulegium)*	*Diamanu montanus*
Rosemary *(R. officinalis)*	*Sitophilus orzae, Tetranychus urticae*
Tea tree Oil *(Melaleuca spp.)*	*Wide spectrum, also antifungal*
Thyme *(Thymus spp.)*	*Plutella xylostella, Pseudaletia unipuncta*

Garden dusts also provide some repellency against a number of insects. The usual active ingredient is *rotenone*, extracted from the roots of two tropical legumes *Lonchocarpus* and *Derris elliptica* [164]. Rotenone is a broad spectrum insecticide, effective against aphids, beetles, and caterpillars, but must be ingested by insects to be effective. Garden dusts can be directly sprinkled on plants or mixed with water and sprayed. As rotenone is very unstable when exposed to air and sunlight, it has a very short half life.

Two other botanical active ingredients that used in dusts and sprays include *ryania* extracted from the stems of *Ryania speciosa*, a native plant of South America and *sabadilla* from the seeds of the tropical lily *Schoenocaulon officinale*. Ryania is a slow acting poison to insects, but has a wide spectrum and works well in hot weather, unlike many other biopesticides. Its principal active ingredient is an alkaloid ryanodine. Sabadilla is effective against a number of insects, so will kill beneficial insects as well. Its active ingredients are cevadine and veratridine [165], extracted from the ground seeds of the sabadilla lily.

Finally, nicotine is extracted from tobacco for use as a pesticide. It is toxic to mammals through skin absorption. Nicotine kills insects through interfering with insect neural-transmitters between nerves and muscles. Nicotine is wide spectrum and used against aphids, thrips, spider mites and other soft insects. Nicotine as nicotine sulfate is usually applied as a spray and is suitable for warm weather use.

The area of biological organic control products will continue to develop in new concepts based on bacteria, fungi, viruses, protozoa, and nematodes, plant metabolites, enzymes, saponins, tannins, ozone, and botanicals, in line with public concern over food security.

Other methods of pest control have been experimented with. For example, ultrasonic pest control was discredited a few years ago through a number of ineffective products on the market [166]. Research has shown that insects use ultrasonic frequencies for communication [167]. This is an interesting area for pest research to reappraise.

WEED CONTROL

Weed management is one to the greatest challenges to any organic farm. Weeds can be defined as any plant which is a nuisance to or interferes with human activity or a plant which is not wanted and growing out of place [168]. Failure to react to early stage weed outbreaks can result in a large amount of lost time and labour manually extracting weeds. Weeds are a major problem in organic agriculture and need to be managed at a very early stage, especially in high rainfall tropical areas. Weeds compete and retard the growth of crops and can potentially create habitats for herbivores insects and pathogens. Weeds may pose a serious problem during early growth periods. At other times weeds may not be considered a problem as the primary crops are healthy and large enough to provide competition for potential weeds.

Weeds in a balanced eco-system can provide a number of positive attributes to a crop system,

a) where some deep rooted weed species can assist in bringing nutrients to the surface soil that would not otherwise be available to the crop,
b) be a very useful indicator of present soil conditions,
c) provide habitats for some beneficial insects, and
d) can contribute to the overall biodiversity of the farm eco-system, which may make it a more stable productive system [169].

Prevention is one of the fundamental components of integrated weed management. Like pest and disease management, weeds can be managed through an *integrated weed management* system, which is based on the following principals;

- Knowledge of soil, crop and pasture systems,
- Knowledge of weed species and how they affect soil, crops and pasture systems,
- Use of mapping and monitoring systems to evaluate weeds populations and damage,
- Knowledge of the appropriate available management options for weeds,
- Making control decisions based on the above knowledge, using a combination of methods to control weeds, and
- Monitoring the impact of weed management and evaluating its effectiveness on the weed species in relation to the soil, crop and pasture [170].

A balanced understanding of weed and crop ecology and managing them according to their biological differences will reduce the need for reactive weed control. The intensity of weeds is greatly influenced by weed populations of previous years. Weed management is a long term activity where the efforts of past years will show up in later years. Weeds are closely related to soil fertility and can be an indirect indicator of soil deficiencies, *i.e., some weeds will prevail when soil is too acidic or alkaline, soil structure poor, or under anaerobic conditions.* Weed populations tend to decrease as soil health builds up [171].

Through *integrated weed management*, weeds can be managed through cultural, mechanical (physical), chemical and biological means. Some common cultural practices that act as a preventative measure against weed development include;

- Crop rotation which helps to prevent weed seed carrying over to the next crop. Utilising differences in crop and weed biological timing can be of great advantage in weed management.
- Ploughing or harrowing a field before primary crop planting, where early germinating weeds can be killed through sun drying on the surface. This provides the crop time to establish itself without competition from weeds. Future weed growth in the field with an established crop will be more difficult due to competition with the main crop. The success of this method depends on the type of weeds. Ploughing or harrowing may bring up deeper weed seeds to the surface, which will germinate and increase weed populations.
- Altering plant spacings to denser crop populations to eliminate potential places for weeds to grow.
- Cattle, sheep and goat grazing in the field is successfully used in tea tree plantations in Australia [172] and Malaysia to control weeds without any damage to the crop. Grazing is probably one of the most important tools in organic farming for weed control, subject to the potential of the grazing animal to inflict damage to the crop.
- Buffers between crops help prevent weed seeds and spores traveling by wind and contaminating the field.
- Cover crops can smother weeds, prevent sunlight from reaching the soil surface and generally compete with weeds to prevent their growth. Some cover crops when mowed and killed will release allelopathic toxins into the soil which hinder weed growth [173].
- Similarly to cover crops, mulches also smother the ground to prevent weed growth in the field. Plastic strips can be laid down crop rows to prevent weed growth, and
- Modifying the soil pH to levels outside optimal target weed growth is another approach.

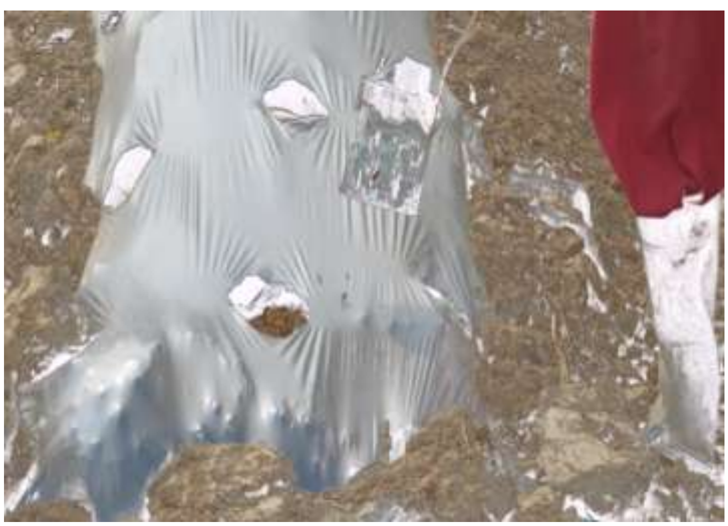

Figure 10.12. Plastic Sheeting Laid and Prepared For Planting by Melting Holes for Plant Growth.

Other preventative measures include utilizing only seed clean of potential weed seed and spore contamination, and cleaning tractors and other agricultural tools and equipment before transferring them from field to field to prevent cross contamination.

While good cultural practices will decrease weeds substantially, mechanized weed management strategies are also needed to assist in weed management. Some potential mechanical and physical weed management practices include;

- Regular observation and manual weeding cannot be avoided in any organic crop system. A few weeds pulled out this year may prevent a much larger number of the same weeds, the following year or season. Some manual or tractor fitted propane flame burners are used to assist in manual weeding and are used widely with great success.
- A number of innovative crop weeders have been invented and developed to mechanically weed specifically identified weeds, with the ability to till very close to row crops without disturbing them. These weeders are usually purpose built by university agricultural engineering extension schemes. These weeders can be used both pre- and post crop emergence and therefore have the capacity to dramatically reduce weed competition under the specific site circumstances they were designed for [174].

Until very recently organic farmers had very few options through chemical means to control weeds. Early organically certifiable herbicides were based on vinegar, citric acid, and some essential oils. These products did not even come close to matching conventional herbicides [175]. Most organic herbicides on the market generally rely on acidic or alkaline pH to 'burn' out weeds. Further, most organic herbicides are non-selective. Organically certifiable herbicides is an area of new development for weed control through microbial, fungi, bacterial, enzyme or plant extract routes in the near future. For example, a *d-limonene* herbicide, under the brand name of *Nature's Avenger,* is effective through stripping the wax coating of weeds, allowing them to dehydrate and die [176]. According to studies by Marambe and Sangakkara during the 1990s, effective organisms (EM), used in *Kyusei nature farming* are very effective in suppressing long term weed growth [177].

Biological weed control involves the utilization of pests, diseases, viruses, nematodes or bacteria to control weeds. The biological control of weeds is still in its infancy, and these methods are not currently in wide use. There are three main types of biological weed strategies. The classical approach involves the release of a small number of natural weed enemies in weed infested locations to control weed outbreaks. Natural enemies are selected from arthropods, nematodes, vertebrates, and other microbial organisms. Augmentative biological control strategies involve using natural enemies against weeds at times when the weed population is most susceptible to attack. Usually microbial organisms are used. The ecological approach is a continual process where known natural weed enemies are promoted, so their populations are enhanced throughout the farming cycle.

Tillage

Tillage is a practice that has both benefits and disadvantages. Tillage is a major weed control strategy, which assists in crop residue management, helps to aerate the soil and prevent anaerobic decomposition, helps to integrate manure with the top soil and destroy potential pest habitats.

Minimum or conservation tillage is not mandatory in organic farming, but encouraged because of the some beneficial effects to soil health. These include the promotion of earthworm and microorganism populations in the soil [178], lowering the cost of field operations through fuel and labour savings, improving soil tilth, increasing organic matter [179], reducing water loss and soil erosion [180].

Interest in some of the benefits of conservation tillage has led to the development of chisel ploughs that can restrict tillage to the upper parts of the soil where the biologically active layers exist. Crop residues and mulches are mixed in at this level to maximize organic material in this layer. This assists in maintaining aerobic decomposition. Other methods include mulch tillage, v-cutting, rolling and mowing which maintain cover crops mulches on top of the soil [181]. Ridge tillage can also be practiced where raised permanent ridges in rows exist on fields for crop bedding. Ridge tillage assists in mechanical methods of weed control greatly. Zone or strip tillage minimizes the impact of harrowing the field, which has some advantages in cold, wet regions.

Comparative analyses of tilled and no-tilled soils consistently show that no-tilled soils exhibit improved nutrient and water holding capacity [182]. However there are many problems preventing universal implementation of conservation tillage due to absence of alternative non-chemical weed control methods and limitations of its benefits in some soil and climate conditions like tropical areas [183].

Table 10.12. Some of the Important Farmscaping Issues

Practice	Comments
Buffers & Barriers	Field buffers or strips made comprising of hedges and/or trees assist as wind breaks to reduce soil erosion, a beneficial insect habitat, an insect trap habitat or as a buffer to protect a field from other physical occurrences.
Ensure Clean Water Supply	Isolate an independent water source that will be free from contamination. The area should also serve as a wildlife habitat.
Bio-Diversity	Ensure there is adequate area for bio-diversity (flora and fauna) to establish and settle.
Bird and Bat Habitats	Ensure farmscape will attract birds and bats for insect control.
Soil Ecology	Utilise the practices of intercropping, mixed crops, crop rotation, cover crops, composting and mulching to enrich soil fertility.
Land Cover	Ensure all land is covered to prevent erosion and maintain soil health.

FARMSCAPING

Farmscaping provides the structural basis of a holistic and ecological approach to farm management. The farmscape should be developed in a way that the farm is integrated with the surrounding landscape. An important influence on the success of converting from a conventional to an organic farm, and the future sustainability of the farm will depend upon initial farmscaping of the property. The farmscape will become the platform and determine the ease in which;

- Pesticide use can be minimized,
- Mulching and composting can be undertaken on-farm,
- The threat of external contaminations can be minimized, and
- Improve the quality of biodiversity in the ecosystem.

The farmscape will have a major impact on soil health and pest and weed management frameworks and strategies. Farmscape design will also influence the integration of farm wet lands, ponds, dams, roads, barriers and buffers, fields and other infrastructure with the surrounding biodiversity and eco-system. Table 10.12. lists some important farmscaping issues.

PLANNING AND SITE SELECTION

Developing an organic farm requires more thought about the management and implementation process than conventional farming would require. Substantial knowledge experience and wisdom is needed to understand and make intervention decisions to manipulate the complex relationships within the farm eco-system, without the option to use synthetic fertilizers and pesticides, as would be the case in conventional farming. Further, general theories and farming techniques must be adapted to the specific climate, soil, geography and terrain and social systems existing at the farm site [184]. These constraints determine how sustainable and viable a specific site can be, with the possible allowable set of farm practices that can be utilized on that farm [185].

An organic implementation and management plan must be carefully devised first to examine viability, around the following issues;

1. the management of soils,
2. biodiversity,
3. weed, pest and disease management,
4. water and irrigation management, and
5. contamination risk.

The planning process requires an understanding of the organic certification standards that will be applied to the farm under each category of the standards. Each standard criterion must be considered against available climate, soil, terrain, surrounding hinterland and eco-system, history of land use, labour skill levels and availability and the level of existing knowledge to assess whether the land has the potential to satisfy all requirements.

Climate constrains the types of crops that can be successfully cultivated. Crops should be matched against the climatic parameters of the site. Climate also determines the growth rate and types of pests and weeds, soil moisture evaporation levels and thus heavily influences the methods and practices that will be utilized.

Organic farming should be primary concerned with soil health. The soil is the basic platform from which all activities will have their base, so soil condition is central to both productivity and sustainability. Soil characteristics will determine what crops can grow and how well, what farming methods and practices will be most effective and how mulches and composts should be used within the farming system. Assessing the site soil characteristics is critical to any site selection.

Soils can be classified according to their relative proportions of silt, sand and clay. Component percentages of the soil can be checked against *'The Soil Triangle'*" [186] (see Figure 10.13.) to determine the soil type. For example, a soil with 30% clay, 40% sand and 30% silt, will be a clay loam. The individual soil components can be determined by particle size in each class, where sand particles are between 0.05-2.0mm, silt 0.002-0.05mm and clay less than 0.0002 mm in size. Experienced farmers can determine this through rubbing the soil between their thumb and fingers [187]. Clays will feel sticky and slippery when wet and hard when dry. Sandy soils are loose and grainy and silts are very fine.

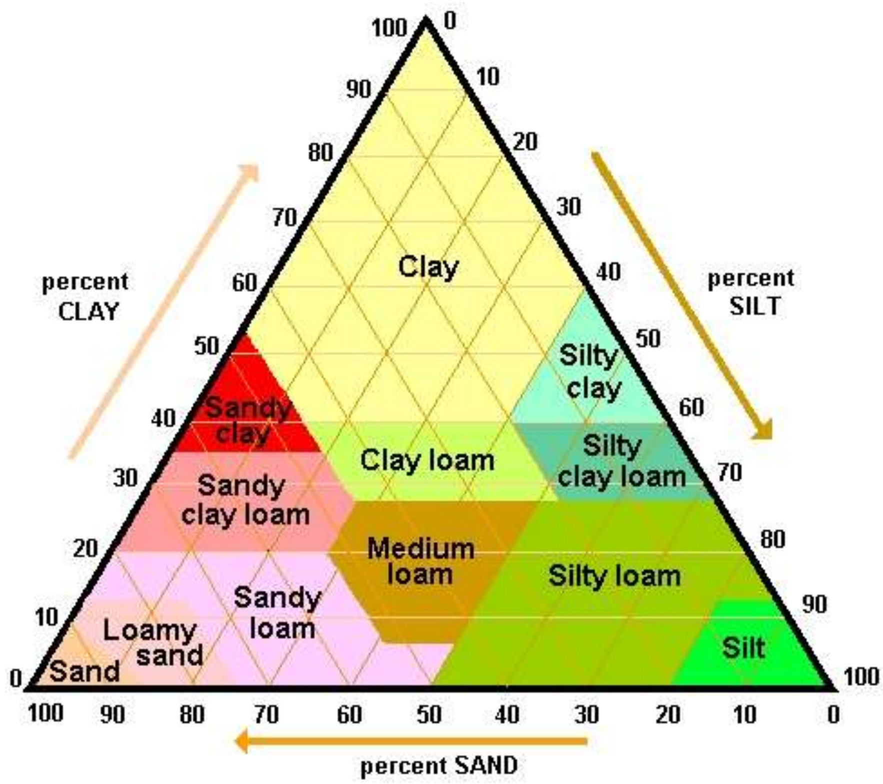

Figure 10.13. The Soil Triangle (used with permission of Idaho OnePlan).

Ideally, a selected site should be some distance from conventional farms and populated areas. This will help prevent contamination from fertilizer or pesticide spray drift, weed infestations, waterway toxins, air and other pollutants. If possible the site should adjoin a forest reserve or jungle area, so the farm eco-system can naturally extend into those areas. This will encourage existing biodiversity onto the farm. If proximity to reserves is not possible, the use of natural and artificial buffers will be important. Live barriers can be utilized to increase biodiversity and protect the farm from pests and contaminants.

If an existing conventional farm is being taken over or converted, farm history should be evaluated to determine the residual effects of past activities on the soil and water reserves. Farm topography should be evaluated for erosion potential and heavy metal and toxin contaminant. The water supply should be evaluated for independence and cleanliness. If possible, streams with no upstream contaminant sources are best. Local regulations will stipulate whether sub-terrain water is allowed. If so, this must also be evaluated for contaminants. Infrastructure and the farm eco-system should be evaluated for its recycling capacity, *i.e., what is needed to carry out mulching and composting activities on the farm and are they available?*

Labour is another very important issue for an organic farm. Organic farming traditionally utilizes more labour than a conventional farm for weed control, compost making and other crop protection measures. Will there be enough available labour in the area to cater for farm needs, or can labour saving devices like weeders be developed? As organic farming requires specific skills, education and skill level will be another consideration. Implementation of an organic system will require competent workers who understand the principals of what they are instructed to do. Will workers accept new methods that may be different from the traditional farming methods they have been used to? This issue cannot be underestimated in its importance for successful implementation and conversion of the farm. It may require very persuasive leadership skills to convince workers of the importance and meaning of their work.

Knowledge and experience are two critical issues in the implementation of a sustainable farming system. Thinking conceptually is one thing, but applying the concepts on the farm is another. Good organic farming practices develop through trial and error and experience. Farming on the ground is about *theory in action-finding ways to adapt what is espoused in theory*. Theory brings understanding and perhaps knowledge, but practice brings wisdom. The process of turning understanding and knowledge into wisdom, *i.e., successfully farming organically, will be much easier if there is already a group of organic farmers in the region and the local agricultural authorities and education institutions conducting courses and extension*.

CERTIFICATION

The organic certification process involves a third party (organic certifying agent) to evaluate a farm and its corresponding processes to determine whether they conform to an established set of operating guidelines, known as organic standards. A farm will only be certified organic after it has gone through a thorough audit by a certification agency. There are many organic certification systems around the World [188]. Some are government agencies, while some are private independent agencies regulated by the International Organic

Accreditation Service (IOAS). Some certification systems are more widely accepted than others internationally. However standards between Australia, EU, US and the CODEX Almentarius are comparable in all major aspects [189]. Standards are regularly reviewed and changed to reflect evolving thoughts and philosophies [190]. Domestic certification schemes in South-East Asia still need to be developed further before they are accepted in the US and EU markets [191]. While fees for actual certification are not expensive, travel and accommodation costs for experts to undertake the certification audits are.

Certification standards will include [192];

- Organic Practices
  - soil fertility and management
  - Organic matter, humus and compost
  - Crop rotation policy
  - Water management
  - Irrigation management
- Landscape and Environment
  - Environmental factors
  - Social justice policy
- Pest and Weeds
  - Pest management
  - The use of pest controls
  - Weed management
- Precautions and Other Requirements
  - Residues and possible contamination
  - Windbreaks and buffer zones
- Leasing of land
  - Requirements
  - Transfer of certification
- Processing
  - On farm processing
  - Off farm processing
- Transport and handling
- Storage and warehousing
- Use of Organic Logo
- Seeds and Propagation Methods
  - General
  - Seedling production, nursery and greenhouse production
- Record Keeping

It is important to find a suitable certifier that covers the local region, so that travel costs are not exorbitant and the certification is widely recognized. Before applying for organic certification, it is important to determine whether the farm can comply with the organic standards. For example, an adjoining property contaminating the farm would prevent certification. Organic certifiers will have a checklist similar to the USDA/National Organic Program [193].

INTEGRITY AND RECORD KEEPING

The integrity of the organic farm is the sum of the farm design, methods and practices put into place, which is reflected in certification. Record keeping allows the trace back of inputs, raw materials, practices and yields in accordance with risk management protocols. This documentation is important in maintaining systems integrity and necessary to maintain certification.

ORGANIC FARMING IN THE ASIA-PACIFIC REGION

With the rapid growth of organic markets in the United States and the European Union, the situation in the Asia-Pacific region is much more mixed. Like their Western counterparts, middle to high income consumers in South-East Asia share health and lifestyle aspirations and are becoming more interested in organic products. Nowhere more than China can this be seen with a 30% annual market growth, mainly in the Eastern part of the country in 2005 [194]. Within the ASEAN region, markets in Thailand, Philippines and Indonesia are growing steadily, with slower growth in Singapore and Malaysia. This growth can be seen in the organic produce sections in regional hypermarkets and the development of specialized organic shops in major cities. Also organic products like cosmetics are beginning to trickle into the region. In Australia, the domestic market is still growing steadily for organic produce and 50% of domestic production is exported [191]. New Zealand's growth is much more dramatic with an increase of 20% each year [195]. International and local organic cosmetic brands are being launched in both markets.

Table 10.13. Land and Number of Farms Under Certified Organic Cultivation [196]

Country	Land use (Ha.)	No. of Certified Farms	Average Farm Size (Ha.)	% Total Farm use	Year
Australia	12,126,633	1,832	6619	2.71%	2004
China	3,466,570	1,560	2,222	0.60%	2004
Fiji	200	10	20	0.04%	2004
Indonesia	52,882	45,000	1.175	0.12%	2004
Japan	29,151	4,539	6.42	0.56%	2004
Korea (South)	28,218	28,951	0.995	1.46%	2005
Laos	60	5	12	-	2005
Malaysia	581	56	10.375	0.006%	2002
New Zealand	45,000	820	54.87	0.26%	2003
Philippines	14,134	34,990	0.40	0.12%	2004
Taiwan	1,092	-		-	2003
Thailand	13,900	2,498		0.175%	2004
Vietnam	6,475	1,022		0.07%	2001

Australia has the largest land area allocated to organic farming because of organic grazing [191]. A small group of organic essential oil producers of lavender and other herb oils exist throughout the country [197]. In New Zealand approximately 45,000 Ha. was under cultivation with approximately 1000 farmers in 2005 [191]. After a slow beginning, certified[2] organic farming in South-East Asia is beginning to grow. Growing export opportunities, local consumer interest, government support and the availability of recognized organic certification agencies now domiciled within the region has quickened growth in the last couple of years, particularly in Thailand, Indonesia and Vietnam. The number of certified organic farms and acreage in the Asia-Pacific region is shown in Table 10.13.

CONCLUSION

There are a number of positive factors to encourage the adoption and growth of organic farming. These include pressures on farm production costs from the increasing costs of fertilizers and pesticides, greater influence from the environment movement, the perceived market opportunities and the passion and satisfaction that organic farming brings to many people. The rising cost of oil is set to maintain upward pressure on farm input costs and continue to bring attention to the options of organic farming.

There are also a number of forces constraining the growth of organic farming. There is still widespread lack of knowledge about organic farming. Population growth is bringing many to advocate strengthening conventional farming methods to enable adequate food supply for increasing world population [198]. There is still a lack of research being undertaken in developing countries on organic farming, matched by a distinct lack of training and extension. Still in many places, low levels of organic education exist, and in many areas marketing channels don’t exist for farmers wishing to send their products to domestic or international markets.

The production of organically certifiable essential oils is still extremely small. Current production is undertaken by small clusters of farmers, putting their interest and passion into producing selected and specialized oils, with equally small markets. Farmers sell their produce online, to farm visitors, to retail outlets in their vicinity and wherever else some sales can be achieved [199].

Many community projects have failed in the past, producing products without a definite market. The Fairtrade movement formed to ensure that farmers receive a fair price for their goods has provided new channels for farmers in marginalized rural areas is growing rapidly [200]. The growing closeness of the Fairtrade movement and organic farming movement is of particular importance to community based production projects [201].

Organic practices are suitable for annual and perennial herbs. Many organic practices can be adapted in a straightforward way. A number of conventional farmers are picking up organic farming practices to add efficiency and save costs on their farms.

It is the volume oils, grass and tree crops that present the challenges to farming organic essential oils. One of the major constraints to the introduction of organic farming could lie in the monocrop production model.

[2] A lot of agricultural production is still by traditional means, which has no chemical inputs and is effectively organic, although not certified.

Organic farming is not without its criticisms. According to a number of studies, it is questionable whether biodiversity on an organic farm is necessarily richer than a conventional farm [202]. If so, it would be difficult to argue that organic farms enhance biodiversity any more than well managed conventional farms [203]. Other studies have shown that energy use on organic farms is similar to conventional farms [204] and organic farms also release as much greenhouse gasses as conventional farms [205]. According to other studies, organic farm costs above conventional costs because of non-chemical weeding costs [206]. Certified organic farm chemicals are not necessarily anymore natural than conventional farm chemicals, as soaps are neutralized with alkaline salts which are not natural. They are not safer as rotenone has been recently associated with Parkinsons disease and *Bt* pesticides with respiratory effects [207]. Finally, current certification procedures do not take into account outside energy usage.

Finally it is important to restate that a large number of essential oils, particularly those produced in developing countries are cultivated organically, even though they are not certified.

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Chapter 11

THE APPLICATION OF ESSENTIAL OILS

This chapter covers the major areas of essential oil application in industry, including flavours and fragrances, aromatherapy, cosmetics, household products, agro-products, natural aroma chemicals and isolates, and pharmaceuticals. The chapter begins with a discussion about the classification of odours and flavours, which is important in many aspects of the industry. The structure of a fragrance and perfume development is discussed due to importance of fragrance in consumer products. The issues involved in developing natural fragrances and cosmetics are canvassed. New product development is discussed as a strategy along with intellectual property strategies. This chapter continues on to review the general issues of product lifecycle and evolution, discovering new opportunities in the market, and the product as a theme. Important regulatory issues including, GMP, HACCP, OSHA, product standards, organic, halal and kosher certifications, and environmental compliance are discussed. Finally distribution and channel strategy is discussed in this chapter, also covering agro-tourism as an enterprise strategy option.

INTRODUCTION

Aromatic materials from plants and animals were strongly associated with spirituality, magic, pharmacology, cosmetology, and the scenting of the environment for many thousands of years. Macerations of myrrh, thyme, marjoram, and chamomile were used for a number of purposes by the ancient Egyptians as far back as 3,500 BC, with the first recorded distillation around 2,500 BC. Around 700 BC the Greeks infused marjoram, sage, thyme, anise, rose and iris with olive, almond, castor and linseed oils, packing them into small jars for sale. Ancient Athens at the time developed into a perfumery trade centre. Other regions like the coast of Somalia also became trade centres for aromatics and other precious items at that time. Records go back to 1,200 BC where the ancient Hebrews used myrrh, cinnamon and calamus to scent their temples.

The use of fragrance continued to grow in everyday life during the Roman Empire, where according to the Biblical scriptures frankincense and myrrh were more valuable than gold. The word *perfume* is derived from the Latin, where *per* means 'through' and *fumum* means smoke, *i.e., the burning of aromatic material like incense*.

The use of fragrance also originated in China during the same time as the Egyptians, where the *Taoists* believed that an extract of a plant represented the liberation of the soul. From the T'ang dynasty around 700 AD, the wealthy Chinese used fragrance on their bodies, in baths, on clothing and in homes and temples. Many items like ink, paper, cosmetics and clothes were scented. China became an importer of jasmine scented sesame oil from India, Persian rosewater via the silk route and cloves, benzoin, ginger, nutmeg and patchouli from Indonesia. A pharmacopoeia *Materia Medica Pen Ts'ao*, was published in China during the 16th Century. It listed over 200 herbs, including 20 essential oils, and moreover, the book described the use of jasmine as a general tonic, rose to aid digestion, the liver and the blood, chamomile to reduce headaches, dizziness and colds and ginger for the treatment of colds and malaria. Records also go back to 500 AD in Japan where distillation existed. By the 4th Century incense in the form of cones were used in Japanese households. India became a large production and trade centre of both aromatics and cosmetics, exporting the flowers of henna, jasmine, chempaka, lotus, hyacinth, rose, violet, narcissus, vetiver roots, musk, sandalwood, aloewood and benzoin.

The Arab world was another ancient centre of perfumery, where words like *algebra, chemistry, alcohol* and *alembic* are Arabic in origin. The Arabs understood distillation from the Syriacs and improved upon these techniques, becoming the centre of rosewater and other tincture production. Herbs were also used extensively for medicine, where the *Al Quran* has a number of passages referring to herbs and perfumes.

Perfumery came to early Europe from the Greeks, Romans and Moors. Theophrastus (372-287 BC) wrote of the fragrant materials plants possessed in their flowers, leaves, roots, branches, which could be macerated into oils, fats and wines. He also mentioned the process of enfleurage. Theophrastus along with other writers of the time showed how much knowledge the ancient Greeks had accumulated. Through Venice the Italian perfumers exported their waters to the rest of Europe, where some like Rếne le Florentin eventually moved to Paris. Many Moor perfumers remained in Spain after the conquest of Granada by the Christian forces, having dramatic influence upon Spanish perfumes and cosmetics trade, which made its presence felt in Southern France. This all assisted in linking Northern Africa, Egypt, Persia, with Spain and Italy and eventually Southern France and Paris.

Traditionally, books on the subject of essential oil applications have focused heavily on the production of fragrance, flavours and cosmetics. This strongly reflects the history where essential oil cultivation and the allied crafts began. Before moving into the applications of essential oils, it is important to understand how essential oil odour and flavour profiles are described. The most important attribute of an essential oil is its odour and flavour profile, as this is the primary reason it is valued by both the manufacturer and consumer.

THE CLASSIFICATION OF ODOURS

Odour is the primary feature of an essential oil when utilized as part of a product displaying a scent. Therefore odours require a standard system of classification, where those involved in the production, trade and eventual downstream product have a commonly understood method of description. A number of systems have been developed over the years by eminent perfumers. Due to the nature of our sense of smell and cognitive interpretation of an odour, each developed system is based on subjectivity, opinion and judgments. Although analytic apparatus like the electronic nose through *fuzzy logic* [1] can catagorise an odour [2], such techniques cannot replace the need for human input in the odour classification process because any automated measurement system would be unable to identify quality *(i.e., a shared subjective opinion on what is liked or disliked in an essential oil)*.

Odour classification systems have been developed over the years, utilizing groupings based on the paradigms of nature, i*.e., floral, woody, fruity, herbaceous, etc.* This reflects the fact that the majority of odours relate to nature and that perfumery has an artistic basis (most classification systems developed relate to essential oil application in fragrance). Some systems were developed as an odour description map, so odours could be placed in various relative categories, while others have attempted to measure odour attributes like tenacity and volatility, qualities important to a perfumer. Table 11.1. shows the major contributions to the evolution of odour classification.

Table 11.1. A Chronology of Odour Classification Systems

Developer	Year	Comments and Contribution
Aristotle	384-322 BC	The Greek philosopher Aristotle was the first person in recorded history to classify odours. He classified them into six groups (sweet, acid, severe, fatty, sour and fetid odours).
Linnaeous	1707-1778	The Swedish botanist Linnaeous based his odour classification on seven groups (aromatic odours, fragrant odours, ambrosiac odours, alliaceous odours, fetid odours, repulsive odours and disgusting odours.
Fourcroy	1798	Fourcroy, a French chemist and politician who founded the French Museum of Natural Sciences classified odours into five groups (extractive odours, volatile odours, aromatic odours, acidous odours and hydrosulfurous odours).
Piesse	1865	George Piesse, a chemist and perfumer from London matched odours to musical notes. Piesse through his classification system developed the concept of producing harmonious chords by matching heavy and light notes together, concepts and terms which remain in perfumery today.

Table 11.1. Continued

Developer	Year	Comments and Contribution
Rimmel	1865	Rimmel published a classification scheme placing similar odours into 18 groups in his *Book of Perfumes* in 1865.
Zwaardemaker	1895	Hendrick Zwaardemaker, a German in his book *Die Physiologie Des Geruchs* (The Psychology of perfumes) in 1895 classified odours according to their content in nine main groups.

Henning	1916	Hans Henning in his 1916 book *Der Geruch* (The Odours), classified odours into six descriptive groupings (flowery, fruity, balsamic, burnt, foul and spicy), placing them on a prism to show their spatial relationship to each other.
Cerbelaud	1920	Rene Cerbelaud, a French chemical engineer developed a classification system based on 45 botanical families of similar odour.
Gatterosse	1881	Rene Gattefosse, a French chemical engineer developed a classification system reducing Cerbelaud's 45 botanical groups to 15 botanical groups based on odour and constituents.
Redgrove	1887-1943	Herbert Stanley Redgrove, an English chemist and writer, classified odours into classes and types.
Croker & Henderson	1927	Crocker & Henderson classified odours into four large groups but assigned a numerical value to each odour after a semi-quantitative evaluation of each odour. This was the first time the intensity of the odour was taken into consideration.
Ellmer	1931	Albert Ellmar was the first to classify odours as top, middle and base notes, according to odour persistence.
Billot	1948	Marcel Billot, another French chemical engineer classified odours into eight groups, floral, balsamic, frutal, empyreumatic, comestible, woody, rural and repulsive. This was eventually extended to nine and ten groups [3].
Amore	1952	Amoore in 1952 classified odours into seven primary categories, ethereal, camphoraceous, musky, floral, minty, pungent, and putrid.
Poucher	1954	Poucher classified odour materials, through subjective evaluation according to their rate of evaporation on a scale of 100 and dividing them into top, middle and base notes. This classification method assists perfumers in selecting materials in the creation of fragrances.
Arctander	1960	Stefan Arctander enlarged the odour classification to 88 groups according to odour, type and suggested use. The scheme contained cross references to assist in finding similar/complementary materials in other groups [4].
Carles	1961	Jean Carles further developed the concepts of top, middle and base notes and harmony for fragrance composition through his odour volatility tables.
Robert	1962	Henri Robert, former chief perfumer of Chanel developed a classification scheme which combines groups of odorants with in declining order of volatility *(i.e., top, middle and base notes)* [5].

The difference in each classification system reflects the subjectivity and various opinions as to where odours should be placed. Some odours can be placed in more than one category, depending on the importance placed on particular odour qualities. Some classification systems have taken wide category views, while others have preferred to increase the number of categories to reflect the diversity within each general odour direction. This is why many perfumers maintain their own private systems of odour classification to suit their own purposes. There is in fact no accepted industry standard of description, although some international fragrance houses publish their own from time to time.

A number of perfume classification software packages and other forms of manuals exist. One example is Stephen Dowthwaite's software classification system which assists perfumers to examine the odour profile of particular notes, the relative impact of the note, odour life and potential application in perfumery [6]. A slightly earlier descriptive classification system developed by Dr. Tony Curtis of the University of Plymouth Business School and Mr. David Williams of the Perfumery Education Centre was published in their textbook *Introduction to Perfumery* in 1994 [7], and used in their teaching programs [8]. Their system classifies odours into families that have features and potential applications in common, arbitrarily excluding odours like the *stapelia* species, where most members exude the odour of rotton fish and are repulsive. Additional modifying descriptors like *light* and *heavy*, *sweet* and *dry* are used to assist in classifying wide ranging odours in categories like floral. Curtis and Williams clearly state that their odour classification system does not attempt to create any absolute odour classification, as this would not have much benefit to the perfumer [7]. Their system is meant to be flexible to assist in developing a common descriptive language accepted by all [7] and does not define any quality of odour except for illustrative purposes [7].

Most perfumers use variations of the odour classification systems described above, modified and adjusted to suit their purposes and experience. A modified version of Curtis and Williams' odour classification system is summarized over the next few pages [7].

The Floral Family

The floral family is a very diverse group of odours. The one thing these odours have in common is that they come from a flower of a plant, with a few exceptions. However there are also a number of non-specific floral odours available in fine fragrance that cannot now be easily described through the nomination of a floral species. The floral group could be further divided into green, aldehydic, citrus-floral, heavy and light, etc. Some descriptions of the floral family are listed in Table 11.2.

Table 11.2. The Floral Family

Ambrette	A slightly sweet musk-floral type odour with underlying cognac notes (Note: This is a floral odour not from a flower, but seed)
Benzoate	An intense fruity-floral, somewhere between blackcurrant upon dilution to Ylang Ylang and tuberose when concentrated or slightly diluted.
Broom	A sweet floral hay-like odour with bitter undertones

Carnation	Powerful, yet delicate floral-clove odour
Cassia	Complex spicy-citrus orange-violet floral odour
Cyclamen	Strong jasmine, lily, lilac, violet floral with green and earthy undertones.
Frangipani	A rich tropical violet like floral
Gardenia	A rich but fresh floral resembling jasmine and tuberose with green and light citrus-orange notes
Geranium	A leafy-rosy like odour with minty undertones
Hawthorn	A diffusive balsamic floral reminiscent of anisic and bitter almond
Heliotrope	A delicate bitter fruity almond floral with balsamic vanilla notes
Honeysuckle	A sweet but heavy floral with tuberose, honey and rose notes, with fresh orange flower note
Hyacinth	A fresh, diffusive, green balsamic jasmine like floral
Jasmine	A powerful honey-heliotrope like floral
Lilac	A fresh hay-like green jasmine-like floral
Lily	Sweet heavy floral reminiscent of hydroxycitronellal
Lily of the Valley	A fresh rosy-lemon floral note with green undertones
Lime blossom	A fresh lily, lilac-citrus odour
Magnolia	A sweet heavy rosy, violet-like floral odour with citrus undertones
Mimosa	A powerful green almond-like floral with citrus undertones
Narcissus	A complex and delicate hay-like sweet green floral with spicy undertones
Neroli	A sweet spicy orange blossom floral (could also be classified as citrus)
Orange flower	A warm spicy bitter orange floral
Osmanthus	An exotic floral odour reminiscent of plums and raisins
Reseda	A green, anisic, herbaceous floral odour
Rose	A powerful sweet warm honey-like waxy, slightly spicy/balsamic floral with very slight undertones cognac undertones
Sweet pea	A delicate and sweet hyacinth-like, lily-like, orange blossom floral
Tuberose	A heavy, Ylang Ylang, orange flower type floral with green and caramel undertones
Violet	An intense peppery/spicy green floral with a powdery undertone
Wallflower	A somewhat lilac-like floral with a bitter almond undertone
Ylang ylang	A heavy but sweet fruity lilac, clove like floral with fruity undertones

The Woody Family

The Curtis and Williams classification system defines the woody family along a triangle of three main types, East Indian Sandalwood, Japanese hibawood and rosewood, where other woody notes can be described with reference to these main notes. Patchouli and a number of other odours can also be placed in the woody family expanding its scope.

Table 11.3. The Woody Family

Agarwood	An oriental vetiver-like odour with phenolic, smoky, earthy and mossy undertones.
Cederwood	A soft woody odour with earthy and smoky undertones

Guiacwood	A sweet balsamic rose-like odour
Hibawood	A dry, intense and pungent woody odour
Massoi	A pungent spicy resinous coconut-clove-like odour
Orris	A violet-like, oily wood odour
Patchouli	A powerful intense smooth spicy woody odour with earthy undertones
Rosewood	A slightly rose-like fatty sweet floral odour
Sandalwood	A sweet rich warm balsamic woody odour

The Animalic Family

This family was originally based on the four basic aromatic extracts of animal origin which included *ambergris, castoreum, civet* and *musk.* These notes with the exception of *ambergris,* smell very pungently repulsive in their undiluted form. In diluted form and skillfully used, these ingredients can add warm and masculine notes to fragrances. Musk in its natural form is rarely used in perfumery today, although a number of specialty chemicals which can provide musk notes exist.

Table 11.4. The Animalic Family

Ambergris	A warm but dry balsamic, tobacco-like, marine-like odour
Amine	Ammonia-like, fish odour
Castoreum	A warm phenolic leather-like, sweet clean herbaceous odour
Civet	A warm musky, slightly faecal odour
Indolic	A heavy lilac-like animalic, naphthalenic odour
Leather	A balsamic cresylic, phenolic, animalic (equine) like odour
Musky	A sweet warm heavy musk-like odour

The Balsamic Family

Vanilla is a theme which runs through a large number of members in this family. These notes are usually modified which cinnamic alcohols, esters, and acids, in the case of Peru, Tolu and Styrax resins, bringing warm oriental and even woody notes. Many of these resins form base notes and blend well with members of the floral family and used in bases for floral, aldehydic and oriental perfumes.

Table 11.5. The Balsamic Family

Cistus	A warm diffusive spicy and balsamic odour with dry woody undertones
Cognac	A warm fruity, nutty-woody rum-like bouquet
Labdanum	A powerful sweet ambergris-like odour
Olibanum	A balsamic spicy, slightly lemon-like odour with resinous undertones
Opopanax	A warm balsamic spicy odour, reminiscent of wine

Peru Balsam	A sweet, rich, soft, balsamic vanilla cinnamate odour
Styrax	A sweet balsamic cinnamate odour
Tolu Balsam	A sweet balsamic cinnamate vanilla odour
Vanilla	An intensely sweet warm balsamic odour

The Agrestic Family

The agrestic family hosts a number of notes from the forest, jungles, meadows and soil of the earth. This is a very diverse group, even within each description as there is a range of earthy smells. For example, differences in pine and other types of forests, a number of different vegetable type odours. Another direction is oakmoss which is green, earthy and mossy.

Table 11.6. The Agrestic Family

Calamus	A heavy, earthy but slightly sweet slightly bitter root-like odour
Earthy	A fresh woody, vegetable odour
Forest	A moist fresh woody, vegetable type odour
Galbanum	A sharp green, spicy, leaf-like odour with earthy, coniferous undertones
Hay	A sweet warm, dry, agrestic and herbaceous odour
Mushroom	A musty fungal-like odour
Oakmoss	An earthy, green, woody, leather, slightly phenolic odour
Vegetable	Freshly cut or cooked tubers, roots or rhizomes, earthy-green in character

The Coniferous Family

This family includes both the pine (fir) and resinous odours that are found in forests and other natural surroundings.

Table 11.7. The Coniferous Family

Pine Fir	Resinous, balsamic and terpentine notes
Resinous	Forest, woody, terpentine and balsamic notes

The Marine Family

A family that has grown in odour importance over the last few decades, however essential oils make little contribution, with the exception of a few (non-commercially produced) that have what one could call marine type odours. Ambergris could also be included in this family.

Table 11.8. The Marine Family

Beach	Fresh, earthy, ozonic, seaweed notes
Ozonic	Fresh, marine, earthy notes (like after rain)
Seaweed	Marine, mossy, amine notes

The Aldehydic Family

The aldehydes in this family referred to are usually the fatty and waxy type aldehydes. These are all pungent materials which only smell orangey, florally, etc., upon dilution. There are few economic sources of natural aldehydes, so most used in perfumery are of synthetic origin.

Table 11.9. The Aldehydic Family

Fatty	Powerful fatty odours, but pleasant and citrusy on dilution
Waxy	Waxy, floral type odours, becoming sweet on dilution

The Medicated Family

Odours in this group are usually culturally accepted odours associated with medication. These include the camphorous and wintergreen type odours in balms and the phenolic and cresylic odours of disinfectants.

Table 11.10. The Medicated Family

Camphorous	Odour of camphor
Cineolic	Eucalyptus type odours
Cresylic	Cresolic and phenolic odours
Juniper	Powerful green, herbaceous odour with pine-needle type undertones
Mentholic	Menthol and peppermint type odours
Terpenic	Monoterpenes
Tymeolic	Thymol and thyme
Wintergreen	Methyl salicylate

The Fruity Family

The fruity family has two distinctive branches which can be broken up into two families, fruity and citrus. Some of the odour types are well known and the fruit is just referred to in the description column. There are numerous fruits not included in this list which have distinct odours and are also in this family, particularly a number of fruits originating from the Asian region. These would include mango, guava, longan, lychee, papaya, mangosteen, starfruit, durian, tamarind and jackfruit, etc.

Table 11.11. The Fruity Family

Apple	As the odour of the fruit when cut
Apricot	Odour of the fruit when handled
Banana	Odour of the fruit when mashed
Blackcurrant	Odour of the fruit
Coconut	A milky-fatty santan-like odour
Pear	Odour of the fruit
Peach	Odour of the fruit
Pineapple	As the odour of the fruit when cut
Prune	Odour of the fruit
Rasberry	As the odour of the fruit when cut
Strawberry	As the odour of the fruit when cut
Watermelon	As the odour of the fruit when cut

The Citrus Family

These notes are the same as the notes of freshly crushed fresh fruits (see table notes). A few citrus notes occur from non citrus fruit plants such as *litsea cubeba* and lemongrass.

The Green Family

Green notes resemble cut grass, crushed leaves, moss, vegetables and other notes from the forest floor. Green notes are important support notes in floral, chypre, oriental and even modern citrus perfumes.

Table 11.12. The Citrus Family

Bergamot	A sharp fresh lively citrus odour with fruity and sweet undertones
Grapefruit	A fresh, bitter citrus-grapefruit odour
Lemon	A very lively and refreshing odour of the peel of the lemon
Lemongrass	A sharp citrus-like odour with grassy-hay and fruity undertones
Lime	A very intense sweet lively citrus-like odour
Mandarin	A lively citrus-like odour with sweet undertones
Orange sweet	Sweet, lively, fruity sweetness, the typical odour of orange peels
Orange Bitter	Lively, bitter, dry, the typical odour of oranges
Pomelo	A similar odour to a grapefruit without the bitterness
Pithy	A dry citrus-note, similar to dried orange peels

Tangerine	A sweet citrus-like odour with floral, aldehydic undertones, something between orange and mandarin

Table 11.13. The Green Family

Cress	Cress and watercress have distinctive green notes that aromatic materials like phenylacetaldehyde dimethyl acetal resemble.
Cucumber	A green note resembling freshly cut cucumber
Grassy	Resembles freshly cut grass similar to cis-3-hexanol
Leafy	Resembles the odour of crushed green leaves

The Mint Family

The mint family has the unique note diffused by peppermint and spearmint. This is primarily from the menthol content of these essential oils.

Table 11.14. The Mint Family

Peppermint	A powerful sweet, fresh minty odour with grassy and balsamic undertones
Pennyroyal	A fresh warm minty with spicy and bitter undertones
Spearmint	A warm green fresh minty odour

The Spicy Family

Spicy notes closely resemble the notes of their respective culinary spice preparations. Most of these notes are warm and rich and difficult to describe without reference to the original spice. This is only a representative list, as there are many other members of this family.

Table 11.15. The Spicy Family

Celery	A warm spicy sweet vegetable odour
Cinnamon	A powerful warm spicy sweet odour
Clove	A powerful warm spicy sweet odour
Coriander	A spicy aromatic odour with aldehydic undertones
Cumin	A powerful soft green spicy odour with anise-like undertones
Elemi	A fresh spicy lemon-like odour with green-woody undertones
Fenugreek	A walnut type odour with woody backnotes
Ginger	A warm spicy woody odour with sweet undertones
Helichrysum	A sweet honey-like fruity-spicy odour with tobacco and celery like undertones

Hyssop	A sweet spicy camphoraceous odour with a warm woody undertone
Lovage	A powerful sweet spicy odour reminiscent of celery and angelica root, also a green mossy note
Nutmeg	A pungent tropical spicy odour with a fruity undertone
Pepper	A very intense warm spicy peppery odour reminiscent of cubeb
Perilla	A powerful oily odour reminiscent of cumin
Pimento	A balsamic odour resembling clove, nutmeg and cubeb

Table 11.16 The Herbaceous Family

Anise	A powerful sweet herbaceous odour
Artemisia	A fresh green-like but lively herbaceous odour
Chamomile	A sweet herbaceous-like odour with fresh fruity undertones, sometimes reminiscent of cocoa
Estragon	A spicy-anise like herbaceous odour reminiscent of celery
Fennel	A sweet anethole-like odour
Hop	A harsh, bitter herbaceous-spicy odour with cheese-like undertones
Lavender	A sweet balsamic herbaceous odour with floral notes and woody undertones
Marjoram	A typical herbaceous odour reminiscent of the herb itself
Rosemary	A powerful woody, herbaceous odour reminiscent of lavender with slight camphoraceous notes
Sage	A fresh herbaceous-camphoraceous note with medicinal undertones
Tagetes	A very intense herbaceous odour reminiscent of fruit.
Tea	Warm, herbaceous and reminiscent of tobacco
Tobacco	A warm aromatic sweet hay-like herbaceous notes with slight green, dry woody undertones

The Herbaceous Family

The herbaceous family is related to the spicy family. Most of these notes described relate to the original herb. Again this is not an inclusive list be examples of members of this family.

Classifying odours was simpler before the era of synthetic materials in the 1950s. This has been made even more difficult with the advent of patented specialty chemicals. Curtis and Williams stated *"that to include a 'miscellaneous' category in a system of classification is to acknowledge defeat in respect of those items so designated, and to establish a kind of dumping ground for the victims of one's ignorance, wherein anything at all may be deposited"* [7]. However, they go on to argue that there is such a diversity of odour qualities in a single odour profile that it would be possible to fit most odours within existing families on the basis of some selected characteristics, but this could be misleading. A number of notes that fall into this category are described in Table 11.17.

Table 11.17 Unclassified Odours

Burnt	Odour of scorching
Caramel	Odour of cooking sugar before any burnt odours
Fatty	Odour of natural fats
Honey	Odour of honeycomb and natural honey
Metalic	Odours suggestive of metals
Naphthenic	Odour of naphthalene and indole
Oily	Vegetable oil odour
Smoky	Suggestive of smoke, liquid smoke
Sulphurous	Sulphur odour
Waxy	Reminiscent of beeswax

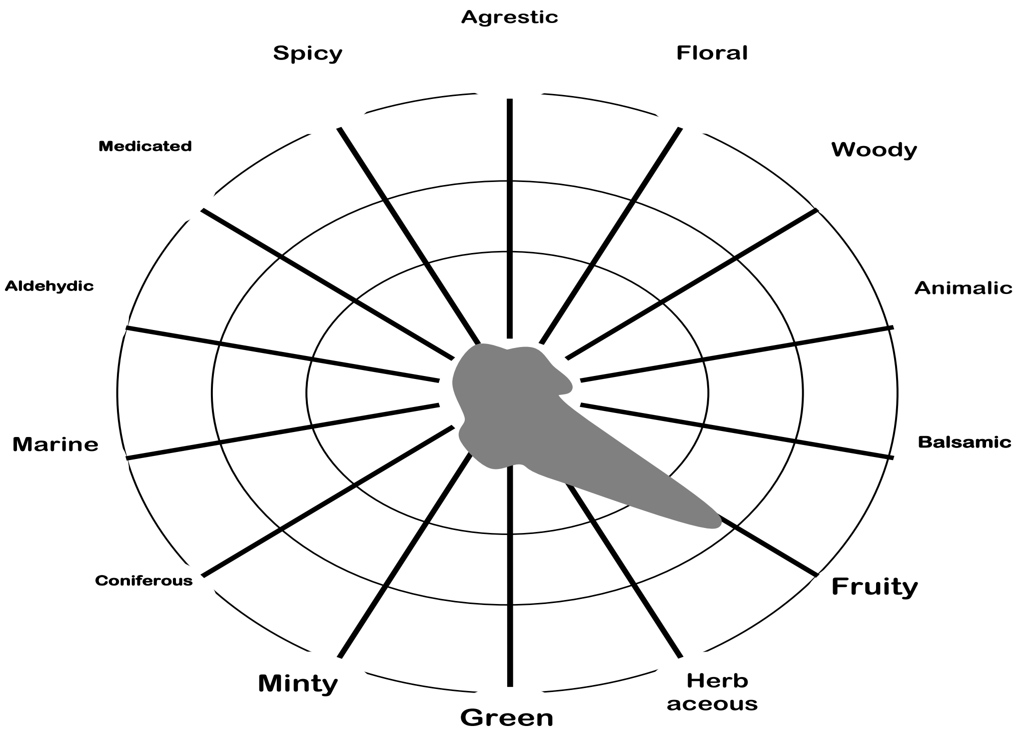
Older classification systems have used additional terms to further desribe the direction of odours. For example, Aristotle used sweet, acid, severe, fatty, sour and fetid as descriptors and fourcroy used extractive, volatile, aromatic, acidous hydrosulfurous categories to classify odours. These systems much wider in their descriptive terms capture all types of odour profiles, but at the same time are less accurate or precise in their class classification, thus rendering the system less useful to the perfumer in understanding the nature of the profile.

Terms normally used to describe other physical things can be adopted for the purpose of odour classification. Characteristic descriptors that have opposites tend to be appreciated better as the terms can be seen as being more relative with an opposite present. If these terms are learned for the purposes of odour description, then communication about an odour characteristic between two people can be commonly understood. Table 11.18 shows some examples of odour descriptors.

Table 11.18 Some Examples of Odour Descriptors

Light	Like in some citrus oils, neroli oil	**Heavy**	Like in some florals like tuberose, ylang ylang
Sweet	Like vanilla, Peru Balsam, Labdanum	**Bitter**	Like bitter orange, also dry-like
Fresh	Neroli and lavender oils	**Stale**	From old rancid essential oils
Cool	Peppermint oil	**Warm**	Clove and nutmeg oils
Soft	Like sandalwood oil	**Hard**	Like vetiver oil
Smooth	Benzoin resinoid	**Harsh**	Ammonia
Rich	Like patchouli, geranium, clove bud oils	**Thin**	Limonene and terpenes
Delicate	Like jasmine, tuberose, violet absolute	**Course**	Naphthenic odours
Dry	Like carrot seed oil	**Moist**	Like Oakmoss
Diffusive	An odour which spreads out	**Weak**	An odour that is barely

	around a room		noticeable around a room
Sharp	Like the odour of freshly cut lemons	**Blunt**	Like petitgrain oil
Tropical	A wide range of oils that can be considered tropical	**Powdery**	An odour that suggests something powdery



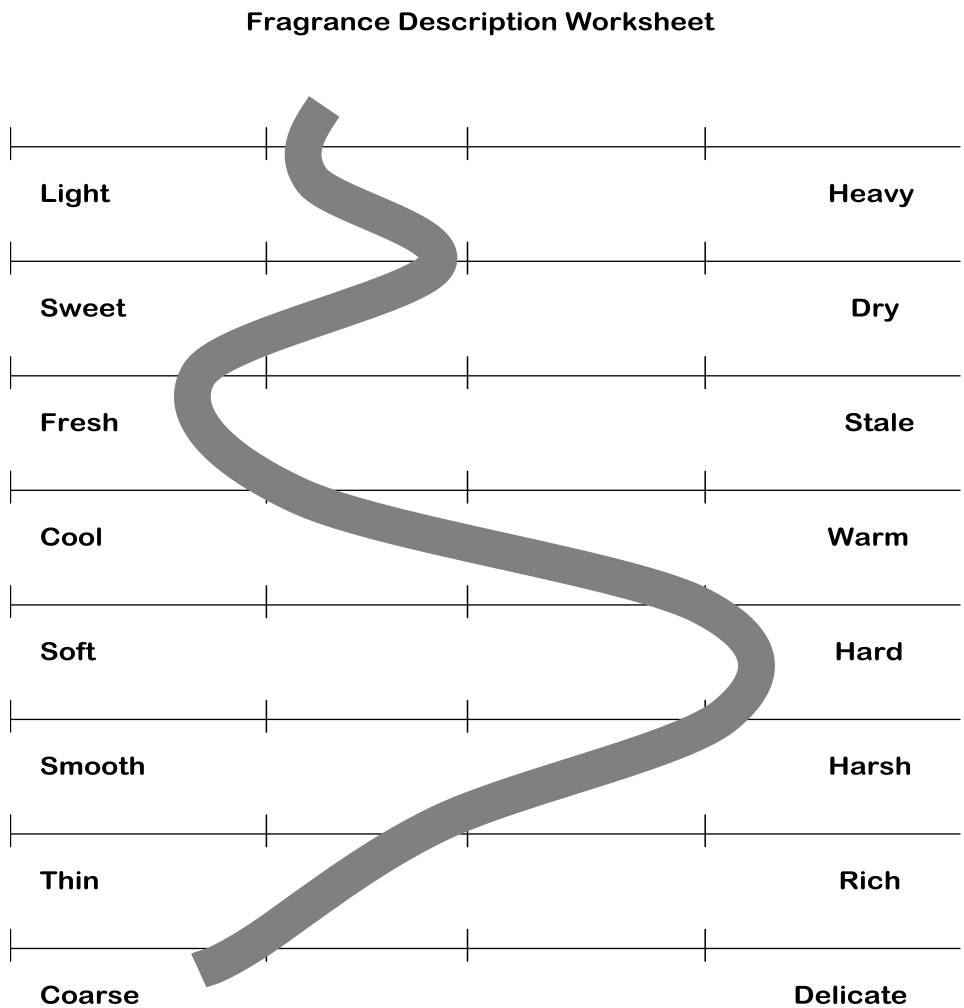


Figure 11.1. A hypothetical Odour Profile for Lemongrass Oil.

Through the use of simple charts to record impressions during an odour evaluation, a picture of the odour profile can be presented and compared with other profiles. A second chart enables the recording of a relative descriptor values by drawing a line between the opposites. Figure 11.1. shows how a profile for lemongrass oil could be represented pictorially.

THE CLASSIFICATION OF FLAVOURS

Flavours must be based on something natural, particularly food products. Fruit flavours are widely used in beverages, soft drinks and cordials. Nut flavours are important in bakery products and sweets, as is the balsam vanilla. Smokey flavours are important for sausages, processed meat, barbeque and steak sauces, tomato ketchup. Tobacco is another product flavoured with menthol to produce a cooling effect, while peppermint and spearmint is used in chewing gums, mouthwashes and toothpastes. Savory flavours are important for pasta, continental and snack foods, while the array of Asian spices form important parts of the fusion flavours now popular around the World. Food products can be hot, cold, solid, gelled, creamy or liquid.

There have been many attempts made to develop odour classification systems, but much fewer attempts to develop a flavour classification system. Flavours have been classified by their intended use, for example, soft drink, milk and dairy, beverage (alcoholic and non-alcoholic), cordial, ice-cream, savory and snack foods, candy and confectionary, and chewing gum flavours, etc. One attempt to develop a flavour classification system was made by Dr. G. Ohloff of Firmenich & Cie, Geneva, Switzerland in 1972 [9]. Dr. Ohloff defined nine classes of food flavour classifications, e.g., fruit, vegetable, spice, beverage flavours, meat flavours, fat flavours, cooked flavours, empyreumatic flavours and stanch flavours, which can be further divided into sub-classes for each classification. Like Curtis and Williams, Dr. Ohloff recognized that his flavour classification system is incomplete and further classes could be added to reflect the Asiatic tastes, and that categories like spices could be further sub-divided [10].

Dr. Ohloff's system lacked a truly flavour descriptive base, as it was tied to process/functional type. Another system developed by Ms. Jill Jessee, with the assistance of a number of flavorists, had a much more oriented descriptive base of the actual expected flavor type, more similar to the olfactory descriptive systems. Jessee's classification system uses seven major categories, e.g., fruit, herbs and spices, nuts, beans and seeds, leaves, barks, bulbs and roots, dairy-type flavours, meat, poultry, fish and seafood flavour groups, with a miscellaneous category [10].

Again, like other classification systems, Jessee's classification is also criticized for not breaking down the categories into natural and synthetic origin. As seen by the two examples above, taste, flavour or onganoleptic classification systems also subjectively describe flavour profiles. Other systems are usually specifically developed by a specialised industry to assist in developing accurate descriptions of the products they produce like cheese, wine, spirits and beer. Flavour classification systems are not dissimilar to odour classification systems, except they must be wider to account for tastes originating from baking, frying and fermentation processes. Most flavour classification systems must also be suitable to describe the aroma of the flavour. A typified example of a flavour classification system used by the author is shown in Figure 11.2. and Table 11.19.

Developing a flavour compound is complex, as the flavour compound must not only taste like the natural flavour, but also have a resembling odour as well. As people have set and pre-determined ideas as to what good natural flavours taste and smell like, there is little scope, unlike perfumery, to modify flavours too far away from the natural taste profile. The materials available to do this is limited due to material restriction through regulation, thus there is a heavy reliance on synthetic aroma chemicals, which are identical to those found in nature (nature identical). Finally, flavours may be produced in the form of liquids, extracts, resins, or spray dried powders, depending upon their intended application.

Table 11.19. Simplified Taste Classification System Descriptions

Flavour Family	Examples	Applications
Fruity	Apple, raspberry, banana, blackcurrant, etc.	Desserts, gelatins, confectionary, baked goods, beverages (juices, soft drinks, alcoholic wines, cordials), tobaccos, chewing gums, instant breakfast foods, cereals, marmalades, jams and pharmaceuticals.
Citrus	Orange, lemon, grapefruit, mandarin, etc.	Desserts, gelatins, confectionary, beverages (juices, soft drinks, alcoholic wines, cordials), chewing gums, instant breakfast foods, cereals, marmalades, jams and pharmaceuticals.
Alcoholic/Winey	Wine, beer, spirits.	Alcoholic beverages and spirits
Dairy	Vanilla, milk, cheese, ice-cream, butter, yogurt, cocoa, etc.	Beverages, confectionary and desserts
Herby	Onion, garlic, horse radish, etc.	Beverages, candy, tobacco, dips, spreads, sauces
Nutty	Coffee, cola, almond, pecan, peanut	Flavoring extracts, desserts, baked foods, confectionary, cereals, snacks, beverages.
Toffee	Candy, syrup, etc.	Beverages and confectionary
Hot	Chili, pepper, watsabi	Main dishes, seafood, Asian and Mexican foods, etc.
Roasted	Breads, meats, processed nuts, etc.	Main dishes (processed), snacks, appetizers, condiments, garnishes, etc.
Fatty	Cooking oil, santan, meat fats, dairy fats.	Processed foods, Asian foods, dairy foods.
Sour	Vinegar, sour cream	Salads, Savories and snack foods.
Bitter	Olive, lemon, tonic water	Baked products, confectionary, beverages, etc.
Astringent	Wine-like and medicinal	Some wines and medicines
Spicy	Mint, sage, marjoram, cinnamon, cloves, oregano, thyme, tarragon, ginger, etc.	Chewing gums, oral care products, salad dressings, sauces, savories, breads, snacks, cereals, beverages.
Salty	Corned beef, some snack foods	Snack foods and small goods

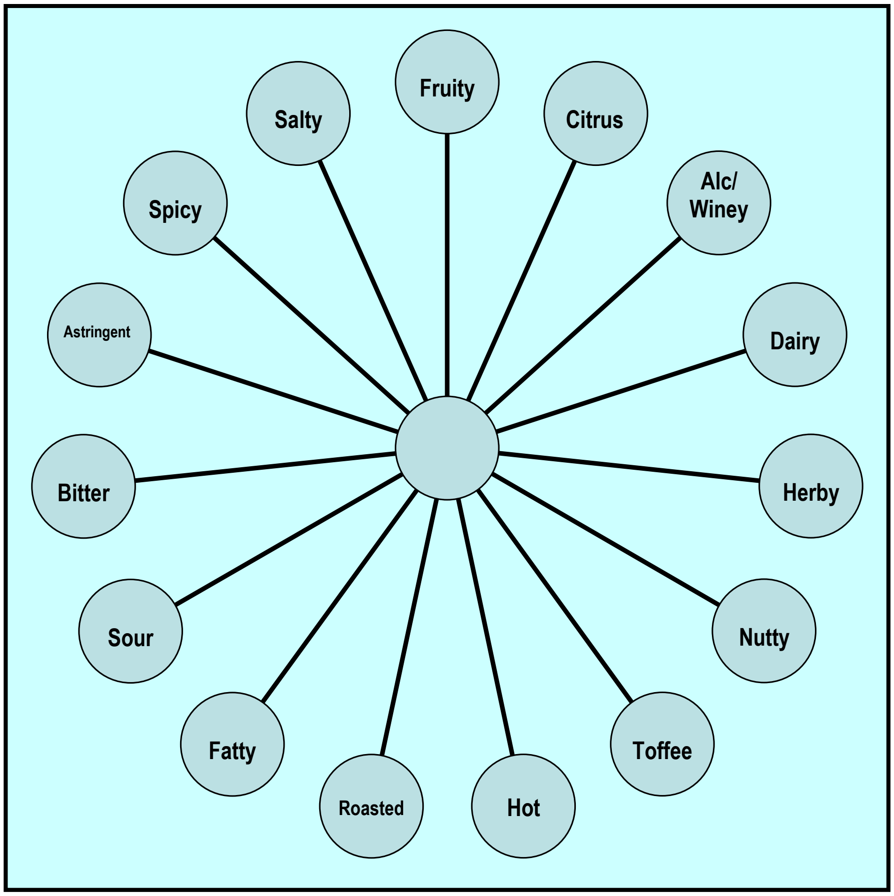


Figure 11.2. A Typified Simple Taste Classification System.

THE STRUCTURE OF A FRAGRANCE

Whether a fragrance is a natural essential oil or created by a perfumer, it is a mixture of different aromatic materials in different proportions, which are characterized by different intensities, vapor pressures, molecular weight and volatility, that give a unique character to an odour. One of the amazing things about plants is that they can evolve complex fragrances by natural synthesis of particular combinations of materials that have our sense of smell rather than an ill assorted random mixture of chemicals [11]. Natural materials exhibit a harmony that the perfumer requires years of experience to achieve in a fragrance.

A fragrance can be broken up into three parts according to the relative volatility of each section. Top notes are the most volatile and will disappear after a very short period, if the fragrance is placed on the hand or a paper smelling strip. Middle notes will persist for a longer time, usually making up the theme of the fragrance and the base notes will form the set of residual notes left on the skin or smelling strip for a much longer period of time. The relative volatility of a fragrance, *i.e., the vapour pressure at room temperature* is determined by more complex characteristics than just boiling point and molecular weight. Volatility can also be influenced by the volume of the material in proportion to the overall mixture and other ingredients as well as a host of other factors. Figure 11.3. shows the basic structure of a fragrance.

Top notes tend to provide the first impression in a fragrance and are usually made up of the relatively high volatile green, citrus and fresh type notes. According to Calkin and Jellinek, top notes would make up between 15-25% of the total fragrance [12]. As mentioned, the middle notes make up the theme or heart of the fragrance and consist of ingredients of intermediate volatility like floral and aldehydic notes. These make up about 30-40% of the total fragrance. Finally the basic aspects and lower notes of the fragrance are made up of the base notes, which are ingredients of the relatively lowest volatility in the fragrance, *i.e., powdery, woody, musky, balsamic notes.* These make the remainder of the fragrance. Consequently, differing material volatility will create slow changes in odour profile during evapouration. When the top notes evapourate, the odour of the middle notes will predominate until they also evapourate and the base notes take over.

Within a constructed fragrance, a perfumer will usually add a fixative to retard the rate of evaporation of the most volatile substances. A fixative is usually an odourless or slightly odourous substance with a relatively high boiling point. These materials would include diethyl phthalate, ethanol, glycerol, isopropyl alcohol di-propylene glycol and propylene glycol. The relative quantity of solvent material in the fragrance influences the duration of evaporation of the total mixture. The problem with fixatives that have low vapour pressures and this tends to flatten a fragrance, often inhibiting the lift and diffusiveness of top notes. Other ways to slow down the evaporation rate of a fragrance is to skillfully mix and blend aromatic substances of low relative volatility within the fragrance that are also part of the theme of the fragrance.

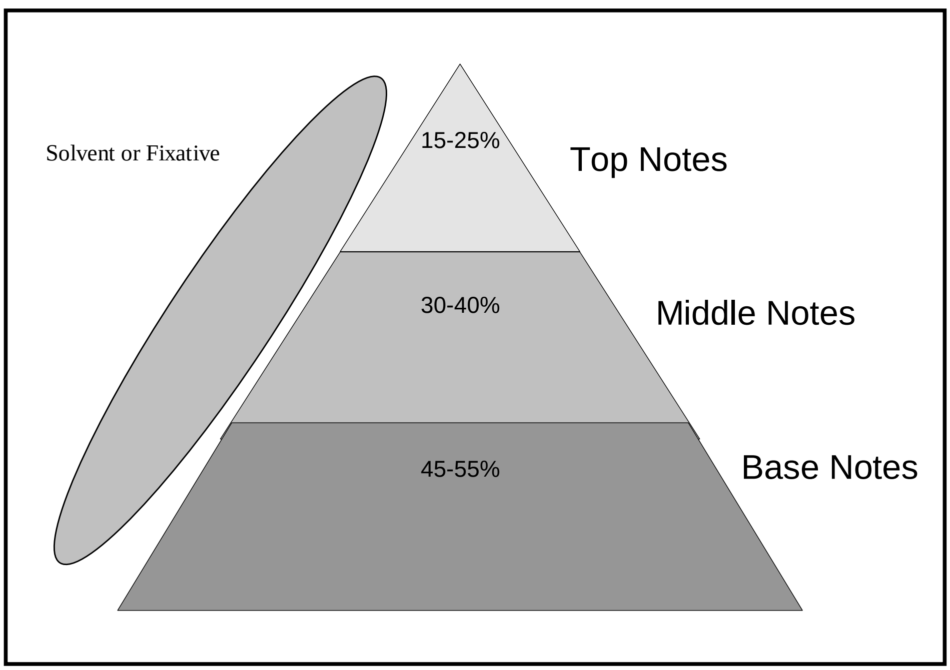


Figure 11.3. The Basic Structure of a Fragrance.

Table 11.20. A General Classification of Essential Oils into Top, Middle and Base Notes

Top Notes	Middle Notes	Base Notes
Niaouli oil	Citronella oil, Java	Cassie absolute
Bois de rose oil	Dill oil	Galbanum resin
Lime oil (distilled)	Guaiacwood oil	Opoponax resin
Mandarin oil	Styrax oil	Orris oleo resin
Coriander oil	Rose otto, Bulgaria	Tarragon oil
Myrrh oil	Orris absolute	Angelica root oil
Pennyroyal oil	Calamus oil	Birch bud
Sassafras oil	Marjoram oil	Benzoin resin
Spearmint oil	Violet leaf absolute	Birch tar oil
Cumin oil	Clary sage oil	Costus oil
Eucalyptus oil	Elemi resin	Cypress oil
Lavender oil	Myrrh resin	Labdanum oil
Neroli oil	Rosemary oil, French	Oakmoss
Bay oil	Cinnamon oil	Patchouli
Bergamot oil	Cloves	Pepper oil
Caraway oil	Orange flower water abs	Peru balsam
Copaiba oil	Broom absolute	Pimento oil
Grapefruit oil	Parsley oil	Tolu balsam
Aniseed oil	Auracaria oil	Tonka resinoid
Ginger oil	Cinnamon bark oil	Vanilla
Pansy oil	Geranium oil, African	Vetiver
Peppermint oil	Ylang ylang oil	
Tyme oil	Eucalyptus citriodora oil	
Violet absolute	Geranium oil, Bourbon	
Cedarwood oil	Ambrette seed oil	
Citronella oil	Gingergrass oil	
Lemon oil	Orange flower absolute	
Rose oil	Celery root	
Spike lavender oil	Hop oil	
Tagettes oil	Hyssop oil	
Lavandin oil	Rose absolute	
Carrot seed oil	Tuberose absolute	
Galbanum oil	Cassia oil	
Nutmeg oil	Neroli Bigarade	
Opoponax oil		
Sweet orange oil		
Petitgrain oil		
Elemi oil		
Cananga oil		
Fennel oil		
Lemongrass oil		
Mastic oil		
Palmarosa oil		

Poucher during the 1950s undertook a tireless project to classify aromatic materials according to their volatility. As boiling point and molecular weight did not directly correlate to volatility at room temperature, especially complex mixtures of essential oils, Poucher examined each material individually on a smelling strip over a four year period. He rated each material with a number between 1 and 100, designating patchouli and oakmoss at 100 because of their long residual odour on a smelling strip [13]. Poucher specified that top notes would correlate with scores between 1 and 14, middle notes between 15 and 60 and base notes from 61 to 100. Table 11.20. shows where a number of essential oils are generally considered in terms of top, middle and base notes in a fragrance.

As in the classification of odour types, the classification of volatility is also a subjective undertaking and subject to opinion. Lists of materials according to volatility are limited in perfumery application value due to other behavioural factors. Fragrance materials are also used in different proportions which lend them differing influence upon the total fragrance. Other characteristics such as the odour intensity, persistence, diffusiveness, odour threshold value [14], and stability are also important, especially in consumer product perfumery. Odour intensities greatly differ among the large number of materials available for fragrance construction. The relative contribution of any material will depend upon intensity. Material intensity is expressed as a ratio between the actual concentration of the compound in the total fragrance and its threshold value.

The top, middle and base note configuration was the traditional structure of a fragrance until the mid 1980s. Fragrances were built this way dating back to the days of eau de colognes and lavender waters in the 1800s, where emphasis was placed on maintaining harmony and equilibrium in fragrance composition [15]. Some perfumers began experimenting with raising the percentage of specialty ingredients from the trace amounts traditionally used in fragrances at the time. Encouraged by public acceptance, these new materials became used in larger doses over the years in what Martin Gras called the *bolero* effect. This led to the overdose of modern fragrances with these materials [16], leading to compositions of an individual character, with dramatic effects [17]. Although this form of structure lacked some of the delicate and ascetic qualities of the traditional fragrance, where maybe five materials make up to 80% of the fragrance, the odour profile of these ‘new’ perfumes remained largely unchanged during evaporation.

NEW PRODUCTS AND FRAGRANCE DEVELOPMENT

Fragrance is an important aspect of a new product and this section will briefly go through the process of a new fragrance development for a consumer product. Most consumer product companies will not develop their own fragrance, but leave it to a specialized flavour and fragrance house to prepare and present a submission for the proposed new product.

If a company is a large user of fragrance, then the chances are that a number of fragrance and flavour houses will regularly call on that company. Many fragrance and flavour houses are reluctant to call on smaller companies due to the costs in servicing them. Thus it is much easier for large companies with new projects of great potential to obtain the best submissions from flavour and fragrance suppliers. This has great implications for small companies with requirements for particular fragrances with specific characteristics, *i.e., alkaline or heat stable fragrances.*

To assist a flavour and fragrance house provide the best fragrance submission it is very important to provide the potential supplier with all the market and technical information they would require to create a fragrance that has the potential of meeting the desired expectations for the new product. This information is usually provided through a perfume brief containing the information set out in Table 11.21.

Table 11.21. The Contents of a Perfume Brief

1. **Product Type and Category**

   Define the product and the role the fragrance is to play in that product, *i.e., its role in the total product concept.* Some background information about the role of the new product within the company's overall product portfolio is also important. The more major a role a fragrance plays in the total product, the more important it is to disclose the type of product to the flavour and fragrance house.

2. **Fragrance Definition**

   This section expands upon the fragrance's role in the product, *i.e., the total product concept, branding, message the fragrance is to convey to the consumer, etc.* This section should also provide a brief olfactory description of the type of fragrance anticipated for the project and the specific communication task of the fragrance.

3. **Market and Brand Positioning**

   This section provides the product positioning in regards to product, price, position and promotion and brand proposition. It should also include target market(s), countries, age demographics, income segments, etc. It may also advise the proposed distribution channel and make relative comparisons with the market for clarity.

4. **Product Composition**

   This section will advise the product composition so the perfumer can understand the chemical requirements the fragrance must meet. This would include;

   a) list of material compositions
   b) Water-based, alcohol based, emulsion, aerosol, etc
   c) Solid, liquid, gas
   d) pH
   e) Odourous background of other ingredients

   If possible a non-fragranced base should be supplied for evaluation.

5. **Manufacturing Procedure**

   This section should briefly describe the manufacturing procedure, especially heat factors and order of ingredient additions to the process. The method of addition to the batch is also important.

6. **Packaging**

   The types of packaging used are important for the perfumer to know what materials could potentially be affected by any fragrance. This would include the method of closure.

7. **Conditions of shipping and storage**

It is important to know how harsh these conditions are and the anticipated length of product storage before sale and consumption to determine required shelf life.

8. **List of Q.A. tests required of the product and fragrance**
   This section lists the Q.A. and Q.C. tests both the product and the fragrance must meet.
9. **Cost Guidelines**
   Should be expressed as the cost per given quantity of finished product as this does not penalize a supplier from submitting a highly concentrated fragrance.
10. **Fragrance Volume Estimates**
    This is important so the flavour and fragrance house can make a decision on how much time and effort they should allocate to the project.
11. **Submission Details**
    This last section will outline the submission details and how many companies are making submissions. This section also tells the potential supplier how many proposed fragrances can be submitted and the sample requirements, *i.e., volume, if made up in finished product, etc.* This section also details the submission timing. Sometimes the company may specific a pre-submission session for evaluation.

Once a flavour and fragrance house receives a submission, the project team will evaluate the value of the submission to the company and make a decision how much time and resources it will allocate to the project. If the project has only minor value to the company, existing fragrance libraries may be scanned for potential fragrances that fulfill the customer criteria. These fragrances can be tested in the product base and modified if necessary to meet any specific technical requirements.

It is the job of the perfumer to develop or 'create' a fragrance that fits all the criteria specified in the perfume brief. He or she maybe guided by the rest of the project team, but must be outgoing enough to express his or her will. A perfumer would have undergone a period of very specialized fragrance training and then spent a number of years under supervision of another perfumer in an apprenticeship before being considered a perfumer in their own right [18]. In larger flavour and fragrance houses they would have spent time developing fragrances in other markets for experience. Successful perfumers are those who have a great knowledge of the strengths, weaknesses and versatilities of the raw materials they use, the nature of the products they go into, and can use that knowledge to fulfill commercial conditions required by industry customers.

A perfumer developing a new fragrance in a commercial situation has the options of either selecting an '*off the shelf fragrance'*, modifying an existing fragrance, using a base, reworking an existing fragrance, matching a fragrance, or creating a new fragrance totally from scratch.

The first action after receiving a perfume brief is to scan the existing company library for any fragrances that may match or closely match the criteria required *(fragrance type, product, market positioning, cost, etc.)*. Library samples that were not accepted in previous submissions may be suitable without any modification or act as a base for slight modification for re-submission. If the cost of the library sample is above the customer criteria, it can be reworked with more cost effective materials to meet the required cost.

Many fragrances are constructed from a base. Bases are either painstakingly developed by a perfumer for their own use or purchased from another company, usually another flavour and fragrance house that has some special expertise or access to specific materials not normally available to the general industry. Bases can be simple accords of two or more materials to complex perfumes in their own right. The distinction between specialty materials and bases is often confusing as many fragrances deliberately display a profile dominated by a few materials, as the case of the *Bolero* effect mentioned previously. This can be seen in *Eternity*, a sweet floral powdery fragrance which is heavily dosed with benzyl salicylate and Iso E super, somewhere around 25% of the total formulation. Traditionally bases were floral, where many specialty bases resembled the classics and other fine fragrances, which could be developed into hybrid fragrances, usually for cosmetics and personal care products. These are still sold around the world by a few companies specializing in these bases because of the enormous work that has gone into creating them. Fruity, woody and marine and metallic bases have grown in importance over the last few decades.

A large amount of work perfumers do is to rework fragrances to meet lower cost budgets due to the competitive commercial demands of the marketplace. Sometimes fragrances also have to be reworked because of an unavailable material, usually natural, with a substitute. Reworking a fragrance involves taking out an ingredient like violet leaf absolute or jasmine absolute for example and replacing it with alternative materials such as the same natural material from another source, or a cost effective synthetic base. This must be achieved with minimal odour change and the perfumer must adjust or add other materials to try and maintain the same profile. This method is also used in creating cheaper and more cost effective versions of fine fragrances for application in cosmetics and personal care products.

Some customers require matches of existing fragrances. These matches could require a fragrance along the same direction, a close match or a total identical replacement. Perfumes along the same direction require only matching of the basic accord. Variances can be made of the basic fragrance to create a similar, but differentiated fragrance within the same family of the original. Close and identical replacements not only require duplication of the basic accord, but also duplication of other notes that complete the body of the fragrance.

Fragrance matching can be achieved by olfactory analysis using the human nose through a number of simple olfactory tests and methods. The disadvantage in this method is the perfumer will not for sure really know the identity of the materials that make up the perfume. Gas chromatography and mass spectrometry can also be used to assist in fragrance matching. The advantage of these modern forms of analysis is that they can identify both the major and minor components of a fragrance. However GC and GCMS will identify the individual chemical components, not an essential oil proper. The disadvantage in GC and GCMS analysis is that it doesn’t show the harmony and balance of the fragrance that human nose olfactory analysis shows.

Matching is a laborious task for the perfumer, as using both the above methods takes a long period of time. A company has to critically assess why it has been asked to match a fragrance before doing so, as it may be an exercise by the customer to make savings from another supplier, which besides having some ethical considerations, may only lead to short term business.

If a perfume with some originality is required, the perfumer will be required to create a new fragrance for the brief. How novel the new fragrance must be will depend upon the brief, although creating new directions from well known themes could involve putting a novel twist into a perfume, while maintaining the central theme. Completely novel fragrances are highly risky in the marketplace, and are usually not contemplated unless a completely new brand and/or product concept is to be launched by a customer. Perfumers usually develop their own creative styles in creating fragrances based on their years of training. This is heavily influenced by training, experience, the bases and raw materials readily available inside the company the perfumer is working within.

The challenge to the perfumer is to construct a fragrance that has the theme, the tenacity, with the balance and harmony, within the cost structure that the brief requires. Normally the perfumer will work within the architecture of the fragrance structure creating a fragrance that over time will behave according to the requirements of the product specified in the brief.

As well as arranging the fragrance notes to behave as the end product requires, the perfumer must blend the top, middle and base notes together with the fixatives in such a way that they will evaporate in balance over a particular time frame. Top, middle and base notes play differing roles in specific functional products, which have very product specific demands. For example, top notes in dishwashing liquids are extremely important, where middle and base notes must disappear very quickly so there is no residual fragrance on eating utensils after washing. Fabric softeners should have very long lasting middle and base notes so consumers can pick up the odour after clothes have been stored in the cupboard. The needs of fragrances also changes in products as they evolve, where for example two in one shampoos will have fragrances with longer lasting middle and base notes than shampoos that require the use of a hair conditioner after use. Air fresheners require very consistent top, middle and base notes that linger for long periods of time. Finally, the consumer product use culture is very important, where for example in countries where fabric conditioners are not used, the fragrances of laundry detergents will have longer lasting middle and back notes than in countries where consumers use fabric conditioner. These examples in fragrance structure are shown in Figure 11.4.

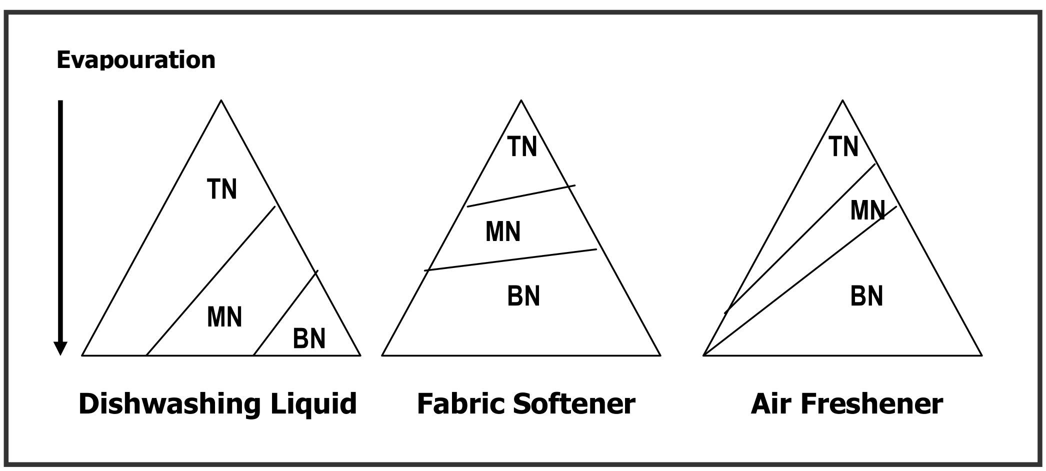


Figure 11.4. Some examples of the construction of top, middle and base notes in fragrances constructed for functional products.

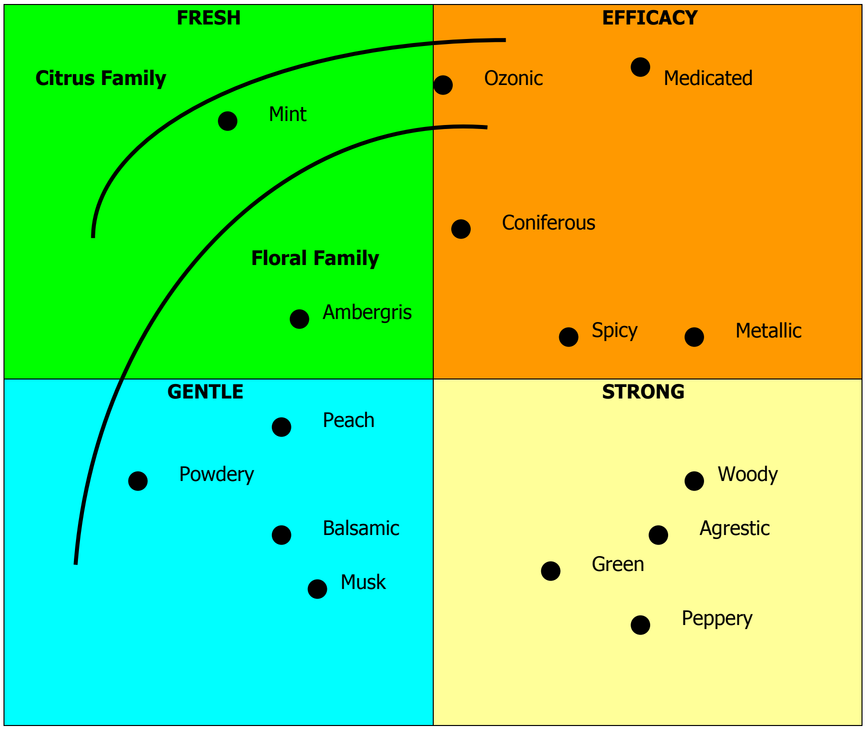


Figure 11.5. Psychological grid of fragrance interpretation.

The commercial importance of a fragrance is to support the efficacy, branding and theme of a product. Paul Jellinek developed a psychological grid of fragrance interpretation in 1954 and enhanced it again in 1993 [19]. Fragrances are signals which can communicate messages to consumers. This message must be converted into an odour. The perfumer must be aware of the issues involved, where various fragrance families can aid in suggesting gentleness, freshness, strength, and efficacy in a product. For example some citrus notes can convey fresh which is important in dishwashing liquids, while laundry products may require either gentle-efficacy or freshness-efficacy. A shampoo may require fresh and gentle or fresh and efficacy depending upon the message the perfumer wants to get across to the consumer.

Figure 11.5. shows a grid where different fragrance families are plotted within the four sectors denoting gentleness, freshness, strength and efficacy. Some individual notes from within a family can differ in their message from the rest of the family, as is the example in the floral family where some are gentle, others fresh, and others signifying strength and efficacy. These are all subjective classifications which are culturally sensitive.

New fragrance themes usually emerge through fine fragrances. Fine fragrance themes usually gain quick acceptance into functional products. This quickly erodes the originality of fine fragrances. There is almost a direct translation of fine fragrance notes into cosmetics and eventually household products. This has partly occurred because of consumer expectations of both quality and functionality and the development of new aroma chemicals which has enabled cosmetic notes to be portrayed into cosmetic and household products more economically than ever before. Some basic fragrance structures based on fine fragrances [20] are shown in Table 11.22.

Table 11.22. Odour Profiles of a Few Selected Fine Fragrance Themes

Joy Type **Floral**

Top Notes	Leafy green, aldehydic, peach, calyx notes	Floral green notes
Middle Notes	Rose, jasmine, Ylang-ylang, orris, orchid, muguet	Rich natural floral
Base Notes	Sandalwood, musk, civet	Floral balsamic

Diorissimo Type **Floral fresh**

Top Notes	Leafy green, bergamot, accenis, calyx notes	Fresh green notes
Middle Notes	Lily of the valley, Lilac, Jasmine, Rose	natural floral
Base Notes	Sandalwood, civet	Floral

Charlie Type **Floral**

Top Notes	Citrus oils, peach, hyacinth, estragon	Fresh green notes
Middle Notes	Rose, jasmine, cyclamen, Lily of the valley, carnation, orris	Light floral
Base Notes	Cedarwood, Sandalwood, Oakmoss, Musk, Vanilla	Powdery balsamic

Chanel No. 5 Type **Floral Aldehydic**

Top Notes	Aldehydic, Bergamot, lemon, neroli	aldehydic
Middle Notes	Jasmine, rose, Lily of the valley, Orris, Ylang-ylang	Light floral
Base Notes	Vertiver, Sandalwood, Cedarwood, Vanilla, Amber, Civet, Musk	Woody, powdery feminine

Opium Type **Oriental**

Top Notes	Aldehydic, orange, pimento berries, bay	Aldehydic Spicy notes
Middle Notes	Carnation, rose, Ylang-ylang, cinnamon, peach, jasmine, orris	Spicy floral
Base Notes	Benzoin, Tolu, Vanilla, Sandalwood, patchouli, amber, musk	Sweet warm balsamic

Table 11.22. Continued

Mitsouko Type		**Chypre**
Top Notes	Bergamot, lemon, mandarin, neroli, peach	Fresh fruity notes
Middle Notes	Jasmine, rose de mai, clove, ylang-ylang	Fruity spicy floral
Base Notes	Oakmoss, benzoin, sandalwood, cistrus, myrrh, cinnamon, musk	Mossy woody balsamic

Imperial Leather Type		**Fougere**
Top Notes	Lavender, Rosemary, anise, bergamot, lemon, petitgrain	Floral herbaceous notes
Middle Notes	Geranium, fern, carnation, heliotrope, cedarwood, patchouli	Floral woody
Base Notes	Moss, musk, vanilla, tonka, amber, leather	Mossy powdery

Denim Type		**Chypre Leathery**
Top Notes	Bergamot, lemon, tarragon, aldehydic, petitgrain, clary sage	Fresh spicy notes
Middle Notes	Rose, geranium, Jasmine, Lily of the valley, myrrh, carnation	Spicy floral
Base Notes	Vertiver, Cedarwood, Leather, moss, musk, amber, olibanum	Mossy warm balsamic

Drakkar Type		**Citrus Grren**
Top Notes	Bergamot, juniper, green, lemon, mandarin, lavender	Fresh floral green notes
Middle Notes	Pine, cedarwood, jasmine, spice notes	Woody, resinous
Base Notes	Musk, moss, amber	Mossy

The final aspect of developing a fragrance for a product brief is performance in the actual product. This involves two aspects, firstly the technical issues of the fragrance and the product and secondly the performance of the fragrance in the product.

Some aromatic materials over a period of time can interact with other materials. Chemical reactions can take place which could affect the quality of the fragrance, product and/or effect the packaging. Thus fragrance can cause a number of technical Difficulties. For example, fragrance can affect viscosity of liquids [21]. Many cosmetic preparations contain free fatty acids, even after neutralization. Some aromatic materials like terpenes tend to polymerise on exposure to light and air and discolour. Stability of water in oil and oil in water emulsions in lotions and creams present many problems even before the consideration of fragrance in the product. Many materials are not suitable in high alkaline or acidic media. Consequently the perfumer must exercise great care in material selection to avoid any potential and adverse chemical reactions.

Another important technical function of a fragrance is to cover any base odour of the product. Many un-perfumed products will exhibit fatty-oily odours from the surfactants. Solvents and paraffin based materials will give off coarse chemical odours. Other ingredients like ammonia, urea, some preservatives and active insecticide ingredients generate strong base odours which require masking just to make the product pleasant. A perfumer will skillfully create a fragrance that uses these background odours as 'part of the fragrance'.

On the performance side, the fragrance must have the correct substantivity to match the requirements of the application. Substantivity refers to the residual of the fragrance left on materials such as skin, fabric and surfaces, rather than its volatility. Skin lotions, fine fragrance and fabric conditioners require fragrances to be very substantive, where dishwashing liquids and vegetable washes should not leave residual odours after washing and drying.

Safety and consumer assurance is important in fragrance. Fragrance ingredients, once completely self regulated now come under greater scrutiny of regulatory authorities. Now in many jurisdictions, fragrances coming into contact with humans require derma-logical and toxicological test data before they can be sold in the market. These issues have been discussed in detail in Chapter 7. In addition, fragrance ingredients must be acceptable to consumers for religious reasons. For example, the Islamic and Jewish communities both require that materials be free of any animal matter that has not been slaughtered according to their respective religious rights, and forbids any material originating from swine. *Halal* and *Kosher* certifications are required.

The selected and/or developed fragrances are usually panel tested by the project flavour and fragrance house project team to bring the number of fragrance down to the number required for submission. The final fragrances will be submitted to the customer with their relevant presentations. The customer will undertake its own internal evaluation of each submission and select the fragrance most suitable for the new product.

Flavours

The use of flavours in food is centuries old, once relying on fresh and dried spices and fruit juices, etc., as the raw materials that were carefully blended and added into prepared food to enhance the taste. The development of expressed concentrates, alcohol and water extracts, essential oils and solvent extracts resulted in a much wider range of materials to use in flavour creation. Natural materials like essential oils have played an important role in the creation of natural flavourings. The industry uses many aroma chemicals found in nature, but synthesized by chemical processes, as nature identical ingredients. Therefore both natural aroma chemicals and nature identical are used. Through biotechnology, enzyme hydrolysis of plant and animal materials, creating hydrolysed proteins have assisted in widening the versatility of available flavour materials. The main types of materials available for flavour creation are shown in Table 11.23.

Table 11.23. The Main Types of Flavouring Materials

Flavour Material	Description	Example
Oleoresins	Usually obtained from a resin through solvent extraction and then concentrated through evapouration of the solvent through vacuum distillation.	Pepper and capsicum oleoresin
Resins	Water insoluble, solid or semi-solid exudates from trees. Usually in the form of gums and balsams.	Oakmoss
Essential Oil	Steam distillation or cold expression.	Peppermint oil, lemon oil, cinnamon oil, cumin oil.
Resinoids	Extracts of gums, balsams or resins, and materials such as orris root. Used as fixatives.	Labdanum
Rectified Oils	An essential oil which has been redistilled to improve the odour and/or remove the terpenes from the oil. Vacuum distillation can also be used to remove the colour and some unwanted components, like phototoxic components of bergamot oil.	Clove, bergamot and cassia oils.
Aromatic Extract	An aromatic material obtained through CO_2 extraction.	Coffee extract.
Extract	A concentrated plant extract usually in alcohol	Vanilla extract, pandan extract.
Herbs and Spices	Ground or processed in other ways *(i.e., freeze dried)* herbs and spices.	Lemongrass, ginger spice.
Natural aroma chemicals	Isolated from a parent essential oil by physical means	Benzyl benzoate from Tolu and Peru balsams.
Nature identical chemicals	Chemicals that occur in nature but are obtained through chemical synthesis	Vanillin.
Artificial aroma chemicals	Chemicals that do not occur in nature	Ethyl vanillin.
Reaction flavours	Amino acids thermally treated and reducing carbohydrates through the Maillard process.	Malt flavours.
Smoke flavours	Produced through pyrolysis	Smoked ham flavours
Specialty Materials	A material, either natural or synthetic or a mix of both that provides a base for further building upon to create a flavour compound. These are usually proprietary products.	Lyral, etc.

The prime importance of essential oils for flavouring remains in the non-alcoholic beverage sector where essential oils are the best materials to utilize to create the body of natural flavours. This is one of the most important parts of the flavour industry. This sector has expanded over the last few years to develop sport beverages and more exotic flavours in products like tea. The types of products in the beverage industry include;

1. Soft Drinks
   a) Sweet water-based (pH balanced)
   b) Juice and pulp based
   c) Carbonated
2. Dry Beverages
   d) Instant beverages
   e) Fruit beverages
   f) Tea and coffee mixes (with/out creamer/sugar)
3. Other Beverages
   g) Flavoured ice tea
   h) Coffee-type beverages
   i) Milk beverages
   j) Soy beverages (with/out additives)
   k) Other.

The process of developing a flavour is similar to developing a fragrance, except focus is required upon both taste and aroma of the flavour. The flavour material developed will be tested for stability through harsh cooking, heating and pasteurization processes.

There are basically three categories accepted by the industry in flavours, natural, nature identical and synthetic. There is some demand for natural flavours in some product segments, however nature identical (legally recognized in US jurisdiction) is the more common approach to formulating flavours. The majority of flavour formulations are synthetic materials, although essential oils still play an important role. Some examples of flavour formulations are found in the Table 11.24.

Table 11.24. A Basic Synthetic Pineapple Fragrance

Aldehyde C10	5
Allyl caproate	3
Ethyl formate	5
Ethyl heptylate	5
Ethyl valerianate	5
Geraniol	18
Isobutyl butyrate	12
Phenyl ethyl alcohol	32
Ethanol 95%	500
Distilled water	415
Total Parts	**1000**

The above example represents how some flavours are compounded with almost totally synthetic materials. A flavour formula utilizing natural materials can be seen in the basic blackcurrant flavour below, where essential oils play a secondary role to aroma chemicals.

Table 11.25. A Basic Blackcurrent Flavour

Acetaldehyde	50
Amyl acetate	50
Amyl butyrate	280
Anisaldehyde	10
Buchu leaf oil	12
Cinnamon oil	20
Ethyl acetate	150
Ethyl benzoate	25
Ethyl heptanoate	25
Geraniol	5
Isobutyl acetate (10% solution)	295
Lemon oil	40
Neroli oil	3
Orris oil	20
Vanillin	15
Total Parts	**1000**

Table 11.26. A Basic Natural Pineapple Extract

Part A	
Fresh peeled and crushed pineapple	10 Kg
Ethanol	10 Kg
Macerate and express for 5 days.	
Add ethanol to the residue	10 Kg
Let stand for another 5 days	
Add vanillin	0.012Kg
Distill	
Part B	
Ground Pineapple peels	10 Kg
Ethanol	10 Kg
Let stand for 5 days and express the residue.	
Add ethanol	10 Kg
Let stand for 5 days	
Add Amyl butyrate	0.001 Kg
Distill	
Put part A and B together and redistill.	

Producing flavours is much more involved than blending aroma chemicals and essential oils. Unlike the perfumery industry, flavours often require the capturing and concentration of flavours from vegetable and fruit materials through physical processes of soaking, maceration, expression, crushing, and smoking, etc. Through the example of Table 11.26. one can see that there is much more work involved in producing natural extract flavours than fragrances. As many flavours are in the form of powders, there is often much work involved in crushing, grinding, mixing and freeze drying materials.

THE NEW PRODUCT DEVELOPMENT PROCESS

Before examining other applications of essential oils, there is a need to look at the general processes companies undertake to develop new products.

Most companies have basic sales and profitability objectives which are underlined by a desire for growth. For companies to survive in the long-term, these objectives should be undertaken in a sustainable way where revenue should cover all costs, compensate capital with the ability to repay debts and replace external resources used. Part of being sustainable is a requirement to replace products that are generating decreasing levels of revenue as they come to the end of their lifecycles.

Instinctively growth is often considered an important objective for an enterprise. Companies have three basic ways to pursue this objective. A company can expand its geographical marketing and sales coverage, *i.e., launch its products in new markets*, acquire new businesses and their products, or develop their own new products.

New product development is a way for an enterprise to maintain its competitive position in the marketplace. Even companies with products based on new *'breakthrough'* technologies cannot maintain their competitive advantage forever and must continue to develop and acquire new products in order to keep in front of their competitors who will eventually catch up with them. Products have a limited life and new products must be created to replace those near the end of their lifecycle. Even in markets that are considered stable there is continual change due to the influence of changing consumer tastes, preferences and new technologies being introduced. This is leading to shorter product lifecycles. Brands may continue, but the products under the brand umbrella will normally change regularly in an almost seasonal fashion (see Figure 11.6.). Thus companies that don't continue to develop new products run the risk of becoming irrelevant to the marketplace, threatening their survival. Markets have changed so rapidly that 40% of the Fortune 500 companies that existed in 1975 do not exist today [22].

New product development is a very important aspect of dealing with the competitive environment and facilitates competitive advantage to a firm. New products are a strategy that companies utilize to introduce enhancements to their offerings to the market, so they can claim benefits over their competitors. If encumbering companies don't launch new products, their competitors will launch products that may give them potential advantage in the marketplace. This can potentially erode other company market positions, revenues, profitability and even threaten survival of firms that do not take any retaliatory action. The significance of this strategy can be seen in the fact that today, on average, 33% of a company's revenue will come from products launched within the last five years [23].

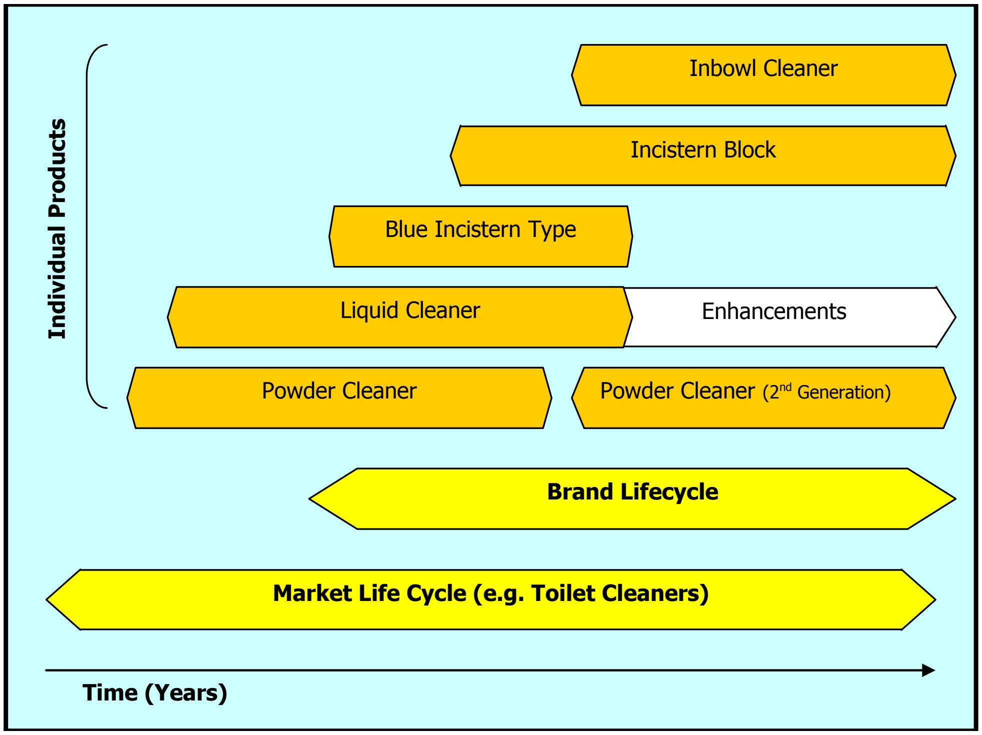


Figure 11.6. The Market, Brand and Product Lifecycle (example toilet cleaner market).

Products have much shorter lifecycles than a few decades ago. For example, pharmaceutical products once had a market life of over 25 years now survive less than 7 years on average. Likewise the lifecycles of processed food products has decreased from 20 years to less than 5 years. A cosmetic product will survive in the market around 3 years before being phased out of the market, where once these products would last more than a decade in the market [24]. Although individual products have much shorter lifecycles, the brand is much more enduring, being continually revived through new product launches under the same umbrella. Companies tend to invest in the brand over the product as a strategy to cope with shorter product lifecycles. This is seen with the major cosmetics and household products brands in the marketplace today.

The purpose of new product development is to find an opportunity and make a strategic decision to develop a product and competitive strategy to meet the basic enterprise objectives of sales, profitability, growth, sustainability and survival. This is manifested through new products being launched in the market place. New product development steers the direction of the company and will have great influence upon the firm's value propositions to consumers and ultimately, it's relative competitive advantage. While new product development is one of the most important aspects of competitive strategy, it is also one of the riskiest. New product failure rates have risen from 45.6% in 1961 to over 80% today [25].

The new product development process begins with the discovery of ideas, screening them for potential opportunity and making a decision to exploit the opportunity. This is very similar to the entrepreneurial process. The new product development process will shape the direction of the company as it will create future sources of revenue for the enterprise. If the new product fails to reflect a need in the marketplace, it is most likely to fail, bringing heavy consequences to the enterprise. If a new product is not differentiated from competitors' products, this will lead to tough competition and price cutting. This will erode potential enterprise revenues and make it very difficult for the new enterprise to survive in an industry of larger and stronger firms. Conversely, if the product is highly differentiated from competitors' products in the marketplace, the new venture will have to make enormous promotional efforts to establish it in the marketplace, requiring a lot of time and resources to do so. The place of new product development within the interrelated web of company strategies and operations is shown in Figure 11.7.

Fundamentally companies regardless of their size adopt similar new product development processes. There is very little difference in the information needed to develop ideas and create opportunities and the procedural steps that need to be taken between companies of varying size. However the new product development process is much more haphazard in a small and new business than within a large company. Yet many small businesses create very successful products just as well, if not better than many large corporations. Although many academics and practitioners advocate a formal new product development process, there is little evidence to suggest that any formal process is more effective than the haphazard way a new venture undertakes new product development. In fact many corporate organizations are looking for ways to make their organizations more entrepreneurial, particularly in the area of new product development.

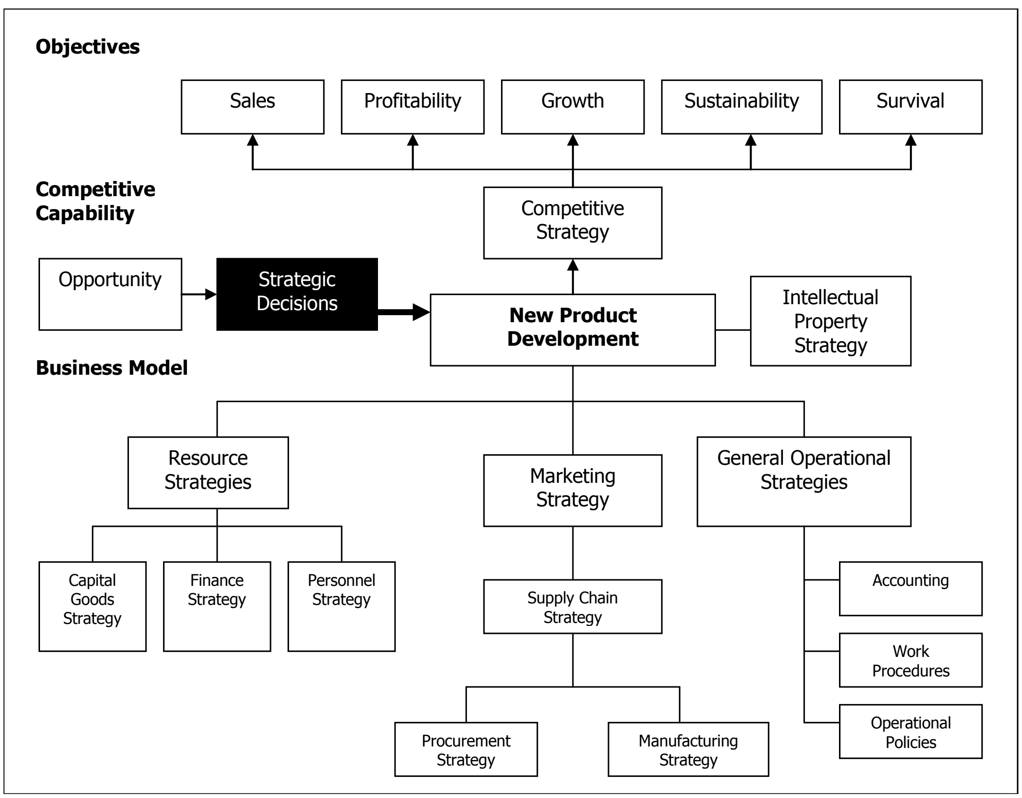


Figure 11.7. The Relationship of New Product Development to the Enterprise.

No standard set of procedures or processes exist in new product development. There are department stage, activity stage, cross functional, decision stage (stage-gate) and process models espoused in the literature. Different industries take different orientations towards new product development, where for example pharmaceutical companies will be dominated by scientific, technological and regulatory issues, while food companies are dominated by consumer research that leads to minor product changes. Yet some industries still take a craft approach, like fragrance creation. A general procedural diagram of the new product development process is shown in Figure 11.8.

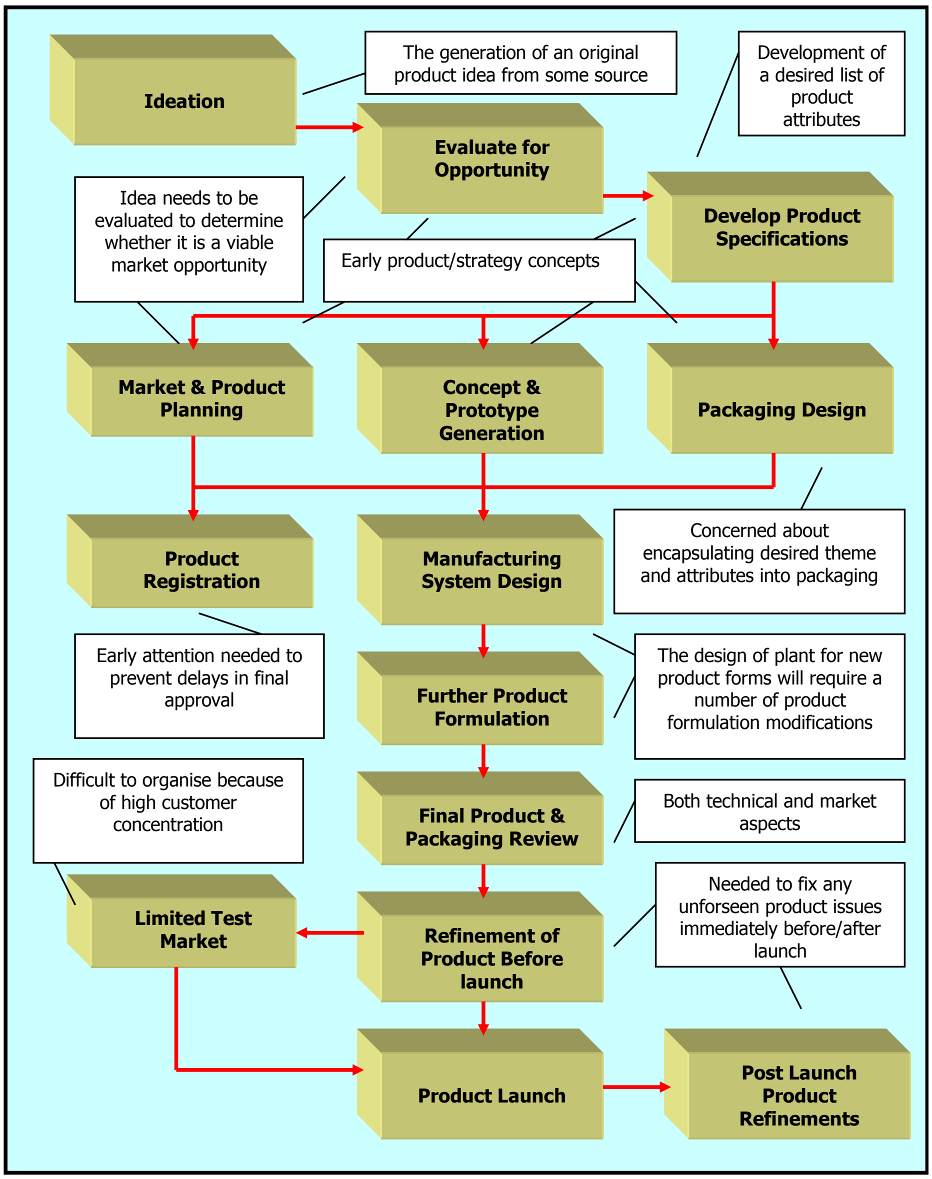


Figure 11.8. A General Procedural Diagram of the New product Development Process.

There is a strong inter-connection between all facets of the new product development process. Opportunity identification and selection is the heart of the process. Opportunities can be identified from ideas through asking pertinent questions, relying both on hard data and intuition for answers. Once an idea is considered viable, product specifications can be developed. Product specifications at this early stage represent a ‘wish list’ of product attributes that managers feel are desirable and necessary for the product success in the market place. The objective is to identify attributes that will give the product an edge over existing competition in the market place.

After desirable product specifications have been created, the processes of concept and prototype generation, market and product planning and package design takes place. Where additional information is gained during these stages, the original idea should be re-examined and re-screened to ensure the opportunity is really viable from the market and technical point of view. The product registration process is often commenced early during the new product development process because of the time lag between application and approval, particularly in jurisdictions which require product pre-registration before launch.

The new product development process will then focus on manufacturing development, where methods must be designed to efficiently manufacture the product. This may require further product reformulation and packaging modifications to facilitate product manufacture. There will usually be a final market review before launch. Sometimes a test or limited market release is undertaken within a single group of stores or a single country market before a wider launch is made. However this option is much more limited than before because of increasing customer concentration and the difficulty of achieving selective distribution. Finally after the product launch, some refinements to the product are usually required. This is usually because of unforeseen technical and market issues.

In reality, new product development is influenced by assumptions, short cutting the logic process through the use of heuristics. Heuristics are little rules of thumb firms implicitly develop through executives’ collective experience in the industry and have grown to take these beliefs as givens [26]. For example *‘30% of people who hear about a new brand will try it’.* Hunches, gut feeling and intuition are heavily relied upon to develop products. This is contrary to what most of the literature about new product development advocates.

Companies competing in the same industries with similar products have basically the same strategy choices and generic themes to pursue with similar groups of customers. Companies launching products in new markets usually face the same competitors or different competitors with similar products. Points of product differentiation occur from the way management groups in different companies hold assumptions set into heuristical rules that put different weights on particular product aspects and issues. This will result in the development of products that differ between companies because of the different sets of heuristic rules relied upon. Thus the influence of heuristics is the primary way a firm differentiates itself from its competitors.

Successful new product development is influenced by experience. Individuals must have the discipline and maturity to know when they are biased in their thinking. Industry knowledge is very important, but it must be used objectively without emotional bias, *i.e., ‘we have a long history in that market and it is ours’*, or *‘we have always been successful with new products in this market’*, etc. These are cognitive biases that can lead to failure, that some would call *market arrogance*.

As MNCs employ more fresh graduate executives to fulfill managerial roles in companies, the insider industry (experience) advantage is weakening. Marketing executives without *grass root* industry experience, and passion for the industry, rely primarily on data without knowing the history for decisions. This has potential weaknesses for the purpose of opportunity identification. This potentially provides some advantage for the entrepreneur who has passion, diligence and sound intuition to be innovative in new product development. The *'new'* executives surrounded with market research and advertising consultants with the power to sign check books, so often get things wrong and wonder why in a country like Malaysia, a champaka fragrance – as beautiful as it is, is not accepted by consumers who associate the fragrance with grave yards.

The difficulty of developing new ideas that are real company opportunities can be seen in the realities of new product development below;

- Less than 5% of new products launched on the market are successful,
- Out of 100 new ideas, less than 2 become a commercial reality,
- Most companies are followers in the market and not innovators,
- Very few really novel innovations are ever launched commercially, and
- Most new products are actually only incremental steps in enhancement of products, rather than something completely new.

Although new product development is one of the most important strategies for enterprise sustainability, too many companies turn away from innovation in reaction to declining performance by cutting costs and expenses. They fail to look into the root causes, which may be product life-cycle or competitive based, requiring a new product development solution. This is usually a panic response further stifling innovation within the company. The new product development option is often seen by management as a more difficult alternative than purchasing a product or company outright. The following problems arise when the firm is under strategic pressure;

- Finding the right opportunities and appropriate innovation necessary to develop them,
- Reducing development times without reducing quality and innovation,
- Building and maintaining brand equity through a strong product,
- Integrating market, design engineering and production processes to produce, and products that are considered useful and desirable by consumers.

The above issues are traps for companies which do not view new product development as a continuous strategic process. New product development should be an implicit and continuous background process within the company and the minds of those who manage it.

TYPES OF NEW PRODUCTS

Among the large number of products entering the market each year, it is sometimes very difficult to distinguish what is really a new product. One could not claim that a new shampoo or hair conditioner launched into the market to be a new product unless there is some form of differentiation from what already exists in the market. Even if there was some differentiation, this must also be recognized by consumers. What is important according to Rogers and Shoemaker is that the product is perceived to be new by consumers [27], *i.e., the product is perceivably different,* relative to what is already on the market. The overwhelming majority of products launched onto the market are usually variations of existing products, with changes in either the brand, level of service, technology, features, packaging, price, or quality dimensions, or a combination of them. Only about 10% of new products introduced are both new to the company and the market – an item not sold by that company before or an item not sold in the market before [28].

There are many ways of classifying new products, given the many forms they can take. One way of classifying the types of new products is described below;

- ***New to the world products*** are the first of their kind in the market. They are usually something invented or enhanced by a significant change or advance in technology, such as a new discovery or different method utilising modified processes, materials or methods in producing a product. These products would revolutionise the market segment or even create a new market, which may require significant consumer learning to become familiar with the new product. New to the world products make up only a small proportion of new products and they are perceived as the riskiest types of new products to launch. Manufacturers have to deal with consumers' inexperience with the new concepts and incompatibilities with their prior consuming experiences, which act as barriers to consumer adoption [29].
- ***New Product Lines (New to the Firm)*** are not new to the market but new to the firm launching them into the market. This is where a company would enter a market for the first time, where success and profitability will depend upon the timing they entered the market, *i.e., as a pioneer, early follower, early or late majority or as a late follower*. Early market entry involves risk because of the newness of the product concept to consumers and doubt over their potential acceptance. Intellectual property value decreases as more firms enter the market with similar competitive products, leaving little room for product differentiation. Later market entry involves competitive risk due to the large number of direct competitors in the market. Late market entries also leave little ability to firms to differentiate their products from other companies, turning the product into a commodity Figure 11.9. shows the competitive situation, potential profitability and intellectual property (IP) value in relation to the time a firm enters a new market.
- ***Additions to Existing Product Lines*** are products that extend a range marketed by a firm. The product is different from existing products either in function or consumer application or as a variant of an existing product, such as a different pack size, flavour or fragrance, etc. Companies usually introduce additions to existing product lines to enhance their position in the market they are competing in, consolidate their position, to fill a perceived gap where consumers aren't served well (incongruity) or to react to competitors.

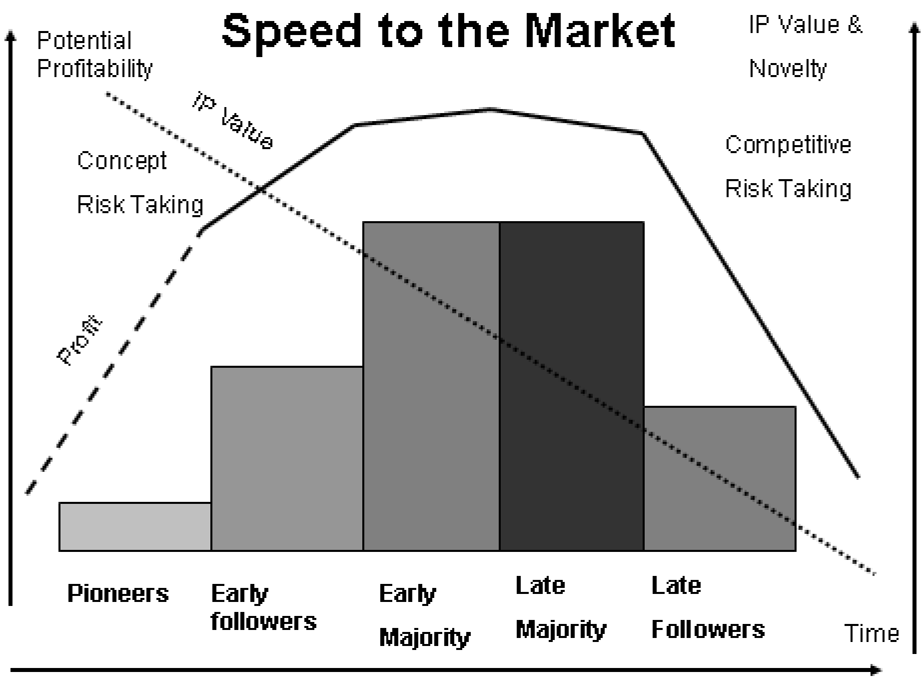


Figure 11.9. Competition, potential profitability and intellectual property (IP) value in relation to the time a firm enters a new market.

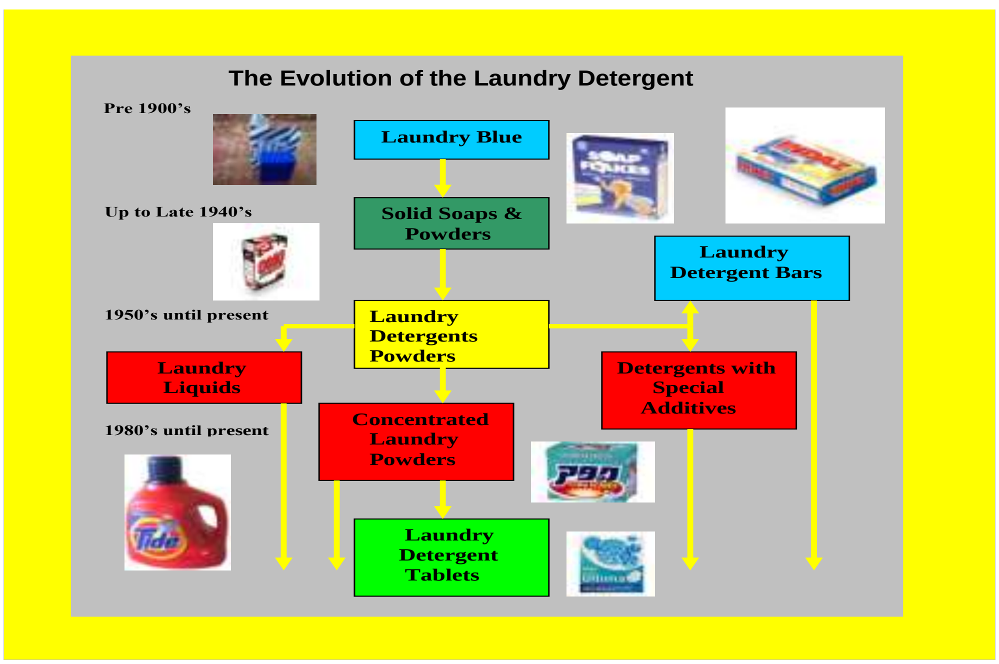


Figure 11.10. The Evolution of the Laundry Detergent.

- ***Improvements and Changes to Existing Products*** are undertaken to improve quality or make the product more convenient to use by the consumer. This is often a continuous process by companies, but when the product has been overhauled substantially, companies may undertake a re-launch or promotional campaign to inform consumers about the change. Sometimes products are phased out with a replacement product to maintain their competitive position in the market. This happens continually in the mobile phone market, sometimes a number of times each year.
- ***Product Repositioning*** are products that are retargeted at new consumer groups or a larger proportion of consumers sharing the same wants. For example, a detergent may be repositioned in a new pack size to attract new consumers, or aspirin was repositioned as a remedy for blood clots, prevention of strokes and heart attacks from an analgesic, which was under attack for health reasons and heavy competition from paracetamol based products.

Kleinschmidt and Cooper reported that around 10% of new products launched are *new to the world products,* which increases to around 18% in moderate to high tech industries. *New product lines* are about 26% of new products, but much higher at 37.6% in moderate to high tech industries. *Additions to product lines* are around 26%, but dropping to 18% in high tech industries. *Product changes and improvements* are around 26% of new products, 19.8% in moderate to high tech industries and *product repositionings* are 7%, but almost non existent in moderate to high tech industries [30]. Thus, the majority of new products are incremental developments and variations of existing products.

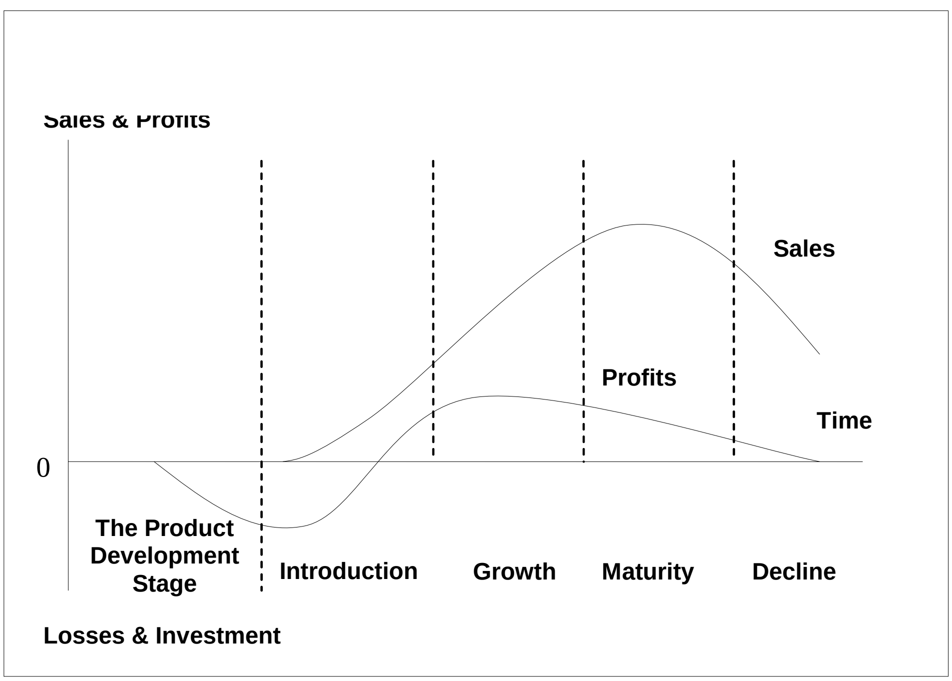


Figure 11.11. The Product Lifecycle.

Schumpeter described the market as a continual evolving situation where new products would supersede those already in the marketplace, through what he termed *creative destruction* [31]. Markets usually evolve through incremental product evolution, *i.e., through incremental product benefit improvements by firms launching products into the market to gain advantage over competitors.* Eventually, all outdated products will disappear and overtime the market will be represented by a set of completely new products.

However from time to time a firm develops a new product based either upon a completely new or a newly applied existing technology from an unrelated field. This creates a completely new form of product for that market. For example, the switch from soaps to synthetic surfactants is an example of a completely new technology. The launch of liquid laundry detergent in the 1970s is an example where technology was picked up from one area and applied to another. This happens in all markets, which can be seen in Figure 11.10. showing the product evolution of the laundry detergent.

Product Life Cycles

Products usually have a finite lifecycle which has a number of definable stages. This finite or limited lifecycle makes it necessary for companies to plan for new products to succeed those that are nearing the end of their lifecycle. However, it is extremely difficult to develop strategy according to the product lifecycle because identifying the exactly where the product is within it's lifecycle is extremely difficult [32]. Strategy can also have a cause and effect relationship and influence the product during each stage of the lifecycle. For example a change in packaging, fragrance, size, price, colour or other feature can prolong the product's time during part of the lifecycle, making it very difficult to accurately rely on assumptions for sales forecasting.

However a general understanding of the product's position in the lifecycle and the factors like consumer tastes, technology and competition can greatly assist in strategy development. The product lifecycle contains five distinctive stages where sales and profits follow distinct patterns [33]. This is shown in Figure 11.11.

The important and distinctive stages of the product lifecycle can be summarized as follows.

1. *The product development stage* occurs when an idea is evaluated and developed into a commercial product. This is where time is spent on developing the product without any sales revenue at all with increasing costs as time goes on. For an entrepreneur, especially during start up this can be a very straining upon personal resources, especially if he or she is devoting their full time to the project without any other source of income.
2. *The introduction stage* is where the product is first introduced into the market. Usually this period takes time, particularly for new enterprises, as they must get to know potential buyers. Established companies with strong relationships with customers may be able to gain much quicker distribution. Once distribution is established the product first moves very slowly and sales growth is slow while potential customers evaluate the product for potential purchase and use. The length of this period depends upon many factors. Profits will be negative or very low during

this period because of the high costs of introduction and necessary promotion required.

The introduction stage is the time when firms must focus on either educating consumers in the case of a new to the world product or convince them to switch brands. Pioneering products that are the first in the market have the potential to develop an incumbency advantage. However they can be very susceptible to followers who can sit back and observe the market, in order to gain some advantage through learning from the pioneer's mistakes. This is especially the case, if they can exercise stronger influence over the channels of distribution. To maintain market leadership, the pioneer must develop a comprehensive defensive marketing strategy (pricing & promotion, etc) to fend off challenges [34] from future competitors.

3. *The growth stage* will commence if consumers accept the new product and repurchase it on a regular basis. When this becomes the case, sales will begin to increase rapidly from both faster shelf off-take and product entry into new distribution points from the more conservative channel outlets that held off on initial purchase decisions. New competitors will be likely to enter the market and existing competitors likely to retaliate through discounting and more vigorous merchandising at store level to maintain their market-share.

On the manufacturing side, increasing sales volumes allow the firm to purchase larger quantities of raw materials and packaging, and negotiate lower prices leading to higher manufacturing margins and profits. The time/experience gained also allows fine tuning of the manufacturing process to make savings through increases in efficiency through process and labour experience. It is not unusual for direct manufacturing costs to come down 30% during this period. Likewise the time/experience factor allows improvement of product quality where the usual unexpected manufacturing and packaging compatibility problems are ironed out.

The primary objective of the firm during the growth stage is to maintain steady sales growth until the cost of increasing sales is higher than the extra profit gained. Shelf off-take velocity, distribution and competition are the three major factors that the firm needs to consider during the later period of the growth stage. Shelf off-take velocity is influenced by advertising and in-store promotion and is usually manipulated and maximized through coordinated promotional campaigns with corresponding in-store activities, utilizing purchased shelf space from stores, participation in gondola or block promotions along the aisles and providing discounts at strategic seasonal times, *i.e., food items leading up to major festivals*. Gaining extra distribution points in the existing channel and looking for distribution points outside the existing channel increases marginal sales of the product, *i.e., moving to the hotel trade to gain extra customers.* Competitor activity will influence sales growth according to the effort and activity they undertake in the market-place to counter the new product and promote and defend their own product. Competitors can be countered to some extend by adding new product benefits and variants to maintain competitive advantage over the competition. This is why some firms hold back on putting all potential features and benefits into the original product, until some future time when leverage over competitors is needed. This is a common strategy used by firms in the telecommunications, electronic, automobile and other consumer good industries.

4. *The maturity stage* is where sales slow down and plateau. Products usually enter this stage when there are a number of competing products in the market. During this period, competitors will use promotion and discounting to maintain sales levels and target erosion of competitors' sales to gain market-share. Competitors will also launch new product variants with added features and benefits to switch consumer loyalty towards their brands. During the maturity stage, where competition has peaked, profitability will begin to decline as extra promotion is needed and firms begin discounting and lowering prices. In markets where the channels of distribution are concentrated, *i.e., international retailers*, some of the smaller brands will be dropped from product ranges and even a category rationalization can take place, leaving only a small number of brands.

   Firms try to prevent erosion of profitability by employing strategies to maintain their market-share and sales level. Competitors will attempt to segment the market with new products designed with added features and benefits and seek new customers, *i.e., development of a special bleach for washing, rather than general purpose.* Failure to do this would normally result in loss of market-share in a competitive environment and relegation to marginality with almost total forced withdrawal from the market.
5. Eventually the product falls into *the decline stage* where sales begin to decline steadily. This can be a very gradual process in stable technology markets like food and household products or be extremely rapid in technology based products like media and communications. The speed of the decline stage is usually governed by the velocity that consumers change their preferences away from the product towards another. In food and household products this is normally gradual, as is with insecticides, or rapid when VCRs where replaced with VCDs and later DVDs in the home media industry, with the arrival of new technologies.

   When the cost of managing the product in the market becomes high in comparison with the returns, most medium and large companies with large product portfolios will usually drop the product. Smaller companies tend to hold onto a product until low sales make it uneconomic to maintain production. Sometimes when all brands have been withdrawn from the market, a small company can hold on to a minimum level of sales for a number of years without needing to support the product with promotion and discounts. The shoe polish market would be a good example of this situation.

The product lifecycle can be used to examine *product categories*, which include classes of products like personal care and insecticides, *product forms,* which would define the type of products, *i.e., in the case of shampoo, dry, normal and medicated and brands*, which are a specific or group of products marketed by a specific firm or group of firms. Different product categories will exhibit different life cycles. For example, petroleum products have an extremely long product life cycle because alternative technology and feed-stocks from renewable resources have not challenged the product category to date, even with all the publicity and debate about renewable resource alternatives. This can be compared to the life cycle of a brand of air freshener which is very short. However the product form as opposed to individual will have a longer cycle, *i.e., a liquid, aerosol or gel type or household room, cupboard or automobile air freshener.*

IDEATION

The initial part of the new product development process is pre-occupied with finding and developing ideas for new products. This is perhaps the most important aspect of the whole process, as it is where new ideas are spotted, evaluated and matched against the current competencies the firm possesses. Various strategy scenarios are extrapolated out to evaluate their effect and benefit to the enterprise, so that the best strategy solution can be selected. This is the most fluid and unstructured part of the new product development process where all these possibilities are evaluated in a way that does not resemble structured work [35]. The quality of information used (market data, knowledge of customers, technology costs, etc) has great bearing on the outcome and final result of this part of the product development process.

Cagan and Vogel described how potential opportunities gaps arise out of environmental change, driven by changes in social, economic and technology conditions [36]. Regulation also influences opportunity in consumer industries through governing what is allowed and what is not. Consequently changing regulation is another driver of product opportunity. These factors together drive product evolution.

Changing levels of consumer affluence, the opening up of the local and national economies to foreign competition and exponential improvements in technology are rapidly decreasing the life cycle of products in the market place. This is partly driven by changing consumer tastes and preferences. Consumer tastes and preferences in the Asia-Pacific region are very different today, than they were a decade ago. With the increasing fusion of desires, tastes and consumer preferences, overseas trends are quickly influencing what consumers buy in domestic markets. This is also reciprocal as domestic tastes also influence consumer tastes in other parts of the world. For example, brands like *Pizza Hut* are well known and are patronized in countries like Thailand, while *tom yum* soup, a culinary delight originating from Thailand has been accepted in many parts of the World. The reciprocal influence of consumer tastes can be seen in the rise of *fusion food*, which is now very popular throughout most continents. Consumers are influenced by the availability of greatly improved products, which encourages rapid superseding of existing products with new models, versions and complete new designs based on newer technologies.

New technologies also drive new product development. Product evolution is influenced through the creation of new materials that perform better and are more cost effective than existing ones. With environmental issues gaining importance, carbon credit schemes will force the development of carbon neutral or non-carbon generating *green* technologies and practices, resulting in new products into the marketplace.

Products are also affected by government regulation. Products and materials used in the manufacture of cosmetic, personal care and agro-products are much more heavily scrutinized than before. New regulations concerning raw materials can force complete reformulations and even complete rethinking of products, as we have seen in laundry detergents in the 1970s aerosol products in the 1980s. Occupational health and safety issues will force more consideration about safety issues. Regulation also greatly influences product opportunities.

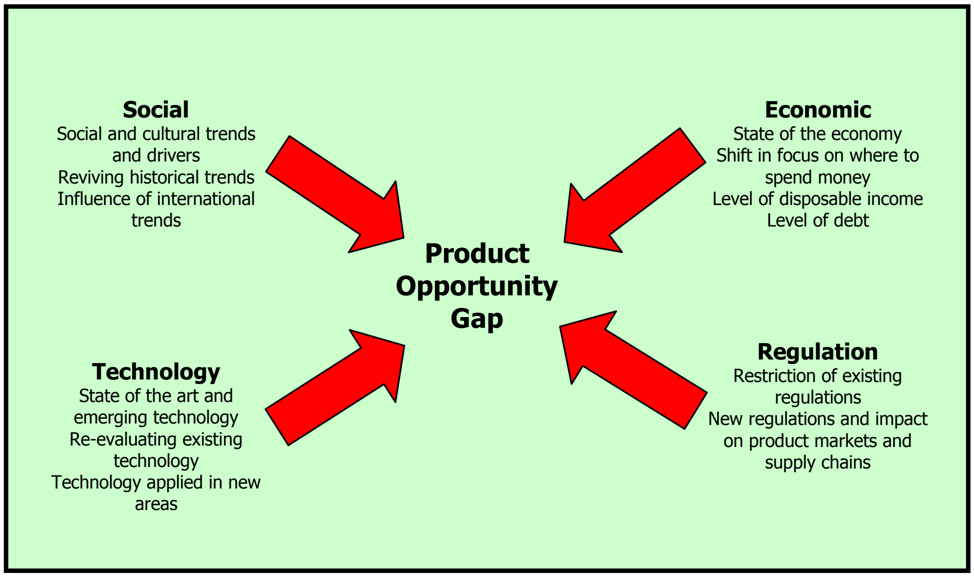


Figure 11.12. The Changing Environment Driven by Changes in Social, Economic, Technology and Regulation.

A company's focus is closely linked to the company mission. Executives tend to scan the environment according to areas the company mission defines. Companies will also tend to favour their stronger attributes, competencies, areas of strong knowledge and sense of history when searching for new ideas and opportunities. Thus companies have their own biases for what types of products they prefer to develop. This is normally linked and related with the company mission and competencies. Many small companies began their existence from a single idea where growth is based on the idea's progression. This can be seen in companies engaged in aromatherapy, organic cosmetics, agro-products and candles, etc. In these cases, the vision of the founder/manager is both the driving and filtering source of ideation for these enterprises. This is called company bias.

General ideas for products will come from anyone of the following sources;

a) Lateral thinking; the adaptation of other ideas in other industries, i.e., the development of blue toilet cleaners based on the concept of blue water used in aircraft toilets,
b) Ideas from handicraft and hobbies, i.e., air freshener candles,
c) Identifying changes in consumer habits, i.e., bath and shower gels, liquid soaps, etc,
d) Correctly perceiving changes in consumer tastes, i.e., green products
e) Changes in Government regulation in the areas of product registration, toxicity and/or occupational health and safety, forcing product change, i.e., disinfectants, herbicides, insecticides and aerosols,
f) New raw materials, two in one shampoo, SPF products,
g) Ideas from customers and friends,
h) Observation of everyday consumer problems, i.e., many household insecticides,
i) Adaptation of existing institutional products, i.e., solvent cleaners,
j) Observation of products overseas (other markets), i.e., overseas visits,

k) Observation of products in the domestic market,
l) Ideas from suppliers,
m) Trade magazines,
n) Trade shows and conferences,
o) Ethno-botanical literature, aromatherapy products, insecticides, etc., and
p) The internet.

IDEA SCREENING AND OPPORTUNITY IDENTIFICATION

The basic difference between an idea and an opportunity differs, in that an opportunity is capable of being exploited to the benefit of the person or organization that has constructed the opportunity, where an idea is yet to be viability tested for potential to benefit anyone.

Opportunity must be constructed from stimuli in both the immediate and outside environment. Consequently opportunity is a cultural phenomena. Culture influences how we perceive the environment [37], how we network and how we shape product/strategy. The ability to perceive opportunity results from the fusion of cognitive attributes, education, experience and skills, which together influence the way we see opportunities [38]. Seeing opportunity also requires tacit or implicit knowledge, explicit knowledge and experience. As peoples' knowledge and experiences differ, opportunities will be seen differently.

The way people see opportunity is influenced by the way they see the environment and the level of their knowledge, which makes opportunity a relative concept. The concept of opportunity as a construct is depicted in Figure 11.13.

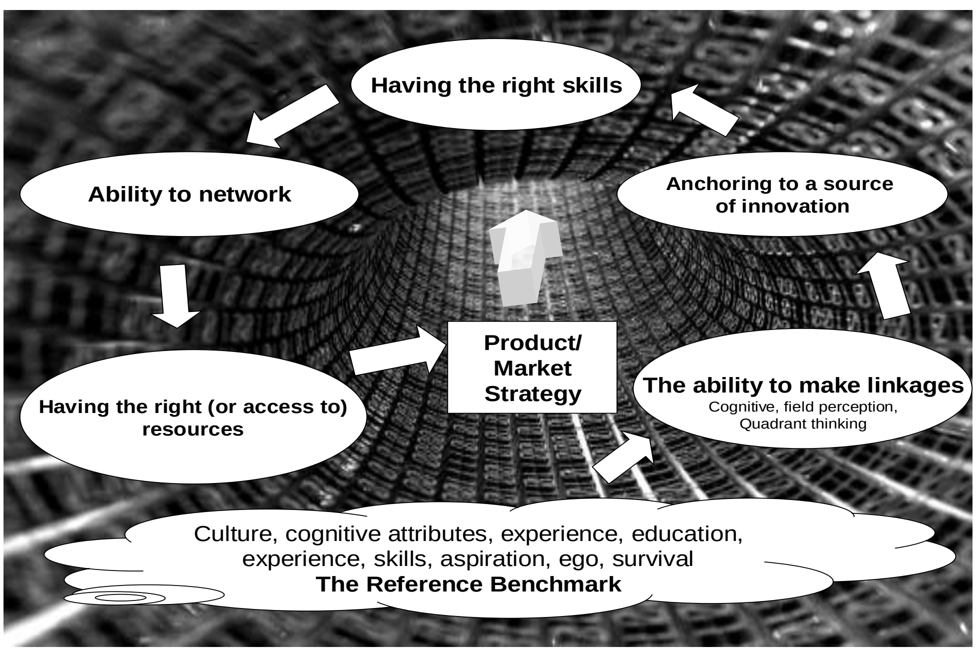


Figure 11.13. A depiction of Opportunity as a Construct.

Opportunity perception can only begin with a reference point. General life experience and exposure to travel tend to widen the scope of sensing opportunity, while individual and group tastes, preferences and customs narrow the ability to sense and see opportunity gaps. Thus opportunity gaps are a social phenomenon. The human ego also plays a role in providing an individual or group with the self assurance, dedication, responsibility, accountability and courage, to assist in seeing opportunity. The ego develops within individuals a sense of survival, perfection, self satisfaction, etc., playing a role in motivating the individual/group to actively scan for opportunity.

To construct opportunity, linkages must be made between apparently unrelated things. For example, the *Ammeltz Yoko Yoko* brand of methyl salicylate muscle relief lotion, manufactured by Kobayashi Pharmaceuticals in Japan [39], well known in South East Asia utilizes a membrane dispenser cap similar to the one used for many paper glues – something totally unrelated with the original product.

Herman Witkin studied peoples' perceptual styles for 30 years and found that people perceive the environment in one of two ways. Some people would perceive the environment and be bound up by all the detail, where they would be deemed *field dependent*, while others would be able to pick individual items out of the complex environment and would be deemed *field independent* [40].

From further studies, Witkins found that field dependent students tended to favour social sciences and education, while field-independent students tended to favour the natural sciences, mathematics and engineering. Field dependent people would rely more on social information and relate to others for opinions, look for social interaction and generally be orientated towards people. Field independent people function with more autonomy and display a more detached and impersonal orientation to others. They are not very interested in others opinions, keep their distance from others and not very social [41]. Further studies after Witkins death found that field independent people tended to be less distracted from stimuli in the environment and able to concentrate on what they felt was necessary to focus on and also able to remember more details than field dependent people [42]. Other studies have shown that field independent people are able to pick out themes more easily in multi-media presentations than field dependent people [43]. Field dependence-independence shows that people also perceive and process information differently. Field independent people are good at selecting information in resource rich environments and block out what is not important, while field dependent people tend to process information in chunks and are good at seeing connections between pieces of information [44].

The above research has implications for the way people learn and how different people perceive environments. This also has great implications in seeing opportunities and developing strategy. Even the nature of information and how it is formatted and presented will influence perceptions. Field dependence-independence also hints at how different people will display creativity skills. Field independent people are skillful at analyzing very complex situations and extracting what they see as relevant information from the stimuli of information, but will neglect social skills. Field dependent people will look more holistically and use their strong social skills to put things more in social contexts than field independent people [45]. Field perception concepts provide some very useful insights into how we perceive and construct our ideas.

Any new opportunity is the result of a creative process that has utlised a source of innovation to create something new or novel, utilisation different marketplace knowledge, use different relationship patterns, the ability to utilise a channel of distribution, a better ability to organize the delivery of product or service, or operation in the market. This will lead to product differentiation from other competitors and may provide some market advantage.

Anchoring the idea to a source of innovation will assist in creating sources of new products, strategy and competitive advantage. Peter Drucker postulates there are seven primary sources [46]. Each source of innovation will have some potential strategies that are best suited to the source of innovation. The firm will also require relevant competencies to benefit from the potential source of innovation and strategy. Sources of potential innovation, matching strategy and competencies required are outlined in Table 11.27;

Opportunity can only be realised through possessing the right skills and core competencies to enable one to exploit them [47]. Competencies and skills influence the ability to see ideas as potential opportunities and select the best ones. Personal skills are vital to developing products and strategies. This has great influence over the ability to develop competitive advantage, which ultimately differentiates the product and venture from others in the market.

Every individual has a set of unique competences [48]. The important skills should include the ability to identify opportunities, an entrepreneurial orientation where more novel strategies will be selected over more generic ones, as well as conceptual, organizational, strategic and technological competencies. Finally focus and commitment are two other important skills required in opportunity. These competencies are not uniform in the general population.

Without any networks, it is very difficult to secure resources and raw materials for developing new products. The ability to source a particular material could mean the difference between being able to manufacture and market the product or just acknowledge that a potential opportunity exists. Lack of a network will also make it difficult to secure specialized expertise required to exploit any opportunity. In many cases specialized knowledge, particularly in specific technical areas is necessary to develop and manufacture a product. Lack of a network that can generate potential sales will greatly restrict potential growth. A strong networked distribution channel is an important key to success of any product. Many emerging companies fail in the market because of poor handling of distribution channels, which can strongly the ability to exploit the opportunity.

An opportunity is not a true opportunity, unless it can be exploited, otherwise it remains as an academic product/strategy scenario. Resources (physical, personal and financial) are critical to exploiting any opportunity. Lack of any key resource will lessen the chance of successfully exploiting any opportunity. New product development is most often undertaken with minimal resources. However there should be adequate resources to cover the key competency areas required to develop and launch the product into the market.

Companies perform very differently in the marketplace. Some appear to grow out of nowhere into household names, while others struggle and seem to go nowhere. Still others grow slowly over a long period of time. How quickly a company grows depends upon how skill, network and resources have been applied to exploitation of the opportunity.

Table 11.27. Sources of Innovation, Matching Strategy and Competencies Required

Source of Innovation	Explanation	Potential Strategies	Required Competencies
The unexpected success, failure or external occurrence	Success of a revolutionary product or the application of technology from one industry to another, sudden or unnoticed demographic changes caused by wars, insurgencies, migration, etc. Example: 2 in 1 shampoo	• Research & Development based strategy • Strong distribution channel development strategy • Strong advertising & promotion strategy	• Research & development • Networking • Entrepreneurial • Opportunity & strategy • Market
An incongruity between reality as it actually is and what it ought to be	A change that is already occurring or can be made to occur within an industry. It may be visible to those inside the industry, often overlooked or taken for granted. Example: Sugar free and fat/cholesterol free products	• Distribution focused strategy	• Sales, distribution and promotional • Networking
Inadequacy of an existing technology or business process	An improvement in process that makes consumers more satisfied based on an improvement or change in technology. Example: Bio-transformation processes, direct e-marketing	• Research & development strategy (for technology) • New channel development strategy (for new business processes)	• Research & development (fro technology development) • Entrepreneurial competence (new business process)
Changes in industry or market structure	New ways and means of undertaking business based on identified opportunities or gradual shifting of the nature of the industry. Example: Internet marketing, eco-tourism, organic products, retail concentration.	• Distribution/supply chain development strategy	• Strategic and entrepreneurial competencies
Perceptual changes	Changes in peoples awareness founded on new knowledge and/or values or growing affluence leading to new fashions and tastes Example: Nutraceuticals, cosmoceuticals, organic products, ethical products	• Marketing strategy • New channel development strategy	• Marketing and network competencies
Demographic changes	Gradual shift of demographics in population by age, income groups or ethnic groups, etc Example: Nutraceuticals, cosmoceuticals, ethnic cosmetics, etc.	• Marketing & promotional strategy	• Marketing
New knowledge	New knowledge or application of existing theoretical knowledge into an existing industry that can create new products not previously in existence Example: Biotechnology, pharmaceuticals, agro-chemicals	• Research & development strategy	• Research & development • Financial

Table 11.28. A Sample List of Questions to Screen Ideas into Opportunities

Idea/Product/Concept
1.What is the idea/product/concept?
2. Is there a consumer need for this idea/product/concept?
3. Do many people need this idea/product/concept?
4. How do consumers cope with their problem/need/want without this idea/ product/concept now?
5. Will this idea/product/concept provide a better solution to the consumer than what is already available?
Marketing
1. Who are the potential customers and target market?
2. How many potential customers are there (how large is the market)?
3. Who are the competitors (and potential competitors)?
4. How are your competitors doing in the market (decline, stable, growth)?
5. Is it their major business (do they rely on other forms of business)?
6. How will you promote the product (what advertising and promotion strategy)?
7. What will be your pricing strategy (what revenue over cost)?
8. Do you have the ability to reach potential customers?
Skills
1. What skills do you need to realize the opportunity?
2. Do you have these skills or can they be acquired?
3. Are these skills commonly available to all competitors (and potential)?
4. Can I manage this venture?
Networks
1. What networks do I need on the supply side?
2. What networks do I need to obtain resources (materials, people, finance)?
3. What networks do I need on the sales side?
4. How crucial are these networks to success/failure?
Resources
1. What resources do I need?
2. Are these resources available?
3. Are these resources within my reach?
4. Are these resources available to everyone?
5. Will I have enough financial resources to sustain this venture?
Product
1. Does the product solve a consumer problem, or satisfy a want or need?
2. Is this problem, want or need an important one?
3. What are the alternative solutions to the consumer?
4. What is the cost to the consumer of these solutions?
Product/Strategy
1. Can I develop a product/strategy that is different from others?
2. Will this different product/strategy be valued (or provide benefits) to consumers?

Risk		Change in how and where people buy the product		
		None	Some	Great
Change In User Habits	None	None	Low	Medium
	Some	Low	Medium	High
	Great	Medium	High	Dangerous

Figure 11.14. The Risk Matrix for a New Product/Strategy.

Opportunity identification is the tool that allows companies to gain advantage over others through the way they see and their ability to exploit what they see. Opportunity identification is the beginning of the new product development process. It manifests both products and strategies that will dictate how the company interacts with the environment and how successful and sustainable the company will be in the future.

Screening a potential idea to determine whether an opportunity exists requires investigating a number of questions about skills, resources, networks, the market and risk. A checklist of questions is listed in Table 11.28.

To make a risk assessment of the conceptual idea, the concept can be positioned on a matrix where one axis shows the required change in user habits (innovativeness risk) and the other axis shows the change in how and where people buy the product. For example a change in a fragrance of a product would only involve a "low" risk, whereas, changing from using fast knockdown insecticides to "green" insecticides (because of change in use practices) will involve dangerous risk. Figure 11.14. shows the risk matrix for a new product/strategy.

Concept Generation

Concept generation is concerned about developing the product concept with a checklist of desired characteristics. This involves packaging design, market and product planning, and developing a product prototype. The product registration process will also commence. These activities should be integrated as the outcomes are mutually influential on each other.

The enterprise product/market environment is complex, interconnected and multilayered. The approach the venture takes in engaging the environment is represented by the product/market strategy that will generate competitive advantage for the firm.

The physical markets, channels and the regulatory system exist on the other layer or macro-level. Inside the macro-level are the environmental elements that relate to consumer issues that define product/market requirements. These include consumer tastes and preferences, competition and technology. Within the inner part of the product/market environment are the elements which can be controlled by the enterprise. These include style, branding, promotion, competencies, finance, logistics, sourcing, manufacturing processes and the company fit with the theme and channels, etc. Finally the physical attributes of the product are at the centre, which include the product form, raw materials and packaging. All these factors influence the potential success of the product once it is launched.

From an enterprise operational view, each element of the system interacts with the rest of the environment in some way or another. Sometimes these are straight linear relationships such as the availability of finance to build a new manufacturing process. Some are restrictive relationships, where for example the set of relevant regulations will either allow or not allow the use of certain materials within the product. Some are circular, style and branding, while others are time lagged, *i.e., promotion and brand recognition*. Some elements are totally controllable, while others are outside firm control, *i.e., competition.*

The new product development process is undertaken within the system described above. All sub-systems should be scanned until common patterns can be seen. This can assist in developing greater insights into the complete market phenomenon, which successful product development relies upon. Concepts can be constructed and linked between the various parts of the environment become linked together and complementary aspects of the product/strategy. The elements of a product/environment system are shown in Figure 11.15.

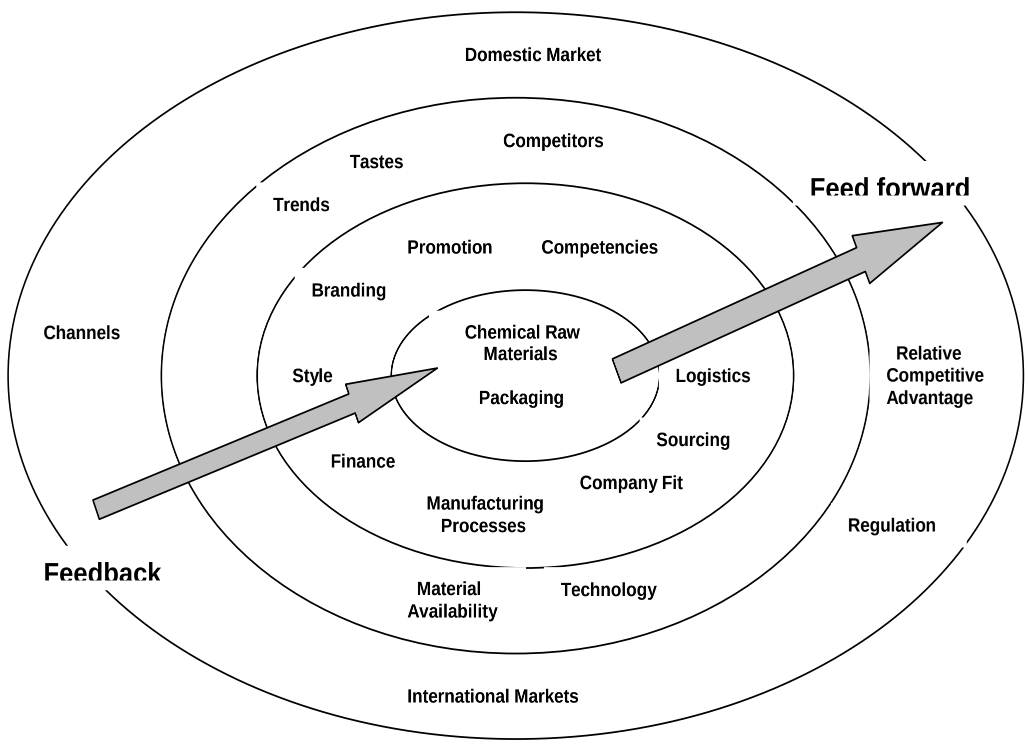


Figure 11.15. The Enterprise Product/Market Environment.

Some of the potential dynamics and environmental interrelationships are described below;

- *Domestic, international markets and channels:* Some products developed according to common themes can satisfy the aspirations of consumers across multiple markets, while some markets are entirely different culturally, running counter to the concept of the cosmopolitan man. What works in one market may not always work in another. The influence of what channel you utilize may have a great bearing on success and may lend credibility to your marketing strategy, while products on the shelf in a crowded market may just loose their meaning. The internet is now a linker of markets and an extension of packaging.
- *Regulation and Certifications:* is both a gatekeeper restricting what you can do and at the same time a useful barrier to entry and also part of a marketing strategy. The influence of the European SCCP will have international consequences. Now many ‘natural’ products must carry warnings on labels and markets have higher entry costs, creating extra barriers for small enterprises. Organic, Halal, kosher and Fairtrade certifications now form part of the labeling and become part of the corporate image of many companies.
- *Tastes, trends, material availability, technology and competitors:* Winning over competitors is dependent upon identifying tastes and trends and providing a product proposition successfully to consumers. Acquiring and developing apt technologies and raw materials is a strategy enabler for a firm and will become a facet of relative competitive advantage.
- *Style, branding, logistics, competencies:* All are now integrated and the same thing. Branding and logistics must be reflected in your competencies. There is no such thing as being ‘half green’ or ‘half ethical’. That will only lead to skepticism on the part of consumers. Many MNCs have made this mistake with new product launches.
- *Finance:* The way of financing the cosmetic and personal care industry is set for great changes. Venture capitalists will finance new bio-materials, look at Silicon Valley. Companies will quickly list on equity exchanges, able to pull in funds from consumers based on the aspirations of their corporate philosophy. Distribution channels will also become funding channels where consumers can invest in the manufacturers through managed trusts.
- *Relative competitive advantage:* will no longer be based economies of scale but have more to do with brand, philosophy, theme and how well a firm manages logistics, material acquisition and channels of distribution. Relative competitive advantage will be with those who see opportunity first and have the means through competencies, resources and networks to exploit them successfully.
- *Chemical raw materials and packaging:* central to the whole picture – if you are what you eat, you also are what you use.

The key to success in new product development is making a set of decisions which creates the best overall set of product/strategy attributes. This is one of the skills in the art of new product development. Successful products are those which have balanced tradeoffs well and appear consistent in their message through the product, branding and channels to consumers.

People tend to look at problems as cause and effect issues and work through jobs in a linear way. However successful new product development will require repeated revisits to many of the elements in the system, due to the complex environmental interrelationships involved. Without a systems framework, everything to do with a new product development project will appear *'fuzzy'* and overly complex, due to the high amount of information that needs to be procured from the environment. Looking at a system using both hard and soft data makes it easier to develop total product concepts and identifying and prioritize the issues into a neat set of factors that can be dealt with in the form of a devised strategy – the created product.

New product development becomes a true interdisciplinary activity, in stark contrast to the way we are taught to think through disciplinary orientated courses like chemistry and engineering, which has been breaking up the body of knowledge into singular disciplinary approaches. The systems thinking view creates a global or *'bird's eye'* view. In this way environment complexity can be broken down into predictable parts, which can be examined holistically, deductively, and functionally to build up knowledge and wisdom from this framework. The objective is to pull out of the enquiry something that is greater than the sum of all the parts [49]. This is where product and business innovations can be created, as a product also requires a well crafted strategy to be successful. A product without a strategy will fail.

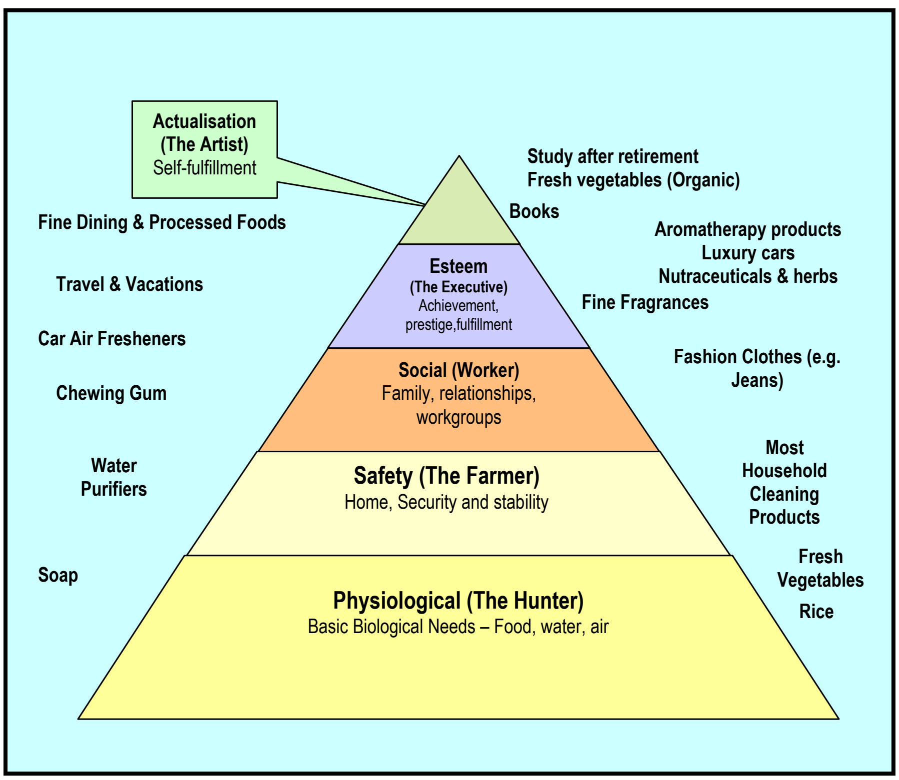


Figure 11.16. Product Types Matched to Different needs Levels of Consumers.

From the product development point of view, the best way to merge all environment based information is to focus it into a single useful idea and strategy. Therefore it is necessary to condense all the information from the environment into a single theme. A theme is not really a radical departure from the conventional marketing mix or customer orientated marketing concepts. A theme attempts to encapsulate the aspirations of consumers and manifest these aspirations into the product. This is not a strange concept to the cosmetic and personal care industry. Most companies work on themes (some passionately), concerning the environment, safety, naturalness, health, beauty, economy, etc. For example, do consumers buy products with tea tree oil because it is tea tree oil, or do they buy a product with tea tree oil because it is natural and perceived to be healthy? Why are organic cosmetics reported [50] to be the fastest growing cosmetic and personal care segment in Europe and the US? Why are anti-aging products such an important market segment today? It all has something to do with aspirations.

Common feelings within a community can be turned in generic typologies of consumer aspirations which can explain why consumers buy particular products. This can be developed into a theme. If enough consumers have these aspirations and if the new product has successfully reflected these aspirations, chances are the new product will be well accepted by consumers. Just think about Aveda, The Body Shop, Innocent Drinks in the UK and Thursday plantations, just to mention a few.

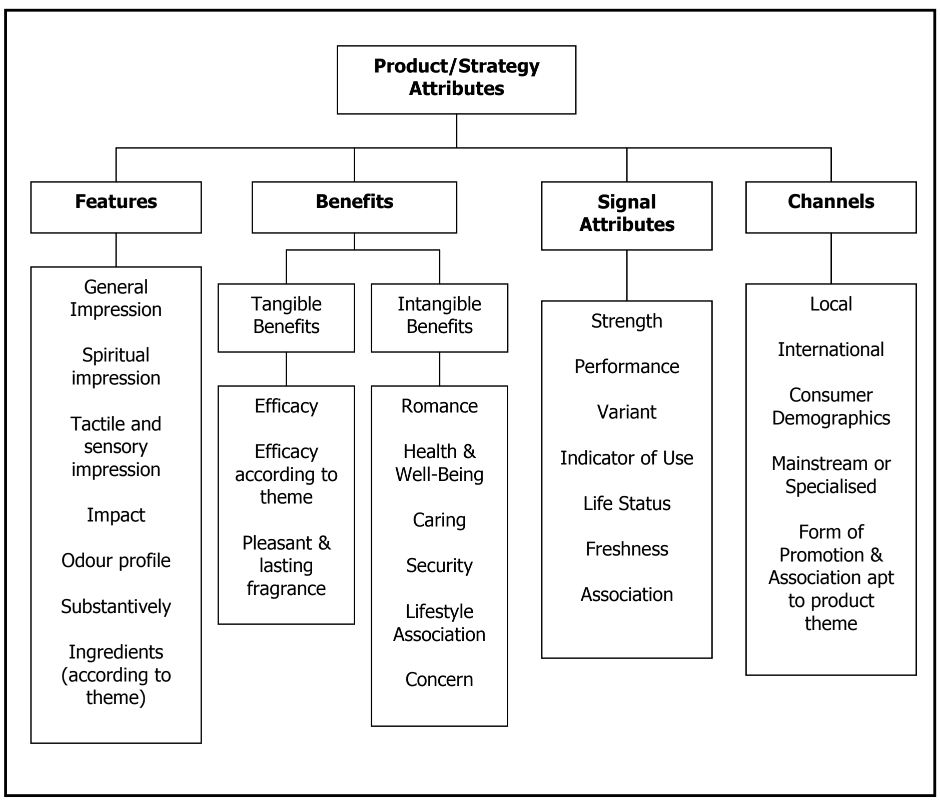


Figure 11.17. A Product/Strategy Attribute Profile.

A consumer typology is related to demographic and psychographic segmentation. Psychographic segmentation is one of the primary marketing tools today, which focuses on lifestyles, attitudes, values and beliefs. This can be illustrated using Maslow's hierarchy of needs as a way to understand market segments [51]. Figure 11.16. shows product types matched to different needs levels (typologies) of consumers. When a product is matched to consumers' aspirations and primary, secondary product attributes and strategy is accurately aligned, this theoretically gives a product a maximum chance of success.

Once identifying consumer aspirations and summarizing them into a theme, a consumer typology can be created. It is the consumer typology that the new product must appeal to. Product attributes should be designed to match the chosen typology. With this product attribute profile the new product development process can continue onto the other steps, as there is a clear idea of what is really required. The aim is to merge the brand image and the physical product together in synergy so the product presentation (formula, packaging, colour, advertising and corporate image), promotion, and other market strategies become all consistent [52]. An example of a potential theme for a hypothetical range of products: Borneo Rainforest products could be as follows; *Sabah is on the World list of 'exotic' locations; There is Mystic; There is cultural diversity; There is history and heritage; There is nature and serenity; Sabah is a place of peace, health and harmony* [53].

The role of fragrance is to help differentiate the product from its competitors [54]. Fragrance in cosmetics and personal care products helps to render a product distinguishable to the consumer in the vast array of products on the shelf. In highly developed markets, cosmetics, toiletries and household products have reached a stage where differentiation of primary product image builders (advertising, promotion, price, packaging) have become difficult to develop as a source of competitive advantage over competing products. Secondary image builders (fragrance, colour, types of ingredients used in the product) took on more importance in the 80s and 90s [55]. Now themes are the great product differentiators. Figure 11.17. shows a product/strategy attribute profile where both primary and secondary product attributes are merged to create the product's image with consumers [56]. If all the product attributes together can successfully espouse a theme, then a very powerful product identity will be created. Look at fine fragrance marketing campaigns, as an example.

The theme approach to new product development is a useful tool to meet the consumer paradigm shifts occurring in various markets. Several contemporary themes can be equated with a number of growing consumer segments.

Some contemporary Western consumers are losing their faith and trust in the established institutions of the Western culture, including the church, government and corporations. This loss of faith and trust is creating a spiritual vacuum where consumers are searching for something that is missing. There is a similar situation in China where growing middle-upper class have been brought up without religion and no longer feel affinity to the *"old revolutionary culture"* of China. This situation is leading consumers in a number of directions;

- As society is becoming more '*self centred'* in their aspirations, custom made goods and personal customer service is now very important. This can be seen in the rise of private banking, custom made computers and cars, tailor-made suits and fashions, and shopping for unique items in specialized shops rather than chains.

- Consumers are looking for unique items that are hand-made, exclusive and come from an ethical background to fill the spiritual void. The rise of Fairtrade and establishment of farmers markets and eco-tourism is providing consumers with more fulfilling consumption experiences.
- Consumer alternatism gives rise to alternative marketing and promotional strategies such as *viral marketing* and *on-line* buying through the internet. Shopping in this way provides the consumer with a story and feeling of control.
- Seeking alternatives is leading to less consumer brand loyalty and more experimentation with new products and new brands, as well as quick changes, meaning shorter product lifecycles. The development of new brands and new images is more widely accepted than before. New brands and images give new experiences like the low cost airline Air Asia has done in winning new customers in South East Asia. Likewise, adventure and eco-tourism is rapidly growing as consumers look for new experiences in their leisure time.
- The new generation feels no guilt about 'over the top' luxury as the post war generation did. Top luxury is acceptable to both self esteem and social exposure as this generation fulfills are role in a live for today in the white collar professional job market. Luxury is about feeling good and looking good.
- People are very concerned about health and the sector is growing rapidly with five star private hospitals, health tourism and the rise of nutraceuticals and cosmoceuticals. Organic foods sold at premium prices are growing. Sports wear and sports equipment is about being seen and trendy, gyms are full and racing bikes dominate the roads during weekends.
- People want to deal with corporate entities *that do the right thing*. People are then doing the right thing by association – a kind of spiritual materialism. This shows in the rise in ethical products and companies with social programs and supply chains that benefit those that are not as fortunate [57].

Successful market paradigms (themes) utilized by well known international companies are outlined in the Table 11.29.

Each company has been able to create a solid position in international markets by following a definite corporate and marketing philosophy based on a theme. Not many companies have completely connected all the possible paradigms together into one complete corporate image and philosophy, except for Aveda and The Body Shop, although the Body Shop has not been without criticisms. There is a link between company platform *(i.e., Aveda owned by Estee Lauder)* and size. Good and opportune branding also requires strong channel access to succeed. One should also note that there is a growing momentum of small to medium young companies that are achieving dramatically high sales growth rates through the utilization of themes in their marketing and corporate strategies.

Table 11.29. Market/Brand Paradigms Utilized by Some International Companies

	Aveda	**The Body Shop**	**Sureco**	**Hain Celestial Group**
Est. Sales	USD120million (1996)[58] USD619mil (2006)	USD1.5Billion (2006)[59]	USD40Mil [60]	USD738Mil [61] (2006)
Location	USA	UK	Malaysia	USA
Established	1978	1976	1999	1926
Products	Personal Care	Personal Care	Herbs	Organic food and cosmetics
Basic Philosophy	To sustain the environment and give back to communities	Social humanitarianism activism on many issues	Halal & Toyyibaan	Free of artificial ingredients, Kosher foods
Ethics		Yes		
Green	Yes	Yes		
Natural	Yes	Yes		Yes
Organic	Yes	Yes		Yes
Community	Yes	Yes		
Cultural				
Religious/Spiritual			Yes	Yes
Mode of Distribution	Direct Marketing/Salon	Retail and e-Commerce	Direct Marketing	General distribution
Owner	Estée Lauder Companies Inc.	L'Oreal	Private Ownership	Listed company

Companies from the 19th Century began developing brands to differentiate their products from their competition. Brands probably developed in the tobacco industry, where different tobaccos in regional America began to be transported to different locations and therefore had to be identified by a brand. Coca Cola was a soft drink that carried the name to distinguish it from the number of other colas on the market. Proctor & Gamble in Cincinnati found in the 1930's that it had a number of successful brands in the same category like *Camay* and *Ivory* soaps that needed a new way to manage so that due focus could be given to each brand. The company gave responsibility for total brand management to a single person (product manager) under a brand management system, which took over all decision making in regards to the brand in the company [62]. Brand management spread throughout most consumer goods companies and is still a widely practiced functional structuring of a marketing organisation today.

The rationale behind the development of products had traditionally been designed around a mix of physical product, price, place and promotion, known as the 4Ps. This was considered the most important part of the marketing strategy [63]. This was not a big breakthrough, but a convenient way to view and think about product strategy. The 4Ps concept was developed at a time when mass industrial marketing was growing rapidly. In recent times the orientation of marketing strategy has dramatically widened as the 4 P's have become much more integrated and other factors like customer needs and wants, cost, convenience, communication, distribution and relationships.

Recently Kotler has taken the approach that a product exists on a number of levels. The core benefit the product provides to the consumer is the nucleus. The physical features, made up of packaging, brand and quality level is considered the actual product. Finally the support features or augmented product include additional consumer services such as installation, after sales service, warranty and delivery and credit [64].

A product theme focus should consider four major issues. Firstly, *what is the central theme of the product?* This must consider the basic satisfaction the product will give to consumers' aspirations. This will include the design of all product features and benefits to consumers, including branding and packaging, etc. Secondly, *how much competition is there?* Are there others out there with similar themes, ideas, philosophies and products? Thirdly, *What will be the channel of distribution?* Will the product and the message be able to reach those who may be interested in the product. Finally, *are there enough consumers?* Are there enough people interested in the chosen theme and product? Company philosophy, branding, strategy, channels and physical product should all support the theme.

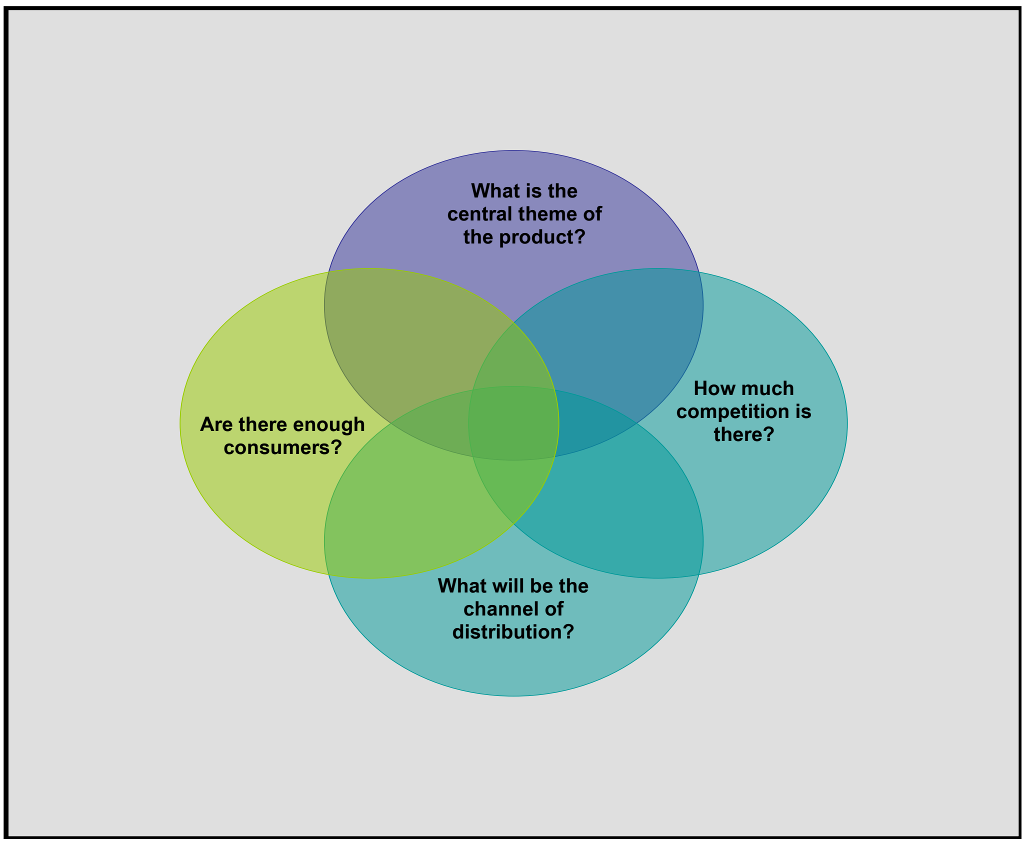


Figure 11.18. The Major Issues Related to a Product as a Theme.

As mentioned, the acceptance of a new product/theme in the market has a high degree of risk associated with it. The further away a company moves away from a generally accepted product theme, the higher the risk. Consumer acceptance depends upon a number of complex factors including the prevailing culture, existing and emerging sub-cultures, product ambience, the target group and the advertising budget.

Products and themes have to meet basic needs of people and provide perceived benefits. New products must therefore solve a consumer problem or meet a particular need or want. Products must also be consistent with consumer culture, although consumer habits can be changed. Themes must also be acceptable and conducive to satisfying consumer wants and needs, whether they be psychological like the need for health, to feel good about something, to keep apace with their neighbours, etc. or spiritual needs such as the need to help, give or save the environment, etc.

Globalism is bringing new ideas to different cultures around the world. Cultures vary in the resistance they have to new ideas. Values and beliefs also differ among age, social, religious, ethnic and socio-economic groupings *(sub-cultures)* within a market. Acceptance by a target group will depend upon how far away the product/theme is from the group's traditional ideas and values.

Table 11.30. Innovation Resistance for New Product/Themes

	Traditional Under Developed Markets	**Developing Markets**	**Cosmopolitan and Developed market**
Culture and sub-cultures	Static and rigid towards change	Slowly evolving or faster changing sub-cultures	Dynamic or in transition
Product Ambience	Ritual		Individual or creative
Target Group	Mass market	Mass market or Selective	Selective
Advertising Budget	Low	High at launch for assistance	High or specifically targeted
Strategy	Keep new products within existing market categories	Can experiment with developing new categories	Can aggressively develop new categories
Risk	Risk of launching innovative products too early in market	Growth may be slow in developing categories	High risk if fail to see correct potential 'niches' 'Niches' too small
Examples	Generic products Local brands in developing markets	Either a major new brand (same product) introduction to mass market or a new product/theme targeted at a specific group	Specific products for specific consumer groups (sub-markets)

Table 11.31. A Sample Shampoo System Profile

Shampoo System Profile

Function	Potential Material	Objective
Primary surfactant	ALS, ALES, TLS, SLES, NaDOBS	Performance, strength, efficacy
Secondary surfactant/ Foam Stabiliser	Coconut MEA, Cocamide MEA, Cocamidopropyl Betaine or amine	Tactile and sensory perception, impact, theme ingredients, efficacy
Pacifier/Pearliser	Ethylene Glycol Distearate, Glycol Stearate	Tactile and sensory perception, general impression, impact
Viscosity Control	Sodium chloride or gums	Ingredients, general impression, strength
Preservatives	Potassium Sorbate, Diazolidonyl urea, Methyl and Propyl Parabens	Ingredients, general impression
Functional Additives	Guar, Hydroxypropyl Trimmonium Chloride Panthenol, Dimethicone, Hydrolysed Keratin Protein	Tactile and sensory perception, general impression, spiritual impression, impact, efficacy, intangible benefits, signal attributes
Fragrance	Primarily aroma chemicals that are synthesized used in conventional products, or natural essential oils that become part of the active ingredients	General impression, odour profile, impact, efficacy, intangible benefits, signal attributes
Ascetic Ingredients	Aloe Vera, Green Tea Extract, Panthenol	General impression, intangible benefits, tactile and sensory perception, impact, signal attributes
Dyes	Mainly synthetic, more naturals	General impression, signal attributes

Advertising is a tool for drawing attention to a new product/theme in the community. Advertising is also a method of assuring the community that the product is good and the theme is something important and should be taken notice of. Advertising increases the scope of a company to be theme innovative. Products with low advertising budgets must generally follow others and emulate others' concepts as much as possible for any chance of sales.

Generally speaking a product/theme can depart more from the traditional when a product is targeted at a specific sub-group, rather than the whole general community. Products aimed at the general community cannot be too radically different from what is already on the market, if risk is to be minimized. To establish how innovative a new product/theme can be, the above factors and market must be thoroughly understood. Often factors will point to different trends and directions, and this must be reconciled as to its meaning for new product/themes. Product differentiation is necessary to gain competitive advantage, however too radical differentiation can miss consumer needs and aspirations, and fail to gain mass consumer acceptance [65]. Innovation resistance for new product/themes is shown in Table 11.30.

Table 11.32. Four Different Gel Air Freshener Systems

System	Carrageenan	CMC	*d*-limonene	Co-polymers
Type	Heat reversible system, strengthened with other gums	High grade CMC, cold process	Sodium stearate/ Di-limonene soap	Co-polymer system
Process	Easy to manufacture hot process	Require very precise manufacturing process	Easy to manufacture, hot process	Non-reversible heat process
Examples	Kiwi Brands, Wizard	SC Johnsons Glade	Various Car air fresheners in S. E. Asia	Japanese Brands/ Benkaiser
Advantages/ Disadvantages	Cheap, versatile, however long term stability problems	Difficult manufacturing process, but can contain fine (very volatile) fragrances	Does not dissipate fully, many fragrance limitations due to heat required and *d*-limonene base	Beautiful clear gels, expensive unit cost

Finally, the company can begin developing the technical aspects of the product concept, knowing what themes and characteristics the project must fulfill. A formulary profile of the product system can be developed from which laboratory development can take place. Table 11.31. shows the profile for a basic shampoo system, based primarily on conventional lines.

Many cosmetic, personal care and household products can be formulated using different systems. Each formulation system will usually have a different material base, manufacturing procedure and cost profile. Each system will also have advantages and disadvantages in manufacturing procedures and final product characteristics. For example, some systems are more suitable in warmer climates than others. Each system can be evaluated for ease of raw material sourcing, manufacture, product quality and cost. Table 11.32. shows four different systems that can be used for the manufacture of gel continuous air fresheners.

There are a number of issues associated with raw material selection. For example, the primary and secondary surfactants of personal care and cosmetic products are still mainly in the synthetic domain. Although oleo chemicals are derived from renewable resources, their toxicity, biodegradability and performance is not much different from the petro-chemical based surfactants. Oleo-chemical based surfactants are only partly natural due to the need to neutralize them with synthetic alkaline materials. Some surfactant producers have developed glucosides and sugar esters resembling the properties of saponins. Glucoside and sugar esters still haven’t been widely applied to shampoos as the use of the sodium and ammonium based lauryl sulphates still dominate. From the cost perspective, alkanolamides and even amine oxides and alkyl amino betaines are more economic to formulate with. Any radical change in shampoo formulation to completely natural materials will result in a large degradation in performance and massive technical problems with neutralization issues to overcome.

Effect, feel and efficacy of the surfactant system are heavily influenced through the materials used to neutralize the surfactants, leaving a range of choices available to the formulator. These choices are shown in Figure 11.19. [66].

The primary surfactant can be synergized with cationic surfactants (Olealkonium chloride, diststearyldimonium chloride or isostearyl ethyldimonium ethosulfate) to provide some conditioning properties and increase viscosity. This was once promoted as a big breakthrough in shampoo technology. Amphoterics like cocamidopropyl betaine or cocamidopropyl hydroxysultaine can also increase viscosity and stabilize the system. Alternatively non-ionics can be employed such as the polyethylene glycol esters to improve cleansing (PEG-80 sorbitan laurate), or PEG-150 disearate and cocamide MEA, which will add slightly different foam stabilization and viscosity effects. A number of effects can be achieved through skillful balancing of various surfactants such as the combination of glycol stearate or distearate to produce pearlescence, ethyl alcohol, glycerol of sodium xylene suifonate to maintain clarity and manipulate system synergy. Balancing all these variables will create a shampoo based with particular properties that should be matched to the desired physical product attributes.

A host of other ingredients can be utilized to supplement the basic surfactant system and/or enhance the formulation. In lower end shampoos salts (sodium and ammonium) can be used with sodium lauryl sulphates or ammonium lauryl sulphates respectively with some cost to the overall quality of the formulation to increase viscosity. Cellulose and gums can also produce an increase in viscosity, without the same drawbacks, but adding more cost to the formulation. Glycerine and propylene glycols, or alternatively the more expensive panthenol can be used as humectants. Silicones like dimethicone and cyclomethicone can be utilized to make hair shiny, moist feeling and slippery. Long chain fatty alcohols can assist in lubricating and binding hair, giving a feeling of body and moisture. This can also be achieved through the use of quaternary ammonium compounds like staralkonium chloride and disteardimonium chloride, or quaternium 5 or 18. Isopropyl palmitate can be used as a skin softener.

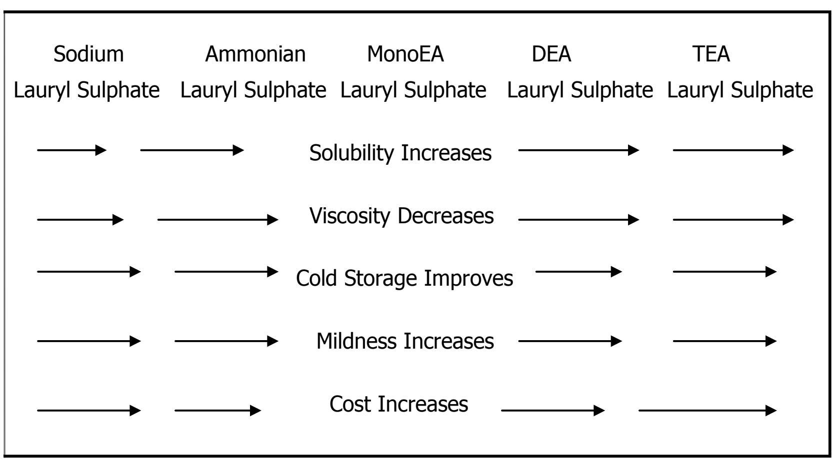


Figure 11.19. The Effect of Different Neutralising Materials on Lauyl Sulphate.

Table 11.33. The Potential Formulation Choices across a Selection of Conventional market Segments

Attributes	Generics	Discount	Lower	Middle	Leader	Pharmacy
Solids Level	5-15%	5-25%	10-30%	10-35%	25-40%	25-40%
Primary Surfactant	SLS SLES	SLS/ALS SLES	ALS/ MEA LS	ALS/ MEA LS	DEA LS TEA LS	DEA LS TEA LS
Secondary Surfactant	lkanolamides	Alkano-lamides	Alkanolamides Alkyl (amido) Betaines & Amine Oxides	Alkyl (amido) Betaines & Amine Oxides	Alkyl (amido) Betaines & Amine Oxides	Alkyl (amido) Betaines & Amine Oxides
Pacifier/Visc. Control	Sodium Chloride Ethylene Glycols	Sodium Chloride Ethylene Glycols	Sodium Chloride Ethylene Glycols	Glycol Stearates	Glycol Stearates	Glycol Stearates
Functional Ingredients	Maybe in ascetic quantities	Maybe in ascetic quantities	Maybe in ascetic quantities	Number of choices	Number of choices	Number of choices
Fragrance	Low cost selections	Low cost selections	Low cost selections	Higher cost selections	Higher cost selections	Higher cost selections
Preservatives	Formalin	Formalin	Sodium Benzoate	Number of choices	Number of choices	Number of choices

Shampoos will also have a preservative system constructed from a number of possible materials to prevent fungal and bacterial growth within the product. Bromelain, papain and other common enzymes are also being used in shampoo formulations to assist in cleaning, grease and organic material (dandruff) removal [67]. The importance of fragrance cannot be underestimated in the product formulation and is always a key consideration.

A major decision about the choice of natural ingredients is whether the material will be an ethical or ascetic ingredient. The choice made will well depend upon the theme the company chooses to pursue, according to its philosophy, although cost and regulation have great influence on the decision.

The formulation of the product should match the selected company and product theme. This is the objective of the formulation development process, which will influence the selected materials from start to finish. This is restricted by environmental issues, regulation, cost and availability and this is where ‘trade-offs’ have to be made. The influence of raw material cost on formulation is represented in various types of formula shown in Table 11.33. Potential formulation choices can become much more complex, if other themes such as organic, community participation and benefit, natural, ethical and spiritual issues are considered.

The formulation should match the selected packaging and channel in developing an integrated product towards the theme. If all aspects of the product and corresponding strategies are not totally consistent with the theme, then consumer skepticism could develop, with disappointment blocking repeated purchases. If corporate, marketing and selling strategies both don't consistently espouse and meet the theme presented in the product, the central marketing message tenant of the strategy will not be well received the consumer. Consumers are becoming more skeptical of companies that just *'join the bandwagon'* of a particular theme. This can potentially destroy a potential market for all. Just look at the quick rise and fall of many *'green'* products in the marketplace. The point to remember here is that consumers are ever more vigilant on reading ingredients on the labeling. A company's theme sincerity is judged by the ingredients.

Trial and error and imagination is required to produce specific product characteristics for target consumer themes. For example silicones allowed formulators to develop specialized products for Latin markets, where certain specific product qualities are required. Relating everything back to theme requires the formulator not just to consider the materials, but also match the source with consumer aspirations. This puts focus back on material availability; whether natural, organic, Fairtrade, Halal or kosher, etc., and the ability of these materials to satisfactorily fulfill the aspirations the product is aimed at meeting. All this is limited by current technology.

Product registration is now an issue that requires very early thinking in the new product development process. This is because many new products now require pre-launch registration which could take some time preparing the application, undertaking any required testing and waiting for the registration authority to examine and approve the application. The regulatory environment is radically changing in many parts of the world and the latest relevant regulations need to be checked thoroughly. Regulation greatly influences what can be claimed and what materials can be used. This issue was discussed in detail back in chapter seven.

Some of the important issues and considerations during the concept generation part of the product development process are listed in the checklist in Table 11.34.

Table 11.34. A Concept Generation Checklist

1. Review existing products in the market *a) what benefits they offer to consumers? (Is this a major issue?)* *b) appearance, efficacy, odour, colour, etc.* *c) branding, image and theme* This study will assist in determining what benefits of the new product should be highlighted in the marketing campaign.
2. Is the product concept compatible with the branding? *Must ensure the finished product formulation reinforces the brand image the company wishes to show consumers – i.e., colour, odour, softness, efficacy, appearance, use of particular materials.*
3. What distribution channels do competitors utilize?, Can I break in?, What are the barriers to entry?, Are there alternative channels?
4. Is the proposed formulation compatible with the proposed packaging? *a) Is the nature of the product consistent with the proposed packaging?*

b) What product bulk densities will be required? *c) Can the product be filled efficiently during the production process?* *d) Will the proposed packaging effect product stability?*
5. What logistic considerations may require special packaging? *a) required storage times* *b) Heat, especially harsh temperature variations* *c) Exposure to light* *d) Transport* *e) Product/supply chain integrity (Halal, Kosher, organic)* *f) Product/supply chain audit trails*
6. Can the product meet organizational expectations? *a) If not, what compromises are required?* *b) What is realistic?* *c) Can the product objectives be achieved within company unit cost expectations? – i.e., products active levels, functional ingredients can become ascetic ingredients, fragrance is the most expensive material, can vary dosage or quality.*
7. Where can I source raw materials? *a) What type of product formulation system is best?* *b) What alternative materials can be used? If not available look for another system.* *c) Can I get good technical support?*
8. Does the product have to be pre-registered before launch? If so, how long does this process take and what information is required? *a) What standards need to be met?* *b) Is any efficacy testing required?*

The Development and Launch Process

The development and launch process involves designing the manufacturing system for the product, the undertaking of the final market and packaging reviews, further product formulation, and any final product refinements before the product launch, if required. Some companies will undertake a selected test market before actual launch to assess the concept, consumer product response and marketing strategies before widening the launch to the general market. After the initial launch or test market, usually minor refinements are made to the product due to unforeseen issues with formulation or packaging, etc.

Manufacturing Plant Design

If the enterprise decides to produce the new product, it must begin focusing on developing a way to manufacture the product. The company's ability to market the new product will depend upon its ability to manufacture it. How well an enterprise can manufacture a new product depends upon the ability to develop the required batch or process technology. The ability to develop new forms of manufacturing processes contributes to an enterprise's competitive advantage.

Production engineers when commissioned with a new product concept begin to think laterally and try to conceptualize what type of equipment is necessary, what process can be used and how the packaging requirements can be handled. The basic relevant questions production engineers will ask are as follows;

4. The type of product requires what type of process?
5. What are the capacity and technological considerations?
6. What specific process technology can be used and what type of workflow pattern can be developed?
7. The number of workers required and what skills they will require?
8. The scheduling, coordination and control systems required?
9. Inter-relationships with other facilities? *(i.e., synergies and cross contamination threats)* and
10. What provision for expansion will be required?

The household chemical product industry is not an industry well known for publishing the latest technology in journals. Information about production processes can be more important than the formulations and usually kept as a firm’s proprietary knowledge, with access to employees on a need to know basis. The latest products are usually on the market before a patent is approved and any technical information is published into the public domain. Thus many new products are launched on a *patent pending* or *proprietary knowledge* basis. Published information in the local domain is usually a number of years out of date describing processes for products that are already in numerous numbers on the market [68].

Developing a production layout and process for a household, cosmetic or agro-product usually requires very specialized equipment and processes that few engineering firms will have experience in. A tertiary education background in the field of chemistry and production engineering may only provide some basic theoretical knowledge on some of the principals and not specific solutions to the problem.

Some planned products may be similar *(i.e., liquid, powder, gel, etc.)* to familiar products in the market and require standard industry equipment already widely available. If this is the case, developing a new plant and commissioning production may be very straight forward. However, when proposed new products are in new and unfamiliar forms from the production point of view, production processes may have to be developed through the process of deduction using the concept of *re-engineering.*

Re-engineering in the case of household product production process layout would involve looking at the relationships between packaging, formulation and the materials used in the product. These can all be examined closely until some deductions about the possible process of manufacturing the product can be made. Usually personal experience and exposure to a wide range of different manufacturing processes is the most relevant knowledge needed to assist in solving these types of problems. This is primarily an intuitive process, which is based on experience and learning. The process of *re-engineering* can be assisted by chemical and packaging suppliers who can also share their experiences. Networking around the supply and procurement side of the business is a very important asset in seeking a solution.

Although the household chemical industry has a number of suppliers who are able to supply *turnkey plant and equipment* for most conventional products like soap, detergents, shampoo, cosmetics and aerosols, etc, many new and novel products have little history of manufacture. Thus engineering firms may not have the knowledge and are unable to build specific plants. In these cases, it is up to the firm to develop its own plant layout and process methods, either alone or in consultation with third parties. This may require building a new plant from complete scratch or assembling bits and pieces of equipment designed for other applications and modifying them to suit the specific purpose.

A firm acquires process technology knowledge through years of operation and the experience that individuals gain can be used to develop new processes and production layouts. This is a heuristic process based on trial and error until each aspect of the manufacturing process is developed into a complete working layout.

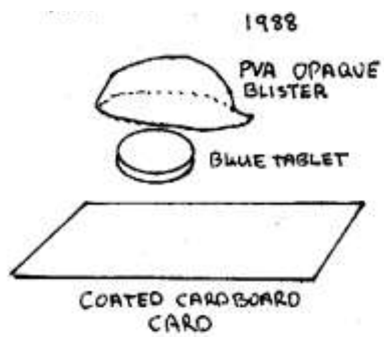
A Case Example of Developing an In-cistern Blue Block Production System (Toilet Blue Water Block)

The best way to explain *re-engineering* as a method of plant and process development is to work through an example the author developed during the mid 1980s. The drawings in this section are scans of the original sketches used in deduction of the processes and development. The same principals would apply in developing any plant, equipment and manufacturing process for any type of cosmetic or household product, etc.

The international toilet cleaner market is worth approximately USD 20 billion worldwide, with incistern blue blocks approximately 30% of this market. There are two primary methods of manufacturing toilet blue blocks. One method is through extrusion, utilizing tungsten lined converted double worm soap plodder, operating at a pressure of between 1500-2500 *psi.* The other method is through the molding of melted surfactants into the packaging components, allowing the emulsion to set into a hard block. The general appearance of the two products looks almost exactly the same to the average consumer as is shown in the two photos of blue toilet blocks above (Figure 11.20.).

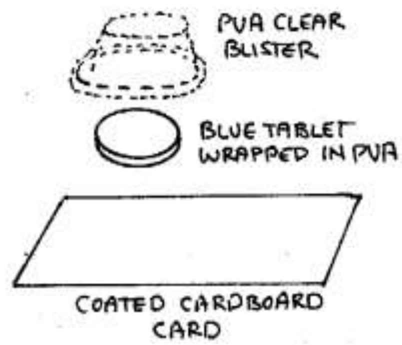
Figure 11.20. Photos of an Extruded Incistern Blue Block (left) and a Molded Incistern Blue Block (right).

Brand A in the Australian market Mid 1980s



A molded block

Brand B in the Australian market Mid 1980s



An extruded block

Figure 11.21. Author's Rough Drawings Showing Exploded Views of Two Toilet Blue Blocks on the Australian market During the Mid 1980s.

The author found in the mid 1980s that there was little difference in unit production cost between both methods, except extrusion is a semi-continuous process and molding is usually undertaken through a batch process. Both processes have occupational safety issues. Extrusion plodders are susceptible to blowing out the front manifold when nozzle pressure becomes too high due to a lack of moisture in the process. The molding process is potentially dangerous due to the need to maintain a constant steam jacket pressure throughout the whole process. Both processes tend to spread cross contamination of acid blue dye to other areas of the factory and therefore need to be housed in isolated and sealed areas. Drawings 1 and 2 in Figure 11.21. show an exploded view of two products on the Australian market in the mid 1980s.

The Development of the Molding Process

The author initially developed the molding process for producing toilet blue blocks. This method was selected due to unavailability of a second-hand soap plodder at the time. The initial step involved trying to understand the way the product was constructed, and then working back to conceptualise a probable process the product could be manufactured by.

Samples of the molded product were purchased. Firstly, the packaging was taken apart to see what could be learnt about the production process. Some were tested in their recommended application, while others were soaked in water to simulate the toilet cistern environment. This period of observation led to some understanding about the product, giving some ideas about product formulation and production process. Some of the information gained through this exercise led to a number of assumptions and ideas about formulation and process design, shown in Table 11.35.

Table 11.35. Information Gained from the Molded Product through Observation and Testing

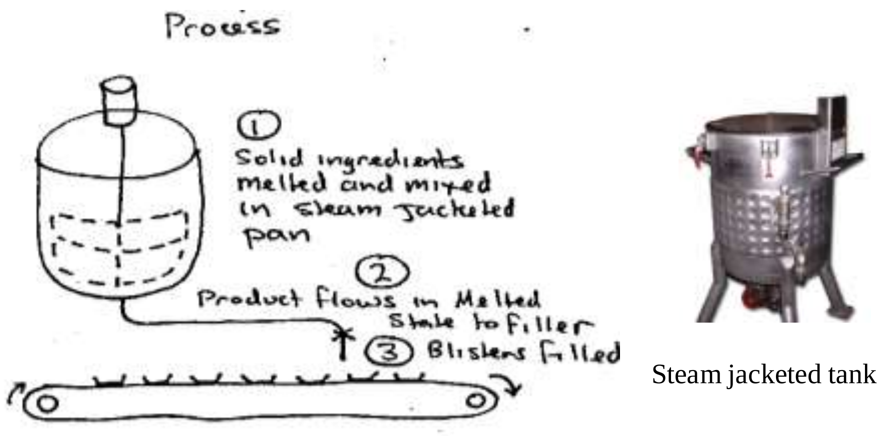
Characteristic	Observation Leading to Deduction
The product was molded through a hot process into the actual packaging	1. Shape of block inside packaging 2. Can observe liquid flow in block while it was a liquid
Product was primarily formulated using surfactants	1. Texture 2. Odour 3. Feel 4. Dissipation in water
The formulation contained ingredients which controlled dissipation	1. Observation of block in water 2. Observation of efficacy
The formulation contained agents that prevented the block from dis-lodging and moving around in the toilet cistern compartment	Observation during use of product

The above observations and deductions led to the development of technical criteria;

a) the packaging (blue plastic blister) must withstand heat during the filling process,
b) The filling process must be precise (50gram without causing any splashing as it would ruin the product presentation),
c) The surfactant used must be in a solid form, with a reasonably high melting point
d) A single or number of dissipation agents must be utilized to control longevity of the product during use (equates to number of flushes),
e) A gelling agent must be used to assist in dissipation control and prevent the block from being dislodged in the toilet cistern, and
f) The production process must not reach too high a temperature to oxidize the dye during manufacture.

A probable process was drawn out in the example in drawing 2 (Figure 11.22.);

The above investigation indicated that there is a critical relationship between packaging, formulation and production process. The process has to ensure that a 50 gram liquid could be poured into a small plastic cup, without melting the cup or splashing the outer flange, which would later be heat sealed onto a cardboard backing card. At the same time, the production process needed to be hot enough to enable surfactants and dissipation agents to melt completely. Thus temperature coordination would be crucial to the whole process. Next, a formula had to be developed to be compatible with the following process shown in Figure 11.23.



Figur e 11.22. Probable Molded Product Production process.

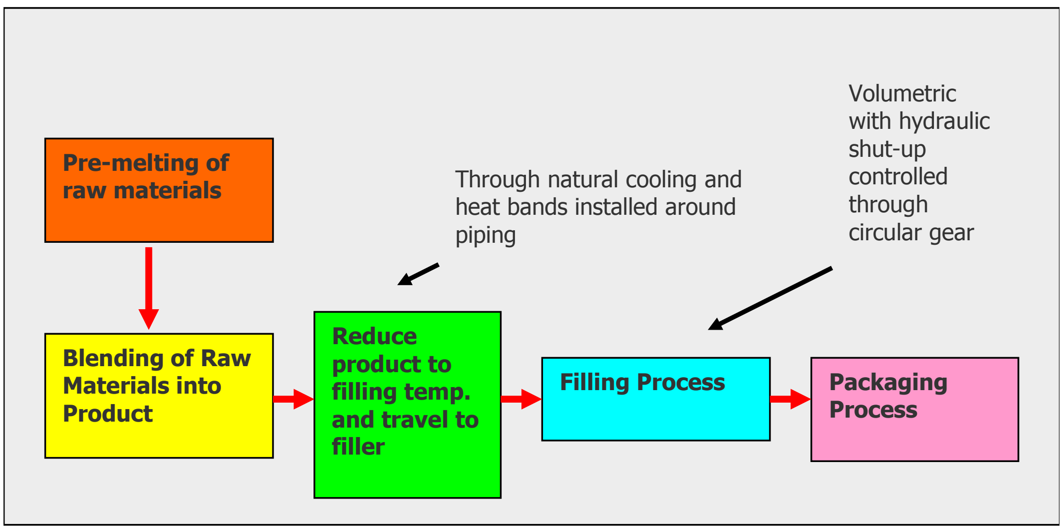


Figure 11.23. Overview of Production Process for Molded Incistern Blue Block.

From the information developed through deduction, a formula was developed to suit the process. At the time of development little information in the public domain existed. Moreover patents, utilizing this method did not exist. Development was based on trial and error, continual communication with suppliers and use of surfactant reference books to understand material properties. The formula should create a suitable combination of ingredients that would, a) have satisfactory efficacy in the intended application of the product, at least good enough to match the market leader, b) would flow through the production process without creating any problems like blockages, c) would solidify quickly once poured, but have a high re-melting point once in the marketplace and, d) was cost effective and economical to produce. This period took nine months to develop a final formulation [69];

Table 11.36. Final Molded Incistern Toilet Blue Block Formulation

	Ingredient	% w/w	Comments
1	Tallow fatty alcohol polyethleneglycol ether (50 EO)	68.5%	A relatively 'soft' surfactant with melting point around mid 50s C. This made a satisfactory base where dissipation could be inhibited through use of other materials.
2	Tallow fatty alcohol C16-18	10.0%	This ingredient, primary used in shampoo preparations was found to be an extremely good dissipation control, as it is almost insoluble in water.
3	Coconut monoethanolamine	4.0%	CME blended with TFA improved the solubility of the dissipation control aspect of the formulation. It has a tendency to become paste in water and in the correct portions had great influence on dissipation control.
4	Zeolite A	10.0%	Primarily selected because of its suspension characteristics in the chemical blend and its free flowing capabilities in the pouring stage. STP tended to block the filling nozzles.
5	Xantham Gum	0.25%	This ingredient helped to attach the block to the wall or floor of the toilet cistern. The material in combination with the others also influenced dissipation.
6	Acid blue dye	5.25%	Commonly used dye in toilet blue products. Not prone to much oxidation during continual high temperatures.
7	Fragrance	2.0%	A methyl salicylate based fragrance as can perform in water closet environment.

The plant was constructed once the formula was developed. The production process is a simple blending of materials, converted to a liquid through heat. Once mixed, the hot liquid emulsion would be released through pipes to the filling head so the material can be dispensed into the plastic blisters. Due to viscosity and temperature, a number of modifications and enhancements were required to modify a reconditioned cosmetic crème filler (see drawing 3 insert, Figure 11.24.) in this application. These modifications included, a) leather stopper at the back of the piston, b) a compressed air driven shut off value at the from of the piston, and c) heat elements placed along the pipes to maintain temperature during the filling process. The basic system can be seen in drawing 3 (Figure 11.24.) s was the actual drawing used for fabrication.

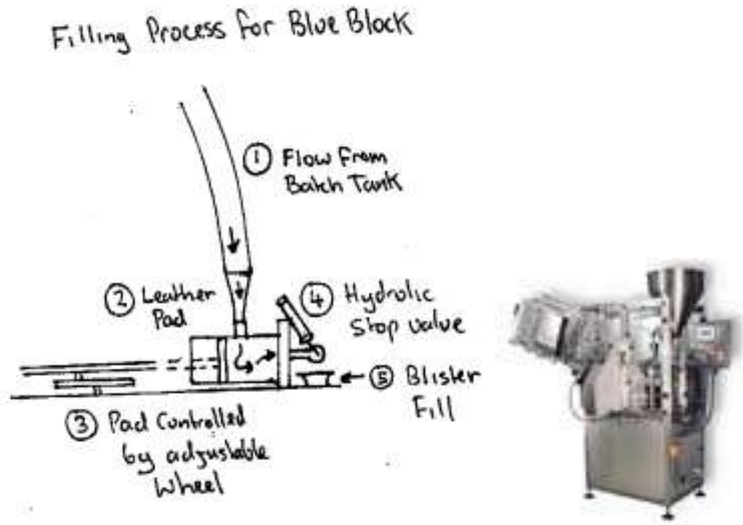
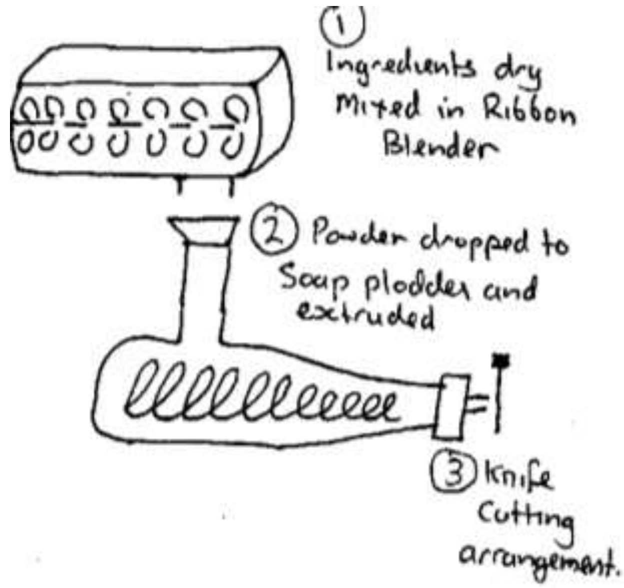


Figure 11.24. Modification of Cosmetic Crème Filler

THE DEVELOPMENT OF THE EXTRUSION PROCESS

During the early 1990's it was decided to switch from the molded process to the extrusion process in an effort to keep up with sales volumes. Although the process is more complex, the learning experience from the development of molded production enabled the author to develop the method quickly. The primary issue was to develop a formula suitable for the extrusion process. This could not be achieved in the laboratory, as extrusion could not be satisfactorily simulated on a small scale. It was necessary to build the plant and equipment before any formulation development work was undertaken.

The extrusion process is similar to the process used to manufacture soap. The raw soap in the form of a soft doughy substance is usually rolled and fed into the plodder, which is extruded out as a long bar and cut. In the manufacture of incistern toilet blue blocks, the powdered materials are fed into the plodder with much less moisture content. This creates much higher friction and pressure levels in the plodder than in soap production. The critical issue was the moisture level where too much moisture makes the material too soft and not hard enough to produce a suitable product. Too little moisture would build up too much pressure in the extruder, either jamming the plodder, which could damage the hydraulics or in the extreme case build up pressure in the extruding head and blow out the front of the extruder manifold. Determining the correct moisture levels could only be achieved through experimentation with the plodder. Experience from the trials also indicated that the moisture level also had to be varied to different humidity levels during the year and different batches of purchased raw materials. The basic process can be seen in drawing 4 (Figure 11.25.).



Basic single screw soap plodder

The ribbon design critical

Figure 11.25. The Basic Extrusion Process for an Incistern Toilet Blue Block Product.

Trials showed that the basic soap plodder had to be rebuilt with more powerful hydraulics and a tungsten lined screw to handle the materials. The extrusion process required a completely different formulation, which had little similarity with the molded formulation as shown in Table 11.37. [70];

Table 11.37. Final Extruded Incistern Toilet Blue Block Formulation

	Ingredient	% w/w	Comments
1	Sodium alkylbenzene sulfonate	75.0%	A hydroscopic material which can compress well and absorb the dye component
2	Polyethyleneglycol ether (MW 20,000)	8.0%	A reasonable hard material excellent for controlling dissipation
3	Sodium Sulphate	6.5%	A filler and regulator also aided in product dissipation
4	Sodium Triploylphosphate	5.0%	Dissipation agent in this application
5	Guar Gum	0.5%	Aided in fixing the block to the cistern during use
6	Acid Blue Dye	3.0%	Common dye used in toilet blue products
7	Fragrance	0.5%	A methyl salicylate based fragrance as can perform in water closet environment
8	Water	1.5%	Regulator during the production process

At the time these two production layouts were built and products formulated, no third party contractor or machinery manufacturer had the knowledge and know-how to supply a turnkey plant for the specific purpose of manufacturing in cistern blue blocks. No literature had been published in the public domain about the formulations and methods of manufacture for this type of product.

Turnkey plants exist in great numbers for common cosmetic, household and personal care products. However where products have an uncommon form, the enterprise may find it necessary to develop its own manufacturing process. The firm will have to develop the project with their own knowledge, supplemented through supplier and other contractor's knowledge.

When confronted with the problem of developing a formulation, plant and production equipment for a unique product, a heuristic approach is the practical way to develop the project. Although careful plans and diagrams may be prepared, there is little doubt that adjustments will be made to the formulation, plant and equipment. Sometimes it is extremely difficult to recreate laboratory situations in the actual production plant, so experimentation needs to be undertaken on the plant itself. A number of considerations that should be reviewed during new production process development are listed in the table11.38.

A heuristic approach to production process development in the household chemical product industry is a way of acquiring proprietary knowledge, which is exclusive to the firm. The effort to develop the process is based on trial and error is not easily duplicated quickly by other firms and can be considered a barrier to entry into that particular product/market, thus enabling the firm to practice monopoly differentiation for a period of time at a price premium to other firms. Thus through heuristic production process development the firm has developed a source of competitive advantage.

Table 11.38. Primary Dimensions for Plant Design

Materials Used	Production Processes	Products Produced	Customers/Markets Served
Physical Properties	Flexibility	Number SKU's	Seasonality/cycles
Chemical Properties	Throughout Time	Size and Shape	Geographical Location
Volume	Cost Structure	Run Length	Size of Firm Competitors
Sources	Scale Economics	Annual Volumes	Delivery Requirements (Lead Times, Order Size, Order Frequency)
Specification variances	Learning Curves	Setups	Field Service Needs
Availability	Automation	Weight	To Order/To Stock
Transportation	Yield	Quality	Purchase Decision
Location	Skills Required	Components	Price Sensitivity
Handling	Equipment Types	Materials	Life Cycle Stage
Cost	Job Categories	Features	Distribution Channel
Preprocessing	Separable Departments	Standardization	Product Function
Lead Times	Value Added	Product Life Cycles	
	Support Staff		

THE FINAL ASPECTS OF THE DEVELOPMENT AND LAUNCH

Final preparations before a launch should include a final market review. The purpose of this review is to confirm all the original assumptions and check whether there has been any major competitor moves. The final market review may also resort to the use of focus groups to check the branding, theme and efficacy of the product is in line with company expectations. This is as much a confidence boosting exercise as it is a confirmation of the product.

There is also the option to undertake a test market. Test marketing is not as popular as it once was due to the high costs of organizing one with the retail trade today. Markets are much more concentrated than before making it more difficult to put products into selected outlets and geographic areas. However MNCs still make limited launches in a single market or region to test some product concepts before undertaking a regional or ‘global’ launch. An MNC is less worried about competitors getting previews of their new products and strategies than small enterprises which prefer the element of surprise in their new product launches. The benefit of a test market is that it can provide invaluable information and data about the product’s acceptance and performance under the chosen test strategy. The disadvantages of test markets are that they give opportunity and time for competitors to develop retaliatory strategies.

A final packaging review is usually undertaken before launch to anticipate potential problems that may occur in the market. At this time a few months of data probably exists from stability testing at the laboratory level, if not also the field level. A review is needed to ensure the right choices of materials have been made to prevent any future mishaps at the field. Potential mishaps can occur from PVC materials being affected by free alkalis or solvents in the formulation, pressure building up inside the packaging due to chemical activity, as would be the case with bleaches releasing chlorine gas and carrageenan gel air fresheners releasing moisture through syneresis. Sometimes clear packaging changes colour because of chemical reactions. Thorough examination of potential problems can save the necessity to undertake a costly product recall after launch.

Product refinements before launch are usually the result of market issues rather than technical issues. These refinements could be made after single country test markets or focus group data, where new information assist in developing further minor refinements before the next stage where the product will be launched throughout a region or globally. Fragrances may be modified to suit a particular market, etc.

Before a new product launch, not all issues can be foreseen and there is no doubt that some issues will require technical and marketing attention after launch. Normally if the product development process has been thorough, these issues will be only of minor importance.

Intellectual Property

Before going onto looking at specific product applications of essential oils, it is important to briefly cover the concept of intellectual property. Intellectual property can be defined as a legal entitlement which is attached to the expressed form of an idea, expression, invention, process, or to some other intangible subject matter. This legal entitlement generally enables its holder to exercise exclusive rights of use in relation to the subject matter of the intellectual property (IP). The term *intellectual property* reflects the idea that this subject matter is the product of the mind or the intellect, and that IP rights may be protected at law in the same way as any other form of property [71]. One of the keys to intellectual property is the concept of novelty which means something that has not been publicly disclosed in any form, anywhere in the world. The basic forms of intellectual property and other relevant terms are listed in the Table 11.39. below:

Table 11.39. Basic Forms of Intellectual Property

Term	Definition
Commercialisation	Commercialisation of intellectual property is taking or using the idea, expression, invention, process or other intangible item to the marketplace for the benefit of the holder.
Patent	Is an exclusive right granted for an invention, which is a product or a process that provides a new way of doing something, or offers a new technical solution to a problem.
Manner of manufacture	A legal term used to distinguish inventions which are patentable from those which are not. Artistic creations, mathematical methods, plans, schemes or other purely mental processes usually cannot be patented.
Plant Breeders Rights	Are used to protect new varieties of plants by giving exclusive commercial rights to market a new variety or its reproductive material.
Industrial Design	An industrial design - or simply a design - is the ornamental or aesthetic aspect of an article produced by industry or handicraft
Trademark	Is a distinctive sign which identifies certain goods or services as those produced or provided by a specific person or enterprise.
Copyright and Related Rights	A legal term describing rights given to creators for their literary and artistic works (including computer software). Related rights are granted to performing artists, producers of sound recordings and broadcasting organizations in their radio and television programs.
Trade Secrets/Undisclosed Information	Is protected information which is not generally known among, or readily accessible to, persons that normally deal with the kind of information in question, has commercial value because it is secret, and has been subject to reasonable steps to keep it secret by the person lawfully in control of the information.

Intellectual property should be defined widely to include trade secrets and commercially confidential information, which can also be called proprietary technology. Patents as a form of intellectual property rights have a number of issues related to their scope of protection, and therefore sometimes hard to justify in terms of costs due to the small market the novelty will serve. Patents are expensive and take a long period of time before they are accepted through process and review procedures [72]. Jaffe and Van Wijk state that in many jurisdictions patent enforcement is very difficult due to slow court systems, bias against foreign plaintiffs, lack of technical competence and a general inability to enforce judgments [73]. A survey undertaken by Lessor found that companies tended not to patent their innovations in many cases, due to the fear that waiting would allow other companies to copy and counterfeit the product first in developing countries that had markets too small to justify the cost of registering a patent [74]. Grubb argues that in biotechnology, patents as a form of intellectual property rights do not serve the same purpose as in the electronics industry, where patents are used as 'bargaining chips' in cross licensing agreements and patent pooling as there are common product standards imposed by necessity and regulation [75].

There are other alternative forms of intellectual property protection used by companies that maintain trade secrecy and advantage over competitors. Trade secrets can be guarded and protected within an organisation by maintaining employment contracts with secrecy agreements that can be enforced through contractual remedies. These include specifically tailored production processes, mode and control of reactions and formulations used in the production of products by a company. Under legal license agreements, this technology, although unpatented can be protected as proprietary knowledge under contract law. The rapid changing nature of technology and continual improvement upon processes and product is itself a mode of protection, as long as the company maintains pro-active R&D in process and product development. Patents applications can often become redundant before the application is even reviewed by the patent office in an environment of continual technology change.

To fully understand the importance of intellectual property and its true value to the strategy of a firm, one has to appreciate its integration within the core of the company's mission and objectives. Intellectual property itself highlights the company's competencies that it uses in its core strategies. To view intellectual property otherwise would miss the very concepts of creating barriers to entry for potential competitors, creating competitive advantage over competitors and understanding the relative nature of the concept. Intellectual property is also at the heart of winning customers *'hearts and minds'*, gaining trust and reputation in the market place and making a strong emotional connection with customers, which is at the heart of any company's core mission [76]. Figure 11.26. shows the integration between a firms core mission and intellectual property.

If intellectual property is viewed as a *box of tools* that can be combined in a particular way to fulfill marketing and protection objectives, then intellectual property strategy can be harnessed to benefit the firm greatly. Thus using intellectual property in this way is the best way to safeguard and protect a company's products and position in the market place. Intellectual property tools will have different values in different industries, but the general array of tools useful to a firm, which can be utilised in different mixes to achieve an overall business strategy is shown in Figure 11.27.

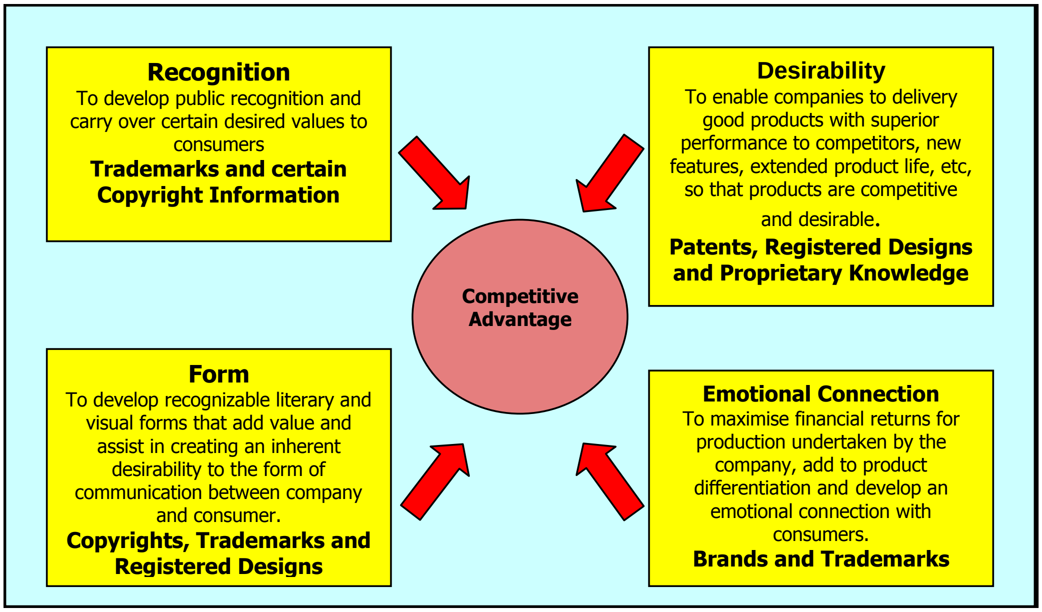


Figure 11.26. Integration between a Firm's Core Mission and Intellectual Property.

The three prime influences on the firm are the advent of new technologies, product life cycles and competition. The firm must be able to apply gathered knowledge to create its source of proprietary knowledge to form the core and basis of its general business strategies to apply to the market place against existing competitors, who will be undertaking their own cycle of strategy development and implementation. The success of the firm's strategy involves packaging its intellectual property into the correct mix of strategies and protections to develop differentiation and relative competitive advantage over its competitors. Skills and knowledge creatively applied to developing a general business strategy to maintain a sustained competitive advantage, which utilises recognition symbols, customer relationships, emotional connections with consumers, correct product forms that are desirable. These are manifested in patents, designs, proprietary knowledge, trademarks and copyright, supported by various employee agreements.

Some aspects of intellectual property are easier to copy and emulate by others. This is why continual improvement, change and new product development are the best methods of protection and maintaining a relative competitive advantage over competitors. Failure to improve, change and develop new products will render companies in slow technology emerging industries as a seller of generic products, like in the pharmaceutical, household cleaning, cosmetics and agricultural chemical industries. In the case of fast emerging technology industries companies will become completely irreverent to the market where they may quickly cease to exist, as is the case in mobile telephones, personal computers and electronic media storage. Figure 11.28. shows the IP/market scenarios with competitive advantage in slow and fast technology emerging industries.

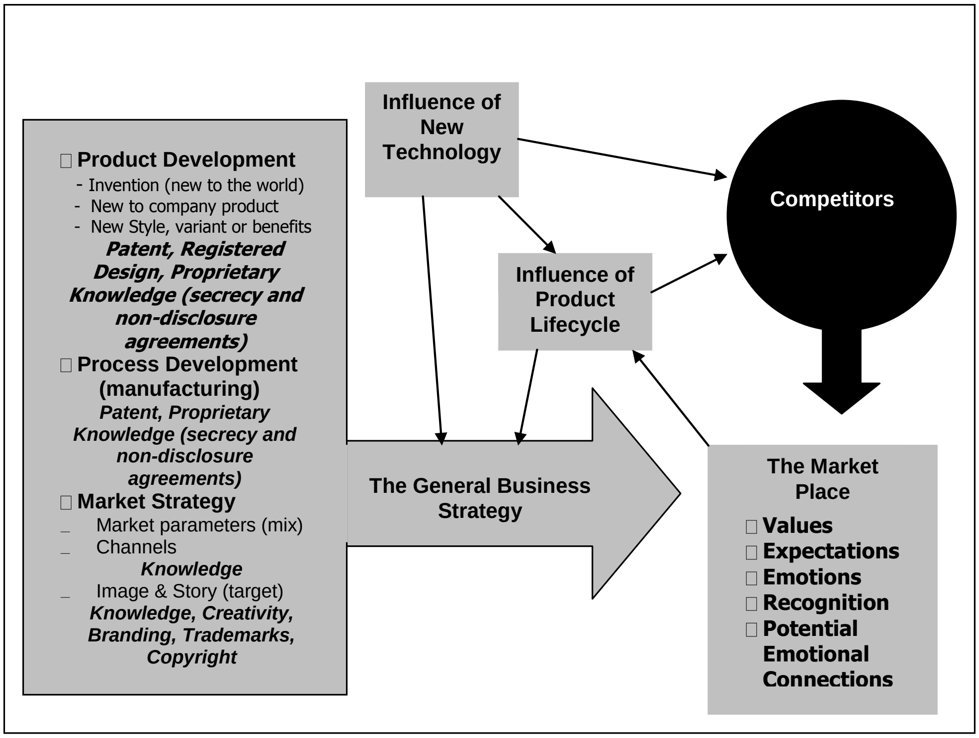
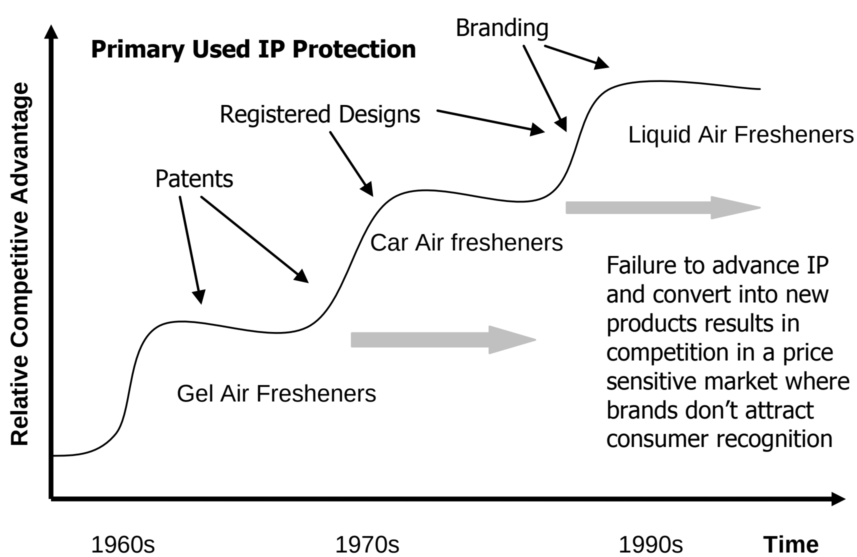


Figure 11.27. The General Tools of Intellectual Property in Business Strategy.

Figure 11.28. a. shows the scenario of a slow emerging technology market where changes in technology as well as being steady, tend to be incremental. In the early years, patents are relied upon for protection, but through time as more companies develop new ways to produce the same product, relative competitive advantage can only be improved through a new technology development. Once a new product based on the new technology is launched into the market and consumers except that technology, the existing market based on the old technology continues, but as more companies enter the market, it becomes difficult to differentiate between different products and the market begins resembling a commodity market. Price discounting will become the primary strategy to maintain market share. As further advances in technology continue to change product form, other methods of intellectual property protection like registered designs to protect the form and branding become more important protection than patents. The situation in the scenario of fast emerging technology markets, shown in Figure 11.28. b. is usually a market protected by patents through the complete evolution of the market as new emerging technology changes the basic technology behind the basic product form. As the new technology is proven to be more efficient and cost effective to consumers, the market for the old product will eventually die out.

To the firm, the most important aspects of the intellectual property mix are those components that assist the product to sell. There is little point developing a new product that has good protection, if it does not sell well in the market. Patented technology does not sell the product. More likely, it will be the perception of it the company portrays to consumers. When Nike developed the encapsulated gas membrane within the sole of the shoe, it was introduced as *"Nike Air',* conjuring an image of the product's desirability through consumer emotions and aspirations, identifying with the emotional rewards in sport and leisure with the slogan *'just do it'.* Although the technology of the shoe may have been brilliant, it was the intellectual property of branding, trademarks and copyright that developed the real value for the company. As was seen, some parts of the concept was quickly emulated by others, but not the complete winning intellectual property mix, so Nike's was able to maintain a relative competitive advantage over its competitors. The images of Mercedes Benz, Harley Davidson, Apple, Listerine, Coca Cola, Marlboro and Calvin Klein conjure up emotional responses in consumers about image rather than technical interest for the actual product artifacts themselves.

a. Slow Emerging Technology Market Air Fresheners



b. Fast Emerging Technology Market Electronic Media Storage

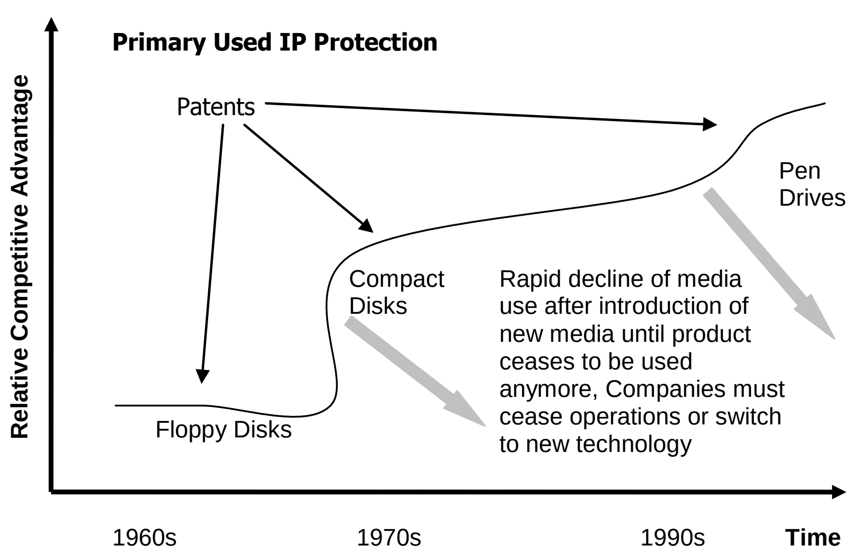


Figure 11.28. IP/Market Scenario with Competitive Advantage in Slow and Fast technology Emerging Industries.

COSMETICS AND PERSONAL CARE PRODUCTS

Although cosmetics have been used for many centuries, their use by the general population is only a recent phenomenon. When an underdeveloped economy progressives towards development, one of the first consumer sectors to emerge is the cosmetic industry, even though many cosmetics are considered luxury items. The cosmetics and personal care industry is one of the heaviest users of media advertising. Cosmetic and personal care items range from products that are important to a person's hygiene, to those that are used purely to enhance self-image and persona to others. People tend to use cosmetics and personal care products for reasons other than the primary product functions, *i.e., hygiene or colour, etc*. The use of cosmetics and personal care products also has something to do with acceptance, approval, image and even hope [77].

Table 11.40. The Classification of Cosmetics and Personal Care Products According to Use

1. Skin Care Products
1.1. Bath Products
1.2. Skin Cleansers
1.3. Skin Care Products
1.4. Eye Care Products
1.5. Lip Care Products
1.6. Nail Care Products
1.7. Feminine Hygiene Products
1.8. Foot Care Products
2. Cosmetic Products with Specific Efficacy
2.1. Sunscreen Preparations
2.2. Skin Tanning Preparations
2.3. Skin Bleaches
2.4. Insect Repellents
2.5. Insect Bite Lotions
2.6. Deodorants
2.7. Antiperspirants
2.8. Acne Care Products (preparations for impure skin)
2.9. Depilatories
2.10. Shaving Creams
2.11. Perfumes
3. Oral Care Products
3.1. Oral Hygiene Products
3.2. Denture Cleaners
3.3. Denture Adhesives
4. Hair Care Products
4.1. Shampoo
4.2. Hair Care Products
4.3. Hair Setting Products

4.4. Hair Waving Products 4.5. Temporary and Permanent Hair Colourants

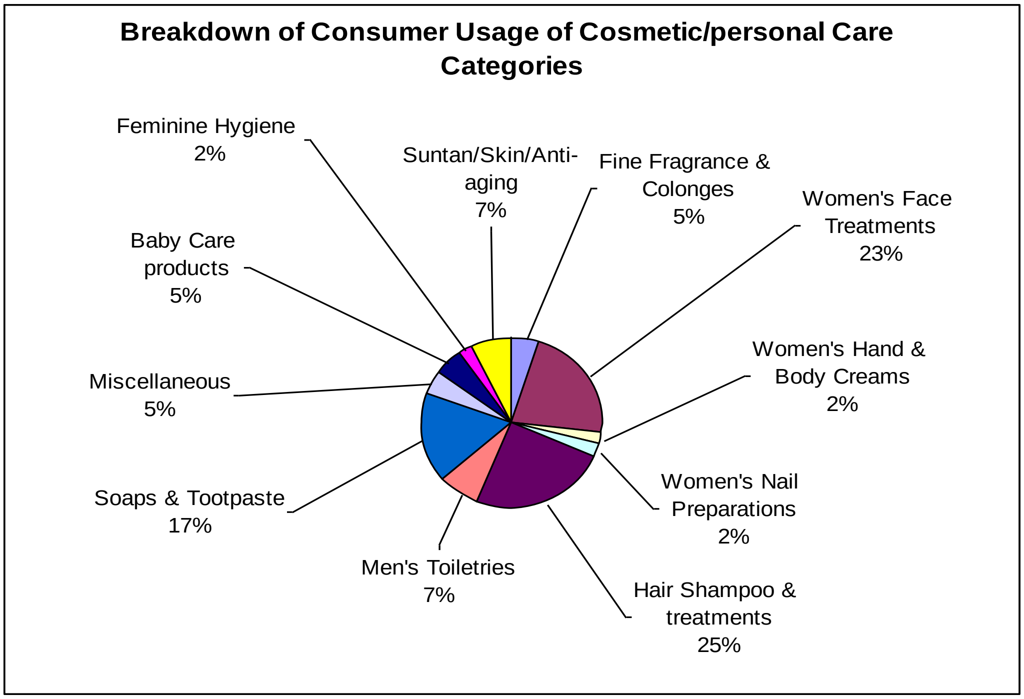


Figure 11.29. Breakdown of Consumer Usage of Cosmetic/Personal Care Categories.

Cosmetics and personal care products comprise a broad category which comes under numerous definitions. Cosmetics and personal care products often take on characteristics and uses of aromatherapy products (lotions, bath foams, etc), pharmaceuticals (topical products, antiseptics, etc), and insecticides (personal insect repellents). Cosmetics and personal care products can be classified according to their intended use at shown in Table 11.40. [78].

A very rough breakdown of consumer usage of each cosmetic/personal care category based on various sources is shown in Figure 11.29.

The oldest manufactured skin cleaning product is soap, which was once prepared from wood-ash (as lye) for both personal and clothes washing [79]. Soaps were found to be too coarse and irritable to the skin, so milder solutions were developed using super-fatting agents. Later skin protecting and anti-bacterial additives to eliminate body odour, like plant extracts were added. Soaps were later combined with synthetic surfactants, with adjusted pH and viscosities to become syndet bars and liquid soaps.

The bath and shower market developed from batch salts, which were crystalline coloured and perfumed preparations based on sodium chloride, trisodium phosphate, tetrasodium pyrophosphate, sodium tripolyphosphate, sodium hexametaphosphate and sodium sesquicarbonate. Due to the limited absorption capacity of these salts, only small amounts of fragrance or essential oils could be added to then product. These products were also available as tablets. Bath salts were developed with surfactants until bath and shower gels containing surfactant systems, foam stabilisers, hydrocolloids, anti-irritants, chelating agents, fragrances and dyes became important items in this category. Today we see a number of cosmetic companies producing bath and shower foams that resemble aromatherapy products and visa versa as the photo below depicts.

Figure 11.30. An Australian Brand of Bath & Shower Gel

Another bath product is an emulsion of fatty acid esters or alcohols that contain either essential oils or fragrances with a solubilizing agent. These products usually don't foam and leave a film on the body after bathing. These products are often encapsulated in gelatine balls that will dissolve in warm batch water.

Bubble or foam baths are another product in this category. These products develop a rich lather or foam in the bath, while at the same time exuding a fragrance. These are formulated with a surfactant such as triethanolamine lauryl sulphate and a foam stabilizer such as coconut diethanolamide, a fragrance and dye. Some basic formulations in the bath products category are shown in Tables 11.41-11.43.

Table 11.41. Some basic Bath Salt (Tablet) Formulations

Ingredient	Bath Salts	Foaming Bath Salts	Effervescent Bath Salts	Bath Tablet
Sodium sesquicarbonate	90.0% w/w	79.5% w/w		10.0% w/w
Borax				
Trisodium phosphate	10.0% w/w	10.0% w/w		
Sodium Tripolyphosphate				
Sodium Dodecyl sulphate		0.2% w/w		
Sodium bicarbonate			50.0% w/w	
Tartaric acid			25.0% w/w	
Starch (maize)			10.0% w/w	10.0% w/w
Sodium carbonate			14.0% w/w	79.5% w/w

Sodium lauryl sulphate			0.5% w/w	
Perfume/Essential Oil	*q.s.*	*q.s.*	0.5% w/w	0.5% w/w
Colour	*q.s.*	*q.s.*	*q.s.*	*q.s.*

Table 11.42. A Simple Bath Oil Formula

Ingredient	**Percentage**
Sulphonated castor oil	60.0% w/w
Dinatured ethanol	15.0% w/w
Isopropyl myristate	15.0% w/w
Perfume/Essential Oils	10.0% w/w
Colour	*q.s.*

Table 11.43. A Sample Formula for Bath and Shower Foams

Ingredient	**Bath Foam Percentage**	**Shower Foam Percentage**
Lauryl ether sulphate	10-20% w/w	10-15% w/w
Coco amidopropyl dimethyl betaine	2-4% w/w	2-4% w/w
Fatty alcohols and ethoxylated fatty alcohols	0-3% w/w	0-4% w/w
Fatty acid alkanol amides	0-2% w/w	0-4% w/w
Quaternised hydroxypropyl cellulose	N/A	0-0.3% w/w
Sodium chloride	0-2% w/w	0-2% w/w
Ethylene glycol stearate	0-2% w/w	N/A
Selected plant extracts or essential oils	0-0.2% w/w	0-0.2% w/w
Preservatives	0.1% w/w	0.1% w/w
Fragrance	0.2-3% w/w	0.2-3% w/w
Dye	*q.s.*	*q.s.*
Water	Balance	Balance

Skincare products include preparations that are applied generally to the skin, either a specific part or over the whole body. They include moisturizers, cleansing creams and lotions, and various types of body lotions and oils. Skincare products help replace the lipid surface of the skin that has been removed through bathing and washing. Other products help protect the skin from the damage that UV causes *(anti-aging)* and other environmental effects *(barrier products)*. Skincare preparations are usually water in oil or oil in water emulsions with a surfactant base to emulsify active ingredients. Fragrances are a minor component of skincare products *(up to 2.0%)*. Plant extracts and essential oils are used either as active or aseptic ingredients. When some skincare products make claims, *i.e., antiseptic or anti-bacterial*, they become regulated as pharmaceuticals and the active ingredients, such as essential oils become much higher, *i.e., around 5.0%*. Some examples of these product formulae using tea tree oil *(Melaleuca alternifolia)* are shown below.

Table 11.44. A Sample Acne Lotion Formulation Using Tea Tree Oil as an Active Ingredient [80]

Ingredient	Percentage
Phase A	
Polar Gel NF	4.0% w/w
Methocel EHM	1.0% w/w
Water	50.0% w/w
Phase B	
Methyl Paraben	0.20% w/w
Propyl Paraben	0.10% w/w
Glycerine stearate	2.0% w/w
Myristyl propionate	2.0% w/w
Polyethylene Glycol 600	2.0% w/w
Diementhicone	0.5% w/w
Titanium dioxide	1.0% w/w
Water	24.0% w/w
Tea tree oil	5.0%

Table 11.45. A Sample Therapeutic Lotion Formulation Using Tea Tree Oil as an Active Ingredient

Ingredient	Percentage
Phase A	
Carbomer 940	0.5% w/w
Propylene Glycol	1.0% w/w
Triethanolamine	0.1% w/w
Water	53.8% w/w
Phase B	
Stearith 21	3.5% w/w
Ethanol	31.0% w/w
Cetyl Alcohol	2.0% w/w
Cyclomethicone	3.0% w/w
Preservative	0.1% w/w
Tea tree oil	5.0% w/w

Table 11.46. A Sample Antiseptic Cream Using Tea Tree Oil as an Active Ingredient

Ingredient	Percentage
Stearic Acid	25.0% w/w
Phenyl Diemethicone	5.0% w/w
Glycerine	8.0% w/w
Aminomethyl propanol	1.5% w/w
Water	55.5% w/w

Preservative	*q.s.*
Tea tree Oil	5.0%

The primary active ingredients used in SPF sunscreen products include *p*-aminobenzoic acid (PABA), avobenzone, Benzylidene camphor sulfonic acide, bisymiazylate, camphor benzalkonium methosulfate, diethylamino hydroxybenzoyl hexyl benzoate, diethylhexyl butamido triazone, dimethicodiethylbenzal malonate, dromatrizole trisiloxane, ecamsule, ensulizole, isoamyl *p*-methoxycinnamate, 4-methylbenzylidene camphor, octyl dimethyl PABA, octyl methoxycinnamate, octyl salicylate, octyl triazone, PEG-25 PABA, Polyacrylamidomethyl benzlidene camphor, sulisobenzene, tinosorb M, Tinosorb S, titanium dioxide and zinc oxide. These are all synthetically based materials, except for titanium dioxide (TIO_2) and zinc oxide, which are mineral based. Consequently there are currently very few natural SPF materials available in the market that can be utilised as active ingredients. However researchers are finding natural materials in essential oils which block UV and could potentially in the future be utilised as active ingredients in SPF and also anti-aging products. For example, (+)-1-bisabolone has been found to block UV [81] and is found in *Stevia purpurea* [81], *Cymbopogon citrates* [82] and *distans* [83]. *Platyphyllol (1-acetyl-4-methoxy-3,5,5-trimethylcyclohex-3-en-2.5-dione)* and some similar compounds which can also block UV, have been found in two different chemotypes of cajuput oil *(Melaleuca cajuputi)* in Malaysia [84] and Papua New Guinea [85].

Personal insect repellents have grown in popularity as consumers have had more time for outdoor activities and sports. Early insect repellents utilised citronella oil as the repellent, but the odour not very satisfactory for most consumers. Insect repellents were then formulated with *N,N-diethyl-m-toluamide* or deet, *ethyl hexanediol* and *3,4-dihydro-2,2-dimethyl-4-oxo-2H-pyran-6-carboxylate.* Insect repellents based on citronella, pennyroyal, tea tree, eucalyptus and lavender oils are also on the market, where a sample formulation is shown in Table 11.47.

Insect bite lotions would have very similar formulations to the above, except the chosen essential oils would include tea tree for healing, lavender for soothing and perhaps peppermint for cooling.

Traditionally deodorants or antiperspirants have relied on aluminium or zinc compounds as active ingredients. Most mass market brands are formulated with aluminium actives. Some products partly utilise essential oils like tea tree oil in synergy with an aluminium compound like the formula shown in Table 11.48. A few products in the pharmacy or health food channels utilise alternative approaches to formulating deodorants like the formula shown in Table 11.49.

Table 11.47. A Sample Personal Insect Lotion Formulation Utilising Essential Oils

Ingredient	**Percentage**
Part A	
Veegum	1.0% w/w
Water	64.0% w/w
Part B	1.5% w/w
Lavender, Tea Tree, Pennyroyal, Eucalyptus Oils, etc	4.0 % w/w
Stearic Acid	4.0% w/w

Sorbitan Monostearate	5.0% w/w
Polysorbate 60	2.0% w/w
Preservative	*q.s.*

Table 11.48. A Antiperspirant Roll on Formula Using Both Aluminium Compound and Tea Tree Oil as Active Ingredients

Ingredient	**Percentage**
Aluminium Zirconium Tetrachlorohydrex-Gly 35% Aqueous Solution	50.0% w/w
Water	32.2% w/w
Magnesium Aluminium Silicate	1.0% w/w
Glyceryl Stearate and PEG-Stearate	8.0% w/w
Glycerine	0.80% w/w
Cyclomethicone	7.0% w/w
Tea tree Oil	1.0%

Table 11.49. A Natural Alternative Antiperspirant Formula

Ingredient	**Percentage**
Potassium Alum	5.0% w/w
Glycerine	5.0% w/w
Borax	0.5% w/w
Essential Oils – *Lime, Lavender, Tea Tree, etc*	0.25% w/w
Emulsifier	0.20% w/w
Water	89.05% w/w

The shaving products category includes products that can be applied to the face and body before shaving to soften and swell the hairs through mild alkalinity, *i.e., shaving soaps and foams and after shaving preparations to sooth the damaging effects of the shave, and after shave lotions*. Shaving foams are mostly aerosols, although shaving soaps still exist. These products primarily consist of the salts of fatty acids to enable fine lathers. After shave and splash on lotions are similar to eau de colognes, which will be discussed next.

Personal fragrances, otherwise known as fine fragrances originated in the late 19th and early 20th Centuries. The word *"extrait"* originally referred to a solution of fragrant material obtained by washing an enfleurage pomade with alcohol, after which it was cooled with ice to solidify any left over traces of fat. The extrait so produced was then filtered to remove the fat. An extrait now refers to a perfume sold at a concentrate level of 20-30%. Products that contain lower concentrations of perfume are called *Parfum de toilette* or *eau do parfum*, which contain between 8-15%. These have proved very popular over the last few decades as they are a cheaper way for the consumer to purchase a perfume. Eau de toilette can be used more liberally than extraits and are sometimes sold as sprays, which give a cooling effect to the skin when used. Any rigid definition of a extract perfume must be regarded with some flexibility as different companies marketing fragrances as extraits, eau de toilette, and colognes, use different concentrations. The normal concentration of various fragrances under the personal fragrance category is shown in Table 11.50.

Table 11.50. The Normal Perfume and Alcohol Concentration of Fragrance Products

Fragrance Type	Perfume Compound Volume	Alcohol Volume
Eau de extrait	20-30%	70-80% w/w
Parfum de toilette/Eau de parfum	8-15% w/w	80-90% w/w
Eau de Toilette	4-8% w/w	Approx. 80% w/w
Eau de cologne	3-5% w/w	Approx. 70% w/w
Splash cologne	1-3% w/w	Approx 60% w/w

There are a few companies specialising in the production of totally natural fine fragrances and colognes [86], as it currently remains a small and specialised market. This will be discussed in much more detail in the next section.

Two oral care products that have traditionally utilized essential oils in their formulations include toothpastes and mouthwash. Early toothpaste utilized mint oils like spearmint and peppermint to create their "refreshing and clean" taste. To some extent many if not most toothpastes today contain some mint oil or menthol for that "fresh" effect. In South-East Asia some brands introduced wintergreen oil *(methyl salicylate)* to add a medicinal flavour. Later clove and nutmeg oils where used by various local brands around the region.

Mouthwashes are used for cleaning the oral cavity, although they are not really considered important to oral hygiene except for mouth freshness and assisting in minor gingival and mucosal disorders. Mouthwashes are usually aqueous solutions containing an antiseptic agent, essential oil as a flavour and ethanol in a water based solution. Some concentrated sprays may contain high levels of alcohol, while a few brands of mouthwash claim to be non-alcoholic by increasing the sorbitol levels. A basic mouthwash formulation is shown in Table 11.51.

Table 11.51. A Basic Mouthwash Formulation

Ingredient	Percentage
Antiseptic agent	02-9.5% w/w
Sorbitol 70% solution	30.0% w/w
Essential oils – Peppermint, spearmint, menthol, cinnamon, clove, etc.	0.5% w/w
Citric acid	0.1% w/w
Emulsifier	1.0% w/w
Ethanol	10.0% w/w
Water	Balance
Preservative	*q.s.*

Colour	*q.s.*

Hair care products are an important and competitive category in the cosmetic industry. Shampoos are a combination of a primary surfactant system to foam and clean the hair, a secondary surfactant system to add synergy and regulate the foams produced from the primary surfactant, functional additives like preservative systems opacifiers, germicides, and viscosity modifiers, etc., and aseptic ingredients like fragrances and colours. The range of additives that can be incorporated into a shampoo system are very wide and include both natural and synthetically produced extracts for dandruff treatments, protein treatment, vitamin treatments, etc. These additives take the function of a shampoo further than just a mild cleaner for the scalp and hair, and become an important part of the company's product positioning in the marketplace.

Hair conditioners are usually applied after shampoo rinses to reverse the swelling of hair from the shampoo process and improve hair quality and manageability. Hair conditioners are slightly acidic substances made up of surfactant emulsions of fatty alcohols and other additives for similar purposes mentioned above in the shampoo. Hair conditioners will also carry antistatic agents based on quaternary ammonium compounds. Plant extracts and essential oils play either an aseptic or functional role in a shampoo and conditioner depending on the dosage in the product. Two in one shampoo-conditioning systems are also on the market. These are manufactured with ingredients like alkyl ether phosphates based on cetyl alcohols, which can be used with anionic surfactants or stearic amidopropyl dimethyl-myristyl acetate ammonium chloride as an amphoteric system. Some basic shampoo systems were shown in the new product development section of this chapter, Table 11.52. shows a basic two-in-one shampoo formula.

Table 11.52. A Basic Two-in-One Shampoo System

Ingredient	**Percentage**
Ammonium lauryl sulphate	30.0% w/w
Cocomide DEA	3.0% w/w
Trimethylsilylamodimethicone	1.0% w/w
Essential Oils – *Lime, Lavender, Tea Tree, etc*	0.5% w/w
Ammonium chloride	1.50% w/w
Water	64.0% w/w
Citric acid (aqueous solution)	Until pH6

THE CASE FOR NATURAL FRAGRANCES

The issue of using natural fragrances usually comes up from time to time in the industry. It is a more complex issue than many consider it to be. This section will briefly canvass the arguments for and against natural fragrances in consumer products. This has become a very important issue where the areas of aromatherapy and cosmetics are merging into one. The use of natural fragrances in consumer products is an issue which brings great polarity between those who passionately advocate natural fragrances and those mainly from the fragrance industry, who are quick to dismiss the possibilities.

The consumer however, is continuing to purchase greater quantities of products where *natural* claims are made. Manufacturers are increasingly using *or highlighting the use* of raw materials derived from renewable resources in the formulation of their products and appear to have little hesitation in aligning the incorporation of botanical materials into their products with consumer concerns for the environment, health and lifestyle.

The case for *naturals* was probably indirectly helped by the problems of the poor image of the chemical industry in the 1970s and spurred on by the concern over the issues of global warming. This in recent years has given momentum to naturals. The 'green' movement has lost its fringe image and become a respected movement in today's society. Personal fitness is now very important, along with health and ethics in society. This is all in great contrast to consumer views of the 1950s where the high-tech image of the chemical industry offered glamorous alternatives to natural materials which became regarded as 'old fashioned'.

The arguments for natural fragrances are strongly aligned with the concept of a sustainable ecological system. These arguments are close to consumer aspirations. One advocate Christine Malcolm in the United States argued *"…there is an attitude in the industry that the evolving interest in naturals can be satisfied through packaging, labeling, and marketing without really changing the ingredients"* [87]. Ms Malcolm believes that the use of naturals is a matter of philosophy in life as natural materials are our link with nature. Ms Malcolm further believes that the argument against naturals because there are not enough natural materials is not correct. There are many new and rediscovered materials available again on the market today and these materials will be available in larger quantities with greater interest.

Arguments against the use of natural fragrances come from mainly within the fragrance industry itself. These arguments have centered on the limited number of natural materials available, the difficulty on the part of the perfumer to create fragrances solely with natural materials, the difficulty in obtaining consistent quality raw materials, the limited availability and regular shortages of natural materials due to adverse weather conditions, natural disasters and political upheavals. Finally, the problem of ethically meeting all natural and regulatory requirements must be deeply considered [88].

The use of synthetic materials in the creation of fragrances is only really a recent phenomenon in the history of perfumery. Up until the 20th Century, materials used for the creation of fragrances were almost entirely of natural origin. The perfumer's palette was limited to around 400 materials, the majority derived from parts of plants and a small number from the animal kingdom.

In the 19th and early part of the 20th Centuries, fragrance was only affordable to the wealthy in society. Toilet soap, alcoholic perfumes and talcum powders were the only perfumed products at the time. Perfumery had remained an artisan based industry. Like other artisan based industries of the 19th Century, only traditional methods were employed in the preparation of materials, perfume creation and compounding. The arrival of synthetic aroma chemicals from the laboratories of the time went largely unnoticed in the industry for many years. Although coumarin was first synthesized in 1868 and known as a major constituent responsible for the odour of tonka bean tincture, it was not until 1882 that coumarin was used as an ingredient in the creation of a perfume. *Fougere Royale* is regarded as the first major perfume where a synthetic material had been used in its creation. However even with the bold move for the times and the commercial success of *Fougere Royale* there remained a general antipathy about the use of synthetic materials in the creation of perfumes.

Synthetic materials continued to play only a minor role in perfumery until well into the 20th Century. Conjecture still remains about whether Ernst Beraux intentionally or by accident used fatty aldehyde C12 in such high proportions in the top notes of a floral perfume that became known as Channel No. 5. This showed the perfume industry the real potential of synthetic materials in perfumery. The use of synthetic aldehydes in such high proportions in the creation of Channel No. 5 also created a new fragrance type – the aldehydic type of which many other classic fragrances like *Arpege* and *Madam Rochas* followed.

From the 1930s onwards, the use of synthetic materials began to gain wide acceptance in the perfume industry. Research into the development of new compounds with interesting odours was increased. Materials that had greater stability over wider pH ranges, resistant to oxidization, not prone to discolouration, and were of consistent quality became commercially available, replacing many natural materials that were more limited in application. This greatly widened the ability of perfumers to be more innovative and produce good reconstitutions of many essential oils. As further research found even cheaper routes to produce aroma chemicals, the creations of the perfumer could at last be incorporated into products that were widely affordable by almost everybody. The perfumery industry itself changed to take it's place in the modern post World War II chemical industry. The development of efficient routes in the synthesis of novel aroma chemicals and the patenting of these processes enabled perfumery houses to develop novel fragrances by keeping these materials captive within their company.

The growth in the use of synthetic materials continued throughout the 1960s. Production of aroma chemicals was undertaken with little concern for wastes and environmental concerns. This assisted in developing an overwhelming cost advantage over aroma chemicals isolated from natural sources, such as essential oils. The cultivation and production of essential oils as sources of aroma chemicals dramatically declined.

Fragrance trends in cosmetics roughly followed the direction of developing technology from the 1940s through to the 1970s. Single flower or straight floral fragrances were popular during the 1940s and 50s, as perfumers were insistent on using their new found materials to imitate natural floral fragrances found in nature. The 1960s saw the development of more complex floral bouquets. Specialties like Hedione, Lilial, Galaxolide, Tonalide, and Lyral started finding their way into fragrances in small proportions to add lift and modify fragrances.

The influence of aroma chemicals on the creation of fragrances can be seen in two *Lily of the valley* fragrance formulae listed in Table 11.53. The 19th Century fragrance was constructed of entirely natural ingredients, while the contemporary perfume heavily relies on synthetics.

The increasing demand for *'naturals'* therefore creates a dilemma for those involved in the marketing of cosmetic and personal care products in considering the positioning of their products in regards to fragrance. On one hand consumers require and expect complexity and sophistication of fragrance in the products they consume, and this is what they have grown accustomed to. On the other hand, consumers prefer a product to be natural.

Table 11..53. An Illustration of *Lily of the valley* Perfume from the 19th Century and Present

19th Century		Present	
Tuberose Extract	21 oz	Hydroxycitronellal	35.0
Jasmin Extract	3 oz	Rhodinol	18.0
Rose Extract	2 oz	Linalool	14.5
Orange Flower Extract	2 oz	Phenyl Ethyl Alcohol	12.0
Spirit of Rose	2 oz	Geraniol	4.5
Essence of Vanilla	2 oz	Di methyl benzyl cabinal acetate	4.5
Ylang Ylang No. 1	½ oz	Amyl cinnamic aldehyde	3.6
Bergamot	½ oz	Lilial	2.0
Bois de Rose Extrait	¼ oz	Iso eugenol	0.5
		Phenylacetaldehyde dimethylacetal	0.2
		Benzyl benzoate	4.2
		Indole (10% solution in Dipropylene glycol)	1.0

Incorporating natural fragrances into products requires a sacrifice of fragrance sophistication as the consumer understands sophistication in fragrance today. Certainly naturals cannot reproduce what synthetic materials have achieved under this criteria. But there is no need to sacrifice the style and special qualities natural fragrances can radiate. The crucial issue here is whether sophistication in fragrance is a more important criteria to the consumer than style and quality.

Mass consumer marketing is an embedded feature of our society. A product in the mass market has to convey to a consumer in everyway possible its functional attributes, branding and image both overtly and sublimely. As the projected overt images can now be matched by those competitors in the marketplace, it is the sublime projections of product functionality, branding and image that become the most powerful communicators to the consumer at the point of purchase.

Although consumers would prefer natural products, the reality is that this preference has not to any great degree resulted in any drastic increase in the use of natural fragrances in cosmetics. The increased importance of aroma chemicals due to the level of sophistication that they can provide in a fragrance with product stability and low cost, has made it very difficult for natural fragrances to be considered for wider use in products by manufacturers. Instead manufacturers of cosmetics have placated the consumer and reconciled this dilemma by creating natural notes. Light and fresh florals, green and herbal notes are very popular in today's cosmetics. Manufacturers have tended to rely on the language and appearance of a product to give the perception of something natural.

The development of new analytical techniques now available to the perfumer may ensure the continued journey down the natural metaphor. Headspace analysis of living flowers will further enhance the perfumer's ability to reconstruct fragrances that are even closer to the natural living scent of flowers.

Some of the main arguments in regards to natural fragrances are summarised below;

a) *The Difficulties of Creating Natural Fragrances*

From the historical perspective, the advantages and widened opportunities synthetic materials have provided perfumery and the cosmetic industry cannot be disputed. The ingredient industry is heavily committed to this path and most flavour and fragrance houses are committed to development and production of synthetic aroma chemicals. There are very few flavour and fragrance houses producing essential oils for perfumery. Thus from the outset, the greatest difficulty in creating fragrances exclusively from natural materials is the orientation of the industry.

Another difficulty associated with creating natural fragrances lies in the properties of synthetic materials that are not available from the use of natural materials. That is the freedom, scope, and versatility that aroma chemicals have given the perfumer to create fragrances for cosmetics. Synthetics have revolutionized soap perfumery from the days of citronella and coal-tar odours, to today, where the odours of soap resemble those of fine fragrances. This could not have been achieved without synthetics.

Synthetics give the perfumer the ability to create a perfume at almost any price. The cosmetic industry itself has put ceilings on prices it is willing to pay for fragrances - admittedly some reasons are outside their control, like buyer power over sellers in concentrated markets. This reinforces the perfumer’s reliance upon synthetic materials. The odour threshold and cost/performance ratio of a material used for perfumery today is one of the most important criteria the perfumer must consider when creating a fragrance. This is where exotic, intensely odoured specialties have made it possible for the perfumer to meet price demands of manufacturers and compete with other fragrance houses.

It is therefore not hard to understand why flavour and fragrance houses are spending great time and money producing synthetic materials. New aroma chemicals introduced into the industry are provided with a great amount of data in regards to their strengths, weaknesses, stability, tenacity, and come with recommendations for use at what levels and for what applications. Producers of essential oils in contrast tend to be poor with the data they provide.

Inventory rationalisations, standardisation on one essential oil grade and the increasing reliance on essential oil reconstitutions have added to the difficulty of creating natural fragrances. The perfume industry is just like any other concerned with efficiencies and economies. As a consequence, fragrance houses now heavily rely upon using pre-developed perfume bases that are modified and enhanced for individual customer requirements. Specialties, accords and Schiff’s bases are efficient from the point of view of purchasing, quality control and production. Procedures in fragrance houses have been changed in the interests of efficiency and today’s perfumers are trained with that in mind. The work of standardising on a particular quality of essential oils and the use of bases tends to be centrally controlled in international organisations. Creating a natural fragrance in these environments may be difficult given that market interest in natural fragrances is very low compared to the total fragrance business of the company. It is in those terms it is not difficult to understand why a valuable perfumer and scarce laboratory resources have not been allocated to developing the concept of natural fragrances further.

For a flavour and fragrance house to create a natural fragrance, the procurement of raw materials outside the usual purchasing procedures is required. This is costly due to the time required to source the materials and put these materials under the required quality assurance tests. Increasing numbers of raw materials will increase inventory levels. It will be necessary to have not just one grade of an essential oil, but perhaps several grades available for different finished fragrance applications. An essential oil from a remote part of the globe may be required for its particular odour profile. Local essential oil traders may have only limited ranges of essential oils for sale at high prices which discourage their use. This may require a flavour and fragrance house to seek the material directly, which is also costly due to the time and small quantities that may be involved.

b) The Difficulty in defining what is Natural

Defining what constitutes a natural fragrance is by no means an easy task. Different interest groups will have different considerations about any definition. Confusion and conflict between the issues of the environment, toxicity, what constitutes a natural material and lack of legal definition in this area has left interpretation open for many to take advantage of.

The narrower the definition of what constitutes a natural fragrance, the greater the difficulty of the perfumer to create a natural fragrance. The International Fragrance Association (IFRA) defines a natural fragrance as a material which has been isolated *"by physical means"* [89]. This immediately leads to problems of defining what is a physical process. This is an argument the food industry has had difficulty agreeing upon. A further issue arising from this is whether feed-stocks should be organically grown.

Any definition of natural should have no implication as to safety and toxicity. It is of great importance to ensure that any natural material used in the creation of a fragrance be free of any constituent that may be toxic or unsafe. This is of particular relevance to fragrances which may come into contact with the skin, as is the case with most cosmetics.

The toxicity and safety considerations reduce the range of materials available for use in the creation of natural fragrances. Bergamot oil contains bergaptene, a furanocoumarin, which is phototoxic. Therefore when bergamot oil comes into contact with the skin, exposure from ultraviolet light can cause potential skin irritancy and dermatitis. Other examples of essential oils that have been recommended for limited use by IFRA in the production of fragrances due to reasons of safety and toxicity are in Table 11.54.

The US food industry resolved many of these issues by defining a category of nature identical. This could be an advantage in cases like bergamot oil. A nature identical material *"is a material produced by synthesis or isolated by chemical reaction from a vegetable product, which is chemically identical to the material in the natural starting product in the unprocessed or processed condition"* [91]. Such a definition would allow a reconstitution of bergamot oil to be used which did not contain bergaptene, or a bergaptene free bergamot oil which did not irritate the skin. However such an approach would widen the definition to a point where many materials which exist in nature but can be obtained via cheaper routes would be acceptable. For example, material like *anethole* which is found in nature but can be obtained more cheaply from cinnamic aldehyde [92] would be able to be used in the creation of natural fragrances. If such an argument is accepted, then many fragrances used in cosmetics today under the nature identical definition would be allowed to be called natural fragrances.

Table 11.54. Examples of Natural materials Not Recommended for Use or Recommended for Limited Use by IFRA [90]

Angelica Root Oil	Limited Use	Phototoxicity
Bergamot Oil	Limited Use	Phototoxicity
Bitter Orange Oil	Limited Use	Phototoxicity
Cade Oil	Prohibited	
Chenopodium Oil	Prohibited	
Cassia Oil	Limited Use	Weak Sensitivity Potential
Costus Root Oil/Concrete	Limited Use	Sensitising Potential
Cumin Oil	Limited Use	
Lemon Oil Expressed	Limited Use	Phototoxicity
Lime Oil Expressed	Limited Use	Phototoxicity
Massoia Bark Oil	Prohibited	
Melissa Oil	Prohibited	
Oakmoss Resinoid	Limited Use	Sensitizing Potential
Peru balsam	Recommended Non Use	Sensitizing Potential
Rue Oil	Limited Use	Phototoxicity
Santolina Oil	Prohibited	
Tagettes Oil	Limited Use	
Verbena Oil	Prohibited	Phototoxicity

c) *The Difficulty of Obtaining Consistent Quality Natural Raw Materials*

One of the most difficult issues in creating natural fragrances is finding consistent sources of quality raw materials. Natural materials will vary in quality according their geographic origin, type of soil in which they are cultivated level of nutrients in the soil climate and weather, rainfall, time of harvest, altitude, pest and diseases and method of extraction. Producers of natural materials have less control over production variables than producers of synthetic materials.

Some of the operational issues involving the use of natural materials would include;

- The problem of producing a fragrance of consistent quality when faced with different odour profiles of the same material from different shipping lots. Different lots of an essential oil may vary in quality, even if from the same producer. This brings a number of problems in product standardisation.
- The problem of obtaining unadulterated essential oils and the extra costs involved in detecting adulteration for the purpose of certifying the perfume

product has been produced exclusively from natural materials. For example, many lavandin oils are blended to create a desired odour profile for perfumery. The unblended lavandin oil may not be as olfactorily desirable as the blended material.

- The added costs of maintaining an inventory of pure blended essential oils.

The quality of materials used in a fragrance will directly affect the quality of the finished fragrance. In today's mass consumer market, variation of quality is unacceptable. Obtaining consistent quality raw materials is therefore a major factor in the viability of creating natural fragrances for cosmetics and personal care products.

d) *The High Cost of Natural Raw Materials*

The cost of natural materials has increased in relative terms over synthetic materials. The concentration of competition has put pressure on flavour and fragrance houses to move away from expensive high quality raw materials to become more reliant on aroma chemicals and specialties. The ability to more easily match fragrances and the proliferation of mid range and generic brands, which follow the market leader, has to some extent, turned fragrances for consumer products into a form of pseudo commodity *(at least at the lower market end)*.

In relative terms, natural fragrances are even more expensive to manufacture than conventional fragrances. Cost conscious management of fragrance houses will be much less inclined to make seasonal purchases of essential oils and hold them in inventory. Acquiring essential oils requires an international organisation with an experienced and coordinated purchasing team, to constantly scan the market in order to guarantee optimum qualitative and quantitative material procurement. This requires specific inventory control procedures different to that of other industries [93]. The wide acceptance of ISO 9000 and 3902 has brought heavily cost burdens on producers of essential oils than those that manufacture synthetic aroma chemicals due to the greater number of variables and procedures required in the production of natural products.

e) *The Limited Availability of Essential Oils*

A strong argument against natural fragrances is the limited supply of natural materials. One of the reasons that production of synthetic aroma materials increased in the 1950s and 1960s was the failure of aggregate essential oil output to cater for the growing demand of for aroma materials. Supplies of a number of essential oils came in short supply from time to time, causing wide price fluctuations because of adverse weather conditions, floods, droughts, cyclones and hurricanes, other natural disasters, wars, political upheavals and the very nature of the marketplace allowing some companies to manipulate prices.

The limited aggregate availability of natural materials and essential oils is not an argument against an individual company using a natural fragrance in a new product. An increase in demand for an essential oil will eventually lead to an increase in supply for the essential oil (or increase in price if supply doesn't increase), due to the market mechanism. The time lag in some cases could be a very long one, depending on the nature and growth characteristics of the material feed-stock. For example, sandalwood oil production dramatically decreased as natural stands were harvested and did not grow back quickly enough to replace what was harvested. Sandalwood oil is distilled from the heartwood of certain varieties of the *Santalum* species and heartwood formation takes at least 10 years to begin and 60 years before they can be commercially exploitable [94]. Notwithstanding, there are many producers in Third World countries who are more than willing to increase production of essential oils if there was greater interest by the industry [95].

The message to manufacturers is to fully research the supply situation of a natural material before making a decision to utilise it in a new product. Careful coordination between producer and manufacture maybe required. For example, the worldwide production of ambrette seed oil is only 500 Kg per annum and around 450 Kg of blackcurrant absolute is produced in Tasmania. Much of this production is already committed to existing customers.

f) The Limited Number of Natural Materials

The creation of a fragrance from purely natural materials is a difficult task. The perfumer was trained to use materials selected from essential oils, concretes, absolutes, aroma chemicals, specialties, Schiff's bases and accords. The palette is complete with a full organ of notes. Restricting perfume creation to only natural materials will effectively take away about 90% of those materials available to the perfumer.

Many tasks in perfumery are difficult without aroma chemicals and specialties. The fixation of a fragrance is a very important task in perfumery. Fixation is the process of retarding the evapouration of the volatile materials in a fragrance by the addition of higher molecular weight materials that are relatively less volatile to increase tenacity. Traditionally musk was used for this purpose. Musk also exhibits some exalting properties on the fragrance. However the material is of animal origin which will not be acceptable to the majority of consumers. Fixatives like musk have mostly been replaced by specialties that have similar exalting properties, for example *Galaxolide* and *Ambrettolide*. Fragrances with exalting properties are very common in today's conventional fragrances. They cannot be duplicated very well when restricted to only natural materials, unless very expensive materials like ambrette seed absolute is used.

The perfumer has to rely on materials like benzoin resinoid, a low volatile natural material to retard the evapouration of other ingredients in a fragrance, Oakmoss resin can also be used to consistently modify the fragrance during all stages of evapouration, however it is under SCCP scrutiny. In fixing a natural fragrance to improve the tenacity, the perfumer will have to use extreme skill in the ingredients he of she selects in accordance with their lasting properties.

Natural ingredients are very limited in the types of green notes available and to date aldehydic notes have been largely missing from the natural palette. Animalic, marine, and metallic notes are almost, if not impossible to achieve. The perfumer when restricted to only natural materials will need great knowledge and skill to be able to create new fragrance themes. The perfumer will have to rely on the substitution of some materials to create some basic notes that widely used aroma chemicals bring to fragrances. Some materials listed in Table 11.55. show some of these possibilities.

Table 11.55. Some Possible Essential Oil Substitutes for Aroma Chemicals

Aroma Chemical	**Essential Oil Substitute**
Linalool	Ho oil, Bois de rose oil, or isolates
Citral	Litsea cubeba oil, lemongrass oil, lemon myrtle oil
Anethol	Aniseed oil
Cinnamic aldehyde	Cassia oil
Cumminic aldehyde	Cassia oil
Methyl salicylate	Wintergreen oil
Coumarin	Tonka bean (25-45% coumarin), Woodruff absolute
Benzaldehyde	Species of Zierea, from bitter almonds
Bornyl acetate	Picea oils (not known to be commercially produced)
Fatty aldehydes C10 + C12	Kesom oil

Nothing is better than using artemisia oil to lift a fougere fragrance according Arctander. Artemisia is very effective in trace amounts and the freshness and naturalness it evokes is magic. Artemisia can convey therapeutic connotations into fragrance [96]. Moreover many essential oils have not been used to their full potential according to Pickthall. Buchu leaf oil can harmonise very well with citrus oils in the top notes of fragrances. It has immense intensity and need only be used sparingly. Violet leaf absolute in traces will leave depth and distinction to a fragrance [98]. Blackcurrant absolute has been another underutilised material until L'oreal added a fruity twist to the floral notes of the fine fragrance *Maroussia* launched in the mid 1990s. Galbanum can give a green balsamic character to a fragrance, much richer than *cis-3-hexenal*, Champaka absolute is waiting to be rediscovered for its unique floral richness and it is very difficult to replace clary sage and patchouli oil with synthetics.

Natural aroma materials exhibit a depth and quality that cannot be matched by their synthetic counterparts. The difference in olfactory quality between a natural and synthetic aroma chemical lies in the proportions of impurities that they contain. Natural isolates from essential oils carry over traces of their parent essential oils while impurities in synthetic aroma chemicals most likely detract from the olfactory quality of the material. Linalool isolated from bois de rose (rosewood) oil has a richer and more interesting odour profile than synthetic linalool.

Natural materials can improve and enhance a fragrance that no synthetic substitute can effectively match. Natural materials are easier to use than synthetics as they are already naturally rounded off. Essential oils are complex fragrances in their own right. Natural fragrances have a unique complexity and quality that cannot be duplicated in a synthetic composition. Imagery is important in brand and product positioning and a natural fragrance can potentially contribute to the perception of naturalness in the product.

g) Another Step in Creating a Natural Product

Consumer pressure has pushed manufacturers to reformulate products containing higher proportions of naturally derived materials from renewable resources. The incorporation of a natural fragrance takes this evolution of the natural product one step further and provides a potential story for the manufacturer to tell the consumer. It is now almost possible to construct a cosmetic formula totally from materials derived from renewable resources as shown in Table 11.56.

Table 11.56. Model Formula for a Natural Cosmetic

Part of Formula	Comment
Surfactant/emulsifier	Products derived from castor, almond, avocado, sesame and wheat germ oils. Also use of enzyme/saponin blends [67]
Waxes	Beeswax, carnauba, candelilla waxes
Mineral oil	Safflower, jojoba, macadamia nut oil
Gums	Guar, Arabic, locust bean gums
Preservatives	Tea tree oil
Colours	Many offered
Fragrance	Essential oils, naturally constructed fragrances

Natural Fragrances as Multifunctional Ingredients

The use of a fragrance as a multifunctional ingredient in cosmetics and personal care products is not a new idea [98]. Natural fragrances and essential oils have great potential to fulfil this role. Lavender and tea tree oil have been observed to be very effective in promoting the healing of skin burns. Tea tree oil has microbial properties and can be utilised as a preservative [99]. Rosemary oil is a good natural antioxidant. Citronella, eucalyptus, lavender, vetiver and clove oils are all insect repellents.

Plant extracts that contain essential oil traces used in cosmetics for phyto-therapeutic reasons can also function either as parts of fragrances or as the fragrance in its own right. Balm mint and birch are two good examples. The issue of efficacy however is often ignored when manufacturers incorporate plant extracts into a cosmetic. For the extract or essential oil to have any therapeutic effect in the product, it must be incorporated at a level that will provide efficacy, either as an individual ingredient or in synergy with other ingredients. Phyto-therapeutics is an area in cosmetics that has tended to rely on folklore, tradition and anecdote due to regulation issues in this area.

The Future Prospects of Supply

The issues discussed so far strongly suggest that the feasibility of incorporating natural fragrances into cosmetics is heavily dependent upon the future supply and price levels of essential oils and other raw materials. It is therefore worth some discussion on this subject.

Dr. Brian Lawrence speaking at the 12th International Congress of Fragrances, Flavours and Essential Oils, held in Vienna back in 1992, foreshadowed a possible crisis in the supply of essential oils derived from botanical sources. Dr. Lawrence believed that pressure from rapidly growing world population will lead to a concentration on food production in the future [100].

Over harvesting of natural resources and competition for alternative uses has caused many problems and shortages of essential oils and even threatened the extinction of some plant and animal species. Ironically research into the development of many synthetic materials has helped save some species from total extinction. The development of synthetic musk compounds definitely helped to preserve the existence of the musk deer.

Sandalwood until recently was not cultivated but collected from the forests and woodlands of Indonesia. High demand for sandalwood in perfumery developed a shortage of sandalwood trees. In the interest of preserving the tree for future generations there is a strong argument for the use of specialties like *sandranol (Dragococ), bacdonal (IFF), brahmanol (Dragoco), and sandalore (Givaudan)* as an alternative to natural sandalwood oil [101]. Controlled industrial production of synthetic substitutes for natural essential oils that are derived from scarce species of flora that are under threat of extinction may be an ecologically sound thing to do.

There are developments in the essential oil industry that may help prevent the crisis in essential oil production foreshadowed by Dr. Lawrence. There are programs underway in Indonesia and Western Australia to replant various species of sandalwood to preserve them for future generations [94]. The same is happening for *agarwood (Aquilaria species),* which until recently wild harvesting was threatening the species around South-East Asia [102].

The assumption that a particular essential oil crop can only be cultivated within a limited geographical areas and climate range is fast diminishing. The production of essential oils is widening from their traditional cultivation areas to new geographical locations. For example tea tree *(Melaleuca alternifolia)* was once thought to be a sub-tropical crop. In the early 1990s it was successfully introduced into tropical climates, where much higher yields were obtained than the crop in its traditional cultivation area [103]. The world map of essential oil cultivation areas is changing. The production costs of European growers have continually increased and cultivation has been transferred to countries like India [104].

Prices of essential oils react to supply and demand conditions like any other commodity. Price rises are usually caused by shortages in supply and/or increases in demand. In real terms over the last 30 years international prices of essential oils have not substantially risen. The low prices of many essential oils in the late 1980s discouraged many growers who ceased production, thereby creating shortages. The rising price of a number of oils during the 1990s was the result of decreased production by marginal growers. High prices will always attract marginal growers until supply increases to the point again where prices will fall.

The cyclic nature of essential oil prices and supply is a problem for the cosmetic manufacturer who needs stability of raw material costs. Price fluctuations are partly the result of the supply structure where growers sell to traders, who resell onto end users. Many companies are bypassing traders and dealing directly with the growers. They are forming close relationships and putting in efforts to assist in the development of that community, under arrangements that benefit all parties. This is an encouraging trend that will do something to bring some stability into essential oil markets.

NATURAL PERFUMERY

Notwithstanding the previous discussion, natural perfumery is re-establishing itself as a craft industry, mainly in the United States. This emerging craft produces fragrances that are composed of totally natural materials, like aromatherapy and exhibit the aesthetic odours of conventional fragrances, according to Mandy Aftel of the Natural Perfumers Guild [105]. Natural perfumes are produced by a number of small companies across the United States that position their fragrances at the top end of the market – where consumers are discerning enough to want to know the origins of each ingredient used in the fragrance. These natural fragrances are also used in very exclusive skin care products, sold to the same group of customers. Natural perfumery is returning to the art of perfumery as known in the beginning of the 20th Century, utilizing natural materials, which were discarded by the mainstream industry because of cost and re-creating tinctures and extracts from natural materials, that industry long ceased to undertake. Perfumers are re-creating the classic type accords and attars of the old industry. This growing field is attracting many novices from aromatherapy. One of the threats to the growth of the natural perfumery movement is the growing regulation against natural ingredients on the grounds of safety. This has to be resolved, so this regulation does not overshadow the growing industry in a state of illegality [106].

Aromatherapy

Aromatherapy is the practice of using volatile plant materials in various forms, but primarily essential oils, to influence a person’s psychological and physiological wellbeing. Aromatherapy is an alternative therapy which can be seen as a branch of general phyto-therapy, which include herbalism, homeopathy, indigenous traditional medicines, traditional Chinese medicine, and ayurvedic medicine, etc. Sometimes aromatherapy is used in conjunction with another therapy. Hospitals in the United Kingdom support aromatherapy as a complementary medicine. Aromatherapy has also branched out to infant, child and pet aromatherapy.

Aromatherapy seeks to treat disorders through both the influence of aromas on the brain through the olfactory system for psychological effect and through the pharmacological effect of essential oils on the body. Support of efficacy is primarily based on ethno-botanical knowledge of the pharmacological aspects, rather than clinical research. Knowledge of the psychological aspects is still in its infancy and is opening up as an area of research. The International Journal of Aromatherapy established by Robert Tisserrand is promoting further scientific research into the discipline.

Unlike other traditional medicines, aromatherapy doesn’t appear to have a base to claim any solid scientific background and support the discipline. Aromatherapy seems to have originated from the art of traditional perfumery and traditional herbal medicine. Aromatherapy is now forming into an advanced discipline. However there is still very much belief in the efficacy of aromatherapy based on pseudo science, and much of the general teaching about aromatherapy practice is of a sub-standard nature. This has led to the increase of regulation of the profession by a number of regulatory authorities.

Aromatherapy is more likely to be offered as an additional service in massage and spas, particularly around the Pacific Rim including the capital cities of South-East Asia. Many companies are producing aromatherapy products that are sold through both specialty shops and major retial chains. Aromatherapy is administrated through diffusion into the air for environmental fragrancing or disinfestation, direct inhalation for respiratory decongestion, topical application through massage, bathing, compresses, or lotions or orally or through rectal or vaginal crevices for infections, fungal disorders and congestions, etc. Aromatherapy practitioners usually use pure unadulterated essential oils and purchase these oils through specific aromatherapy oil wholesalers to ensure the integrity of the product.

Plant materials utilised in the practice of aromatherapy include essential oils, absolutes, hydrosols and infusions. The claimed benefits of essential oils and plant materials from aromatherapy are summarized in Table 11.57. However it should be noted that different practitioners will favour different essential oils (or blends of essential oils) for particular applications based on their own experiences from treatments, and therefore it is difficult to compile an exhaustive list of potential essential oil applications in aromatherapy.

Table 11.57. Claimed Benefits of Essential Oils through Aromatherapy [107]

Essential Oil	Botanical Name	Comment
Angelica Root Oil	*Angelica species*	To combat infections and restore energy levels, aid digestion.
Artemisia Oil	*Artemisia species (A. absinthium & A. vulgaris)*	*A. absinthium:* digestive tonic, uterine stimulant, expels worms, antibiotic, bile stimulant, carminative, antiseptic *A. vulgaris:* digestive tonic, uterine stimulant, stimulating nervine, menstrual regulator, antirheumatic.
Basil Oil	*Ocimum species*	Anti-depressant, antiseptic, stimulates the adrenal cortex, prevents vomiting, carminative, expectorant, sooth itching, reduce blood sugar levels, lowers blood pressure.
Bay Oil	*Pimenta racemosa*	Dandruff, improve circulation, muscle aches.
Bergamot Oil	*Citrus bergamia*	Acne, abscesses, anxiety and depression, boils, cold sores, cystitis, halitosis, loss of appetite.
Bitter Orange Oil	*Citrus aurantium*	Digestive stimulant, aids energy, constipation, cough relief, flu, gum treatment, calms nerves.
Blue Cypress Oil	*Callitris intratropica*	Arthritis and asthma?
Cajeput Oil	*Melaleuca cajeputi*	Coughs and colds, respiratory problems, rheumatic aches, stomach upsets, ease nasal congestion.
Camphor Oil	*Cinnamomum*	To treat influenza, coughs, bronchitis,

	camphora	clear the head, nasal congestion, stimulates the heart, raises low blood pressure, good for cold sores and backaches.
Cananga Oil	*Cananga odorata*	High blood pressure and stress and anxiety.
Cardamom Oil	*Elettaria cardamomum*	Treatment for loss of appetite, colic, fatigue and exhaustion, halitos and stress.
Carrot Seed Oil	*Daucus carota*	Eczema, gout, detoxification.
Cassia Oil	*Cinnamomum cassia*	Digestion, colic, diarrhoea, rheumatism and colds/flu
Catnip *(Catmint)* Oil	*Nepeta cataria*	Anti-inflammatory, rheumatism, astringent, carminative, nervine, sedative, topical anesthetic.
Cayenne Infusion *(less irritant to skin)*	*Capsicum frutescens*	Circulatory stimulant, promotes sweating, gastric stimulant, carminative, antiseptic, antibacterial, nerve stimulant, topical counter irritant (increases blood flow to area).
Cedarwood Oil (Atlas) Cedarwood Oil (Viginian)	*Cedrus atlantica/Juniperus virginiana*	Acne, bronchitis, coughs, cystitus, dermatitis, stress.
Celery Seed Oil	*Apium graveolens*	Antirheumatic, sedative, urinary antiseptic, reduces blood pressure, anti-fungal, diuretic, treatment of gout.
Chickweed Infusion	*Stellaria species*	Astringent, antirheumatic, wound healing.
Cinnamon Oil	*Cinnamon species*	Antibacterial, antifungal, uterine stimulant.
Citronella Oil	*Cymbopogon nardus*	Fatigue and exhaustion, headache, insect repellent.
Clary Sage Oil	*Salvia sclarea*	Amenorrhea, asthma, coughs, dysmenorrhea, stress and anxiety, colic, labour pains, throat and exhaustion.
Coriander Oil	*Coriandrum sativum*	Arthritis, colic, fatigue and exhaustion, indigestion, nausea, rheumatism.
Davana Oil	*Artemisia pallens*	Aniety, healing of wounds, antiseptic, coughs, inducing menstruation.
Dill Oil	*Anethum graveolens*	Amenorrhea, infant gripe pains
Elemi Oil	*Canarium luzonicum*	Bronchitis, catarrh, coughs, healing wounds, stress.

Table 11.57. Continued

Essential Oil	Botanical Name	Comment
Eucalyptus citriodora Oil	*Eucalyptus citriodora*	Arthritis, bronchitis, catarrh, cold sores, colds and coughs, fever and flu, to improve blood circulation and sinusitis.
Eucalyptus Oil	*Eucalyptus globulus*	Antiseptic, antispasmodic, treatment of scarlet fever, influenza, measles and typhoid, infusion reduces blood sugar levels.
Fennel Oil	*Foeniculum officinale*	Digestive problems, mild expectorant, coughs, respiratory complaints, bruises, cellulites, nausea, obesity and detoxification.
Fir Needle Oil (Silver)	*Abies alba*	Arthritis, bronchitis, colds, coughs, flu, muscle aches, rheumatism, sinusitis.
Galanga Oil	*Alpinia galanga*	Stomach, spleen, relief of pain, treatment of flu and colds, travel sickness, aphrodisiac, easing heart pain and angina, dizziness and fatigue
Galbanum Oil	*Ferula galbaniflua*	Abscesses, acne, boils, bronchitis, lice, muscle aches, blood circulation, rheumatism, stretch marks, wounds.
Garlic oil	*Allium sativum*	Infections and chest problems, digestive disorders, thrush, cardiovascular problems, cholesterol, atheroselerosis, thromboses, blood pressure, regulate blood sugar levels, cancer preventative.
Geranium Oil	*Pelargonium graveolens*	Acne, cellulites, lice treatment, menopause.
German Chamomile Oil	*Matricaria recutita*	Abscesses, allergies, anti-inflammatory, anti-spasmodic, cold sores, colic, dermatitis, dysmenorrhea, ear ache, head ache, insomnia, nausea, sedative, sprains, eczema, asthma.
Ginger Oil	*Zingiber officinalis*	Circulatory stimulant, nausea, relaxes peripheral blood vessels, promotes sweating, expectorant, prevents vomiting, antiseptic, anti-spasmodic, carminative, antibacterial, increases blood flow to area through topic use.
Grapefruit Oil	*Citrus decumana*	Cellulitis, detoxification
Gurjun Balsam	*Dipterocarpus species*	Antiseptic, anti-inflammatory, bronchitis, colitis, anxiety.
Hyssop Oil	*Hyssopus officinalis*	Increases alertness, uplifting and

		relaxing nerves, nervous exhaustion, anxiety, used topically as an anti-inflammatory, bruises and anti-viral.
Jasmine Absolute	*Jasminum species*	Massage and rubs for menstrual pain, depression, impotence and frigidity, also chest pains for coughs and colds, during childbirth to encourage parturition and ease labour pain.
Juniper Oil	*Juniperus communis*	External remedy for arthritic and muscle pains. Increases the filtering of waste products by kidneys, antibacterial.
Khella Oil	*Amni visnaga*	Antispasmodic, relaxant, antiasthmatic, diuretic.
Lavender Oil	*Lavendula species*	Relaxant, headaches, colic and indigestion, antispasmodic, circulatory stimulant, nerve tonic, antibacterial, analgesic, carminative, bile flow promotion, antiseptic.
Lavendin Oil	*Lavandula hybrida and other species*	Abscesses, asthma, blisters, boils, burns, cuts, cystitis, eczema, fatigue and exhaustion, irritated skin, insect bites, shock, sores, sprains, vertigo, wounds.
Lemon Oil	*Citrus Limon*	Athletes foot, chilibains, colds, corns, flu, skin blemishes, varicose veins, warts.
Lemon Balm Oil (Melissa)	*Melissa officinalis*	Depression, treatment of cold sores, sedative, digestive stimulant, relaxes peripheral blood vessels, promotes sweating, relaxes nervous system, anti-bacterial, anti-spasmodic.
Lemon Myrtle Oil	*Backhousia citriodora*	Athletes foot, colds, flu, skin blemishes, insect repellent, stress.
Lemongrass Oil	*Cymbopogon citrates and flexuosus*	Acne, Athletes foot, excessive perspiration, insect repellent, muscle aches, scabies, stress.
Lime Oil	*Citrus aurantifolia*	Asthma, chilibains, colds, flu, varicose veins.
Litsea Cubeba Oil (May Chang)	*Litsea cubeba*	Acne, indigestion.
Mandarin Oil	*Citrus reticulata*	Acne, insomnia, scars, skin blemishes, stress and wrinkles.
Manuka Oil	*Leptospermum scoparium*	Astringent, antimicrobial, treatment of intestinal worms, sores, fever and diarrhoea.

Table 11.57. Continued

Essential Oil	**Botanical Name**	**Comment**
Marigold Oil	*Calendula officinalis*	Antifungal for thrush, anti-inflammatory, heals skin wounds, menstrual regulator, stimulates bile production.
Marjoram Oil	*Origanum majorana*	Amenorrhea, bronchitis, chilibains, colic, coughs, down libido, hypertension, muscle aches, neuralgia, rheumatism, sprains, stress.
Mint oil	*Mentha species*	Analgesic, calming, cooling for migraines, anti-bacterial, clear nasal congestion, prevents vomiting, relaxes peripheral blood vessels, promotes bile flow.
Mullein Infusion	*Verbascum thapsus*	Expectorant, demulcent, mild diuretic, sedative, wound healing, astringent, anti-inflammatory.
Myrrh Oil	*Commiphora molmol and other species*	To assist in healing wounds, anti-inflammatory, anti-fungal, antiseptic, immune stimulant, circulatory stimulant, assist in preventing atherosclerosis, haemorrhoids, use in rubs for bronchitis and catarrhal colds.
Myrtle Oil	*Myrtus communis*	Asthma, coughs, sore throat.
Neroli Oil	*Citrus bigardia*	Antidepressant, calming, chronic diarrhoea, insomnia, stretch marks.
Niaouli Oil	*Melaleuca quinquenervia*	Acne, bronchitis, colds and flu, constipation, sore throats, cuts, aching muscles.
Nutmeg Oil	*Myristica fragrans*	Rheumatic pain, treatment of toothache, aid digestion, appetite stimulant, anti-inflammatory.
Olibanum Oil (Frankincense)	*Boswella carterii*	Anxiety, asthma, bronchitis, coughs, stress, treating stretch makes.
Parsley Oil	*Petroselinum sativum*	Amenorrhea, arthritis, cellulites, cystitis, frigidity, infant gripe pains, digestion, detoxification and rheumatism.
Patchouli Oil	*Pogostemon cablin*	Acne, athletes foot, dermatitis, eczema, fatigue and exhaustion, frigidity, stress.
Pepper Oil	*Piper nigrum and other species*	Aches and pains, coughs, chills, cramps, digestion, antiseptic, anti-bacterial, topical use increases blood flow around area.

Petitgrain Oil	*From the leaves of Citrus aurantium*	Acne, fatigue and exhaustion, stress.
Pimento Berry Oil	*Pimenta officinalis*	Treatment of rheumatism, digestive system, nervous system, antidepressant, exhaustion.
Plai Oil	*Zingiber cassumunar*	Anti-inflammatory, uterine relaxant.
Roman Chamomile Oil	*Anthemis nobilis*	Abscesses, allergies, arthritis, boils, colic, cystitis, dermatitis, dysmenorrhea, ear ache, head ache, anti-inflammatory, insomnia, nausea, PMS, rheumatism, cold sores, sprains, stress, treatment of wounds.
Rose Oil	*Rosa species*	Anti-depressant, anti-spasmodic, aphrodisiac, astringent, sedative, digestive stimulant, increase bile production, expectorant, anti-bacterial, antiseptic, kidney tonic, blood tonic, menstrual regulator, anti-inflammatory.
Rosewood Oil	*Aniba rosaeodora*	Acne, colds, fever, flu, frigidity, head ache, sensitive skin, stress, stretch marks.
Rosemary Oil	*Rosmarinus officinalis*	Astringent, digestion aid, nervine, carminative, antiseptic, promotes bile flow, anti-depressant, circulatory stimulant, anti-spasmodic, cardiac tonic, analgesic, increases blood flow through topical use, antirheumatic.
Sandalwood Oil	*Santalum album*	Antiseptic, anti-depressant, antibacterial, urinary problems, abdominal discomforts, skin irritations.
Spanish Sage Oil	*Salvia lavandulaefolia*	Acne, cuts, dermatitis, eczema, hair loss, muscular pain, poor blood circulation, cough and colds, flu, head aches, anxiety, rheumatism.
Spearmint Oil	*Mentha spicata*	Asthma, exhaustion, flu and fever, nausea, vertigo.
St. Johns Infusion	*Hypericum perforatum*	Astringent, analgesic, antidepressant, antiviral, topically for anti-inflammatory and burns.
Star Anise Oil	*Illicum verurn*	Rheumatism, bronchitis, coughs, colic, cramps, aid digestion.
Sweet Orange Oil	*Citrus sinensis*	Digestive stimulant, aids energy, constipation, cough relief, flu, gum treatment, calms nerves.

Table 11.57. Continued

Essential Oil	Botanical Name	Comment
Tagetes Oil	*Tagetes glandulifera and patula*	Corns and warts.
Tea Tree Oil	*Melaleuca alternifolia*	Anti-bacterial, anti-fungal, antiseptic, anti-viral, Candida, cold sores, corns, cuts, flu, ringworm, diaphoretic, expectorant.
Thyme Oil	*Thymus species*	Antiseptic, expectorant, antispasmodic, antiseptic, astringent, antibacterial, antifungal, diuretic, coughs, antibiotic, wound healing, increases blood flow through topical use.
Vetivert Oil	*Vetiveria zizanoides*	Acne, cuts, anti-depressant, exhaustion, insomnia, muscle aches, sores and stress.
Violet leaf Absolute	*Viola odorata*	Bronchitis, head ache, insomnia, rheumatism, poor blood circulation, sore throat.
Yarrow Oil	*Achillea millefolium*	Anti-inflammatory, for chest rubs for colds and influenza. Also as a mosquito repellent.
Ylang Ylang Oil	*Cananga odorata*	Anxiety, anti-depression, frigidity, hypertension, palpitations, stress.

According to Catty, hydrosols are *"the condensate water coproduced during steam or hydro distillation of plant material for aromatherapeutic purposes"* [108]. This implies that hydrosols should be specifically produced for aromatherapy. Hydrosols exclude floral waters which are manufactured and formulated. Infusions are the result of soaking plant materials in water, a carrier oil or other solvent. Infusions can also be made through boiling the herb in water like tea. The advantage of hydrosols and infusions is that they contain the maximum amount that the carrier solvent can absorb and thus contain diluted aromatic materials which should not cause skin irritancy.

Many essential oils require mixing with a carrier oil to dilute them for application to the skin. Carrier oils are usually cold pressed from the fruit, nuts or kernels of plant materials and include almond oil, apricot kernel oil, avocado oil, borage seed oil, camila seed oil, evening primrose oil, grapeseed oil, hazelnut oil, hemp seed oil, jojoba oil, macadamia nut oil, olive oil, peanut oil, pecan oil, rose hip oil, sesame oil and sunflower oil. These oils may or may not have therapeutic properties in their own right but may have some underlying sweet fatty odour.

Most practitioners would argue that aromatherapy oils should be either certified organic or biodynamic or at least chemical free.

Over the last few years there have been a number of safety concerns leading to scrutiny of a number of essential oils by regulatory authorities. Citrus oils have created concerns over phototoxicity, lavender and tea tree oils over sensitisation and gynecomastia, eucalyptus oil over oral toxicity and sage, hyssop and cedar wood oils for liver damage. Secondly, many essential oils, particularly those wild collected are endangered and in jeopardy of extinction when harvested in an unsustainable way. These essential oils were discussed back in chapter one of this book.

Companies within the aromatherapy industry produce a number of products including essential oils, hydrosols and infusions. Companies also usually offer a wide array of burners, carrier oils and blends for specific applications. There is also diversification into floral waters, candles, cosmetics and cosmoceuticals. Aromatherapy products are sold through pharmacies, department stores, supermarkets, and cosmetic suppliers, health food stores, through direct selling and through the internet.

Aromatherapy products also marketed in a number of different grades and qualities. Many grades like *grade A'* and *'therapeutic grade'* are sold on the market, but have no corresponding regulatory standard or certification, and are just *labelling gimmicks.* Many products at the lower end are labelled as aromatherapy products, but are just synthetic fragrance blends trying to take advantage of the consumer.

The aromatherapy industry has merged with the cosmetic and pharmaceutical industry where many products cannot be easily differentiated and defined as either a cosmetic, pharmaceutical or aromatherapy product. The aromatherapy industry has its specialised producers, product manufacturers and distributors, retailers and spas, and practising therapists as well as representative organisations.

HOUSEHOLD PRODUCTS

There are a number of household products that utilise essential oils in their formulations as active ingredients. These include products in the laundry, cleaning, air freshener and insecticide categories. Like the cosmetic industry, companies in the household industry are putting more emphasis on developing 'green' products. This has involved strategies such as replacing raw materials in products to improve biodegradability [109], reducing the product environmental footprint [110], developing 'green' and organically certified products [111], and making takeovers of established companies in the 'green' market [112]. Clorox recently announced that it is committed to developing a 'mainstream store range' of cleaning products that utilise renewable surfactants based on coconut and essential oils as the active ingredients [113]. What will be noticed while travelling through a number of 'green' product websites is that there is very little agreement about what makes a 'green' product [114]. However it should also be noted that not all products utilising essential oils as active ingredients claim to be 'green' products. The following products show a few examples of household products that utilise essential oils as active ingredients.

Laundry Products

d-Limonene constitutes up to 90% of orange oil and used by many low grade laundry powder manufacturers as a cheap alternative to fragrance. Other alternatives like *Litsea* *cubeba*, verbena, lemongrass and orange oils are also used as a replacement for fragrance. *d*-Limonene or other citrus type essential oils are used at approximately 0.2-0.3% in the product formulation. However with the advent of 'green products', *d*-limonene levels were increased to as high as 3-4% to take advantage of its solvent properties in the washing process. The disadvantage of *d*-limonene through the washing process is that it doesn't provide much residual fragrance effect on the clothing that most modern laundry detergents provide. A typical formula of a concentrated laundry powder utilising *d*-limonene is shown in Table 11.58.

Table 11.58. A Conventional Contracted Laundry Powder Formulation Using *d-Limonene* as a Fragrance

Ingredients	**Percentage**
Alcohol Alkoxylates	10% w/w
Sodium Tripolyphosphate (or blend of sodium citrates/zeolites)	40% w/w
Sodium Metasilicate	12.5% w/w
Sodium carbonate	15.0% w/w
Carboxy Methylcellulose (CMC)	3.0% w/w
Enzyme (Protasease)	1.0% w/w
Optical Brightener	0.5% w/w
Sodium sulphate	15.25% w/w
d-limonene	3.0% w/w
Ultramarine Blue Dye	To colour

Figure 11.31. A *d*-Limonene Fragranced Concentrated Laundry Powder Developed in Australia by the Author During the 1980s.

A number of products have been developed for specialised sections of the laundry market such as light washes for woollens and denims. Eucalyptus wool washes were popular in the Australian market during the 1970s and 1980s. A typical eucalyptus wool wash formula is shown in Table 11.59.

Table 11.59. A Typical Wool Wash Formula (soap based)

Ingredient	Percentage
Oleic acid	10.8% w/w
Ethanol	2.4% w/w
Sodium hydroxide	1.5% w/w
Eucalyptus oil	1.5% w/w
Preservative	0.2% w/w
Coconut Diethanolamide 80%	3.0% w/w
Phosphoric acid 81%	q.s.
Water	80.60% w/w

In Indonesia and to some extent in Malaysia cream detergents are sometimes used for the cleaning of clothes and dishes. Some of the more basic brands used citronella oil as the fragrance of choice. A basic cream detergent formula utilising citronella oil [115] is shown in Table 1.60.

Sometimes a unique application is found for an essential oil, as was the case with *Eucalyptus dives oil.* A stain removal soap was invented in Melbourne using *Eucalyptus dives* oil as the active ingredient under the brand of SARD® Wonder Soap [116]. This product removed stains so well, that it quickly developed a very loyal customer following and drew the attention of multinational companies and brand was purchased by Colgate-Palmolive Australia. The product is basically a standard soap formulation with approximately 2.0% *Eucalyptus dives* oil. The product is restricted to the Australian and New Zealand markets.

Table 11.60. A Sample Cream Detergent Formulation

Ingredient	Percentage
Sodium Tripolyphosphate	1.5% w/w
Trisodium Phosphate	0.75% w/w
Sodium hydroxide	0.75% w/w
Sodium carbonate	3.60% w/w
Coconut monoethanolamine	0.75% w/w
Carboxyl methyl cellulose	3.60% w/w
Alkylbenzene sulphonate	15.0% w/w
Kaolin	0.1% w/w
Water	71.95% w/w
Citronella Oil	2.0% w/w

Figure 11.32. SARD Wonder Soap in the Stain Removal Section in Australia.

Pre-wash stain removers can also be manufactured using other essential oils like orange oil, lemon oil, lime oil and *d*-limonene at around 2-5.0% w/w in the total formulation. The photo below shows an orange oil based product developed by the Author for the Malaysian market.

Figure 11.33. Orange oil Stain Removal Bar in the Malaysian market.

Pine Oil Disinfectants

One of the earliest products to utilise an essential oil as an active ingredient were pine oil disinfectants. Pine oil is a phenolic disinfectant, which was widely used because of its broad spectrum antiseptic qualities before quaternary ammonium compounds were available. Two types of pine oil are used, pine oil, steam distilled from the heartwood and stump wood of *Pinus palustris*, *P. ponderosa* and other species, and pine needle oil from the needles and twigs of *Pinus sylvestris*. Because of consumer acceptance of the clean and medicinal pine scent, these products have become important products in the United States, United Kingdom, Australia, New Zealand and the Philippines under various brand names. Today, pine oil type disinfectants take their place in the market along side quaternary ammonium compound, chloroxylenol-pine and chlorine type disinfectants [117].

There are two basic types of pine oil disinfectants, soap based and surfactant based.

Table 11.61. Soap Based Pine Oil Disinfectant

Ingredient	**Percentage**
Oleic Acid (Oleine)	5.5% w/w
Caustic potash	1.25% w/w
Pine oil	10.0% w/w
Terpinolene	0.4% w/w
Eucalyptus oil	0.4% w/w
Ethanol	25.0% w/w
Dye (caramel)	To colour
Water	Balance

The terpinolene and eucalyptus oils are added to the formulation for odour enhancement. Eucalyptus oil became very popular in Australia as a disinfectant odour during the 1950s.

A simple old formula for a pine oil disinfectant boosted with quaternary ammonium compounds is similar in style to a number of brands on the market. Pine-o-Clean, an Australian brand created by the Author's grandfather Len D. Hunter Snr. during the 1930s [118], now owned by Reckitt-Benckiser Australia [119] is shown below, among other brands on the Australian market in 2005, where the product has also developed into aerosol and concentrated forms.

Table 11.62. Non-Ionic Surfactant Based Pine Oil Disinfectant

Ingredient	**Percentage**
Non Ionic surfactant	7.0% w/w
Quaternary Ammonium compound	6.0% w/w
Pine oil	6.0% w/w
Ethanol	30.0% w/w
Water	Balance

Figure 11.34. Disinfectant Products on the Australian Market in 2005.

Insecticides and Repellents

Essential oils are part of a plant's defence system against pathogens and herbivores. These may have toxic effects to insects or interfere with their sensory systems. Consequently, essential oils offer a potential alternative to conventional insecticides, which are considered toxic. This is an area where commercial research and development is very active on developing new applications for essential oils.

Citronella candles utilise more citronella oil than any other application. Citronella candles have become part of the American outdoor summer lifestyle scene, followed in countries like Australia and New Zealand. S. C. Johnson market a citronella candle under the "Off" and 'RAID" branding [120]. In South-East Asia citronella candles are used to repel flies and mosquitoes away from food stalls. In Thailand they are also popular as a herbal product. Citronella candles are either solid candles manufactured from paraffin wax and stearic acid or liquid paraffin in a sealed container with a wick. There is some conjecture about the true effectiveness of citronella candles by consumers [121]. The variance in effectiveness may occur because of the different strengths of various brands and the variance of outdoor wind conditions, which may blow the citronella smoke away from where it is desired. The pictures below show both the solid candle and liquid paraffin types.

Figure 11.35. Liquid Paraffin Citronella Candle.

Figure 11.36. Solid Paraffin Wax Type.

Essential oils are also used in other forms of insect repellents. This includes blocks for repelling cockroaches and other crawling insect and powders for repelling ants. Essential oil scented blocks are common as a replacement for toxic paradichlorobenzene, which has been linked to liver damage and cancer [122]. Various essential oils known for their insect repellency are used either alone or blended with other oils to act in synergy. The products shown in the photo below use citronella, clove, lavender and peppermint oils in different blends. The ant and cockroach repellent was developed by the Author for both the Australian and Malaysian markets and their formulae are shown in Tables 11.63. to 11.65.

Figure 11.37. Roach Attack is an essential oil blend of citronella and lavender oils, Ant Attack is an essential oil blend of citronella, clove and peppermint oils. Ant Attack comes in both a powder (calcium carbonate) and liquid (ethanol base).

Table 11.63. Formula for PDCB Replacement (Insect Repellent) Blocks

Ingredient	**Percentage**
Microcrystalline wax	0.75% w/w
Paraffin Wax 55°C Melting point	45.25% w/w
Stearic Acid	42.0% w/w
Citronella Oil	6.0% w/w
Lavender Oil	6.0% w/w

Table 11.64. Formula for Ant Repellent Powder

Ingredient	**Percentage**
Calcium carbonate and Talc blend	90.0% w/w
Essential oil Blend (see blend for ant repellent liquid)	10.0% w/w

Table 11.65. Formula for Ant Repellent Liquid

Ingredient	**Percentage**
Ethanol	93.0% w/w
Essential oil blend	7.0% w/w
Essential Oil Blend:	
Citronella Oil	15.0% w/w
Clove Oil	75.0% w/w
Peppermint Oil	10.0% w/w

The development of an aerosol based knock down insecticide has been attempted by many companies over the years [123]. A large number of patents exist in this area, but very few actual products exist in the market place. However in the first couple of months of 2008, Ecosmart Technologies Inc. have launched a 'knock down' aerosol insecticide for household use based on peppermint, sesame, cinnamon, wintergreen and canola oils [124]. Biomor Israel has also launched a 'knockdown' household insecticide under the brand of *Timor C,* utilising natural pyrethrum and tea tree oil as a synergist [125].

Mosquito and Incense Coils

Mosquito and incense coils are one of the oldest ways of fragrancing an open area. Sticks and coils of fragrance wood or grated coconuts have been ground and stuck together using resins mixed with aromatic materials like spices, resins and balsams for many years. These items are used in Buddhist temples throughout South-East Asia and then manufactured in coil form with an insecticide added to repel mosquitoes. In undeveloped and developing countries in the region, mosquito coils made up the bulk volume of consumer insecticide markets dominated by multinational brand names. These odourants in the form of incense cones have found their way into many *"western"* markets as aromatherapy and general mood items, a number of years ago. Incense items of quality usually contain myrrh, benzoin, labdanum, styrax, mastic, elmi, tolu, peru and other oleoresins and balsams, sandalwood, agarwood, deodorwood, cedarwood, cascarilla and other woods, cloves and cinnamon barks, vetivert, patchouli, and various other essential oils, as well as crystalline materials like vanillin, coumarin, heliotropin, rose oxide and nitro musks [126]. The downmarket items in discount stores will most likely contain low cost fragrances.

Air Fresheners

Air fresheners cover a wide range of products including sachets, potpourris, continuous gel products, liquid wicked diffusers, candles, aromatherapy burners, solid and impregnated materials like plastics and aerosol products. Although many products in the air freshener market portray themselves to be based on natural materials, in fact very few really are. Most products, at least in the mainstream market utilise conventional fragrances. However some very specialised products from smaller companies utilise essential oils for particular markets, like the aromatherapy market – for example oil burners, potpourri, continuous gels, etc. *d*-Limonene was a major ingredient in the can type car air fresheners sold in South East Asia during the 1980s and 90s. This type of formulation utilising *d*-limonene and sodium stearate soap was mostly superseded with copolymer technology (see Table 11.66.) that allowed fragrances that provided wider scope for non-citrus fragrances.

A number of air freshener type products came into the market in the early part of the decade that are duel function fragrance and malodour eliminator. For example, Procter and Gamble's brand Febreze is a range of duel function air freshening products that include candles, fabric refreshers and laundry odour eliminators, liquid, aerosol and solid air fresheners [127]. Proprietary compounds that react with odour source compounds make up the basis of these types of products. One patent, the basis of some of these products, utilises cornmint oil and citral in high proportions [128].

Table 11.66. Formula for *d*-Limonene Type Gel Air Freshener

Ingredient	**Percentage**
d-limonene	63.5% w/w
Hexylene Glycol	5.0% w/w
Ethanol	6.0%w/w
Water	2.0% w/w
Sodium stearate	8.5% w/w
Fragrance	15.0% w/w
Dye solution	*q.s.*

Orange Oil and *d*-Limonene Cleaners

Orange oil and *d*-limonene cleaners have been on the market for many years and household all purpose cleaning versions have gained popularity due to orange oil being a natural product. Orange oil and *d*-limonene cleaners include all purpose cleaners, stain removers, engine and oven degreasers, carpet cleaners, paint and chewing gum remover, and hand cleaners, etc. Many of these cleaners are actually ethanol or isopropyl alcohol mixed with orange oil or *d*-limonene, although some are pure *d*-limonene. The photo below shows a product manufactured by a multinational on the Australian Market [129]. *d*-Limonene has been used for a number of decades in the manufacture of industrial hand cleaners. Table 11.67. shows a formula for a *d*-limonene cleaner, popular in the 1970s.

Figure 11.38. An Orange Oil/*d*-limonene All Purpose Cleaner on the Australian Market.

Table 11.67. *d*-Limonene Industrial Hand Cleaner

Ingredient	Percentage
Alkylbenzene sulphonate	4.0% w/w
Non-ionic surfactant	3.0% w/w
Oleic acid	4.0% w/w
Lanolin	0.5% w/w
d-limonene	26.0% w/w
Potassium hydroxide	0.45% w/w
Preservative	0.2% w/w
Water	61.85% w/w

AGRICULTURAL CHEMICALS

The *'green revolution'* in agriculture brought with it a great leap forward in yields and productivity. However it also brought with it a number of toxic chemicals. This is the same case with garden products, primarily consisting of herbicides, fungicides and pesticides, widely available in most supermarkets and hardware outlets throughout the Asia-Pacific region.

The first agricultural pesticides were developed in the second half of the 19^{th} Century as a mixture of copper arsenite, known as *Paris green* in the United States. Around the same time in Europe, lime sulphur, called *Bordeaux mixture* was introduced to control downy mildew on grape vines. Bordeaux mixture was also applied as a herbicide to competing vine plants. Iron sulphate was also used to kill dicotyledonous weeds, without disturbing cohabitating cereal crops. In the early 1900s, organomercury compounds, used in medicine to fight syphilis were found effective in protecting seeds from insect attacks. In the 1930s, tar oil was used to kill aphids and dinitro-orthocresol was patented in France for the control of weeds in cereal crops. During the Second World War, organophosphorus compounds and DDT was developed in Germany and phenenoxyacetic acid (2,4-D) types of weedicide were developed in the United kingdom. After the Second World War carbamate herbicides were developed in the United Kingdom, the organochlorine insecticide chlorodane in the United States and Germany and carbamates as insecticides in Switzerland. Pyrethrum, a natural extract from *Chrysanthemum cinerariaefolium* cultivated commercially in the highlands of Kenya, was used as a knock-down insecticide. Soon after Allethrin, a synthetic substitute for pyrethrum was developed as well as a number of synergists, like piperonyl butoxide, piperonyl cyclonene, sulphoxide, *n*-propyl isome, MGK 264, sesame oil extracts and bucarpolate, which enhanced the strength of pyrethrum and similar insecticides. During the 1950s urea based compounds were introduced as herbicides, captan and glyodin as fungicides, the insecticide malathion and triazine as a herbicide from Switzerland. New product development continued through the 1960s where the fungicide benomyl and soil-acting herbicide glyophosate were introduced into the United States market [130].

There was once a prevailing belief that the environment can be totally controlled through fertilisers, pesticides, herbicides, hormones and trace elements. However these accepted practices began to show their shortcomings and basic assumptions about agriculture re-questioned. Evidence showed conventional practices led to phosphates, heavy metals and herbicides seeping into water tables, crops absorbing unsafe levels of chemicals and land just failing to provide satisfactory yields, due to unsustainable practices. Toxic chemicals left little margin for error and would result in pesticide residuals in food, if harvests occurred shortly after applications of insecticides, fungicides and herbicides. Some pesticides, chlorinated hydrocarbons, pyrethroids, copper compounds and captan were also killing fish in near by waters where they were sprayed, birds died from chlorinated hydrocarbons, such as aldrin, lindane and heptachlor, earthworms from benomyl, dithicocarbamates and other chlorinated hydrocarbon pesticides and bees from pyrazophos [131]. The dangers of pesticides, herbicides and fungicides became apparent with a production mishap in Italy during 1976 when a cloud of dioxin was released. This brought to light numerous accounts and stories of industrial mishaps where employees and the public were endangered [132].

As a result, many involved in agriculture began to re-evaluate the practices and methods of the past. New paradigms have been developed with the catch phrases of *'sustainable', 'integrated', 'organic'* and *'balanced eco-system'*. The *'new-age'* farmer is much more sensitive to the eco-system that supports the viability of the enterprise. As a consequence some farmers are beginning to use a much wider information base to make decisions, with a *holistic* orientation, understanding in great detail relationships between *'inputs'* and *'outputs'*, focusing on balance.

This awareness is spurring the rapid increase in production of organic foods. Organic farming is now practiced by 700,000 farms in 138 countries, where 30.4 million hectares (73 million hectares) are under cultivation in 2007. This is an increase from approximately 100 countries throughout the world, with 24 million hectares (59 million acres) under organic management, in 2004 [133]. This represents 0.65% of total global agriculture. Australia leads with approximately 12.3 million hectares (30 million acres), up from 10 million hectares (24.6 million acres), followed by China with 2.3 million hectares (5.5 million acres), Argentina, with approximately 2 million hectares (4.8 million acres), and the United States with 1.6 million hectares (3.8 million acres). Latin America has approximately 3.84 million hectares (9.2 million acres) under organic management, Europe has more than 5.76 million hectares (13.8 million acres), and Asia has nearly 4.8 million hectares (11.52 million acres) [134]. Organic farming has shown an increase of 20% per annum over the last decade and now approximately 2% of the U.S. food supply is grown using organic methods [135].

The global market for organic food and drink reached $38.6 billion in 2006, more than double 2000 [136]. However, with the 2008 financial crisis yet to show its full impact, there are signs that organic sales are dropping in some key markets like the U.K [137]. As a result there are reports of farmers cutting back on production levels [138], requesting certifying authorities to relax standards [139], or quitting organic production all together [140].

As consumers become more concerned about what they eat, many agricultural enterprises are switching to organically certified pesticides, herbicides and fungicides. As was noted in Chapter Ten, only certain types of agricultural chemicals are allowed in organic farming, including those derived plants, animals, or mineral bearing rocks and micro-organisms. Soaps are also allowed under many certifying authorities. Generally, pesticides and soaps allowed for organic farming are those that will break down quickly and non obtrusive to the eco-system. This is the fastest growth market in the agricultural chemical industry, with many young companies, rather than established multinationals, taking the lead in innovation. The discussion will now turn to some of the types of agricultural chemicals using essential oils as active ingredients that are organically certifiable.

Essential Oil Based Fungicides/Insecticides

Essential oils as secondary metabolites have the function of protecting a plant from fungal diseases. Many essential oils have anti-bacterial properties against bacteria, fungi and viruses. Research has found that some essential oils are effective against various bacteria and fungi in horticultural and agricultural situations. These include cinnamon, clove, fennel, lavender, rosemary, tea tree, thyme, and oregano oils.

A new generation of crop protection products is emerging in the market, based on a water-in-oil emulsion, where it is converted into an oil-in water emulsion containing tea tree and other essential oils and plant extracts [141]. These products take advantage of the anti-microbial properties of tea tree oil *(Melaleuca alternifolia)* and function as a fungicide. Biomor of Israel manufactures these products under the trademarks of *Timor* and *Timorex* [142]. These products are certified as fully organic and are sold as fungicides and insecticides. The company claims that these products can be tailor made to selectively attack insects, leaving those beneficial alone. It is further claimed that these products leave no residual and can fully negate the need to use copper or sulphur in field application.

The company solved the problem of essential oil volatility through patented encapsulation processes [143], and sales have grown rapidly to a turnover of USD 50 million per annum, within the first three years of operation [144], through South America, South Africa, Philippines, Greece, Australia and the United States. According to the company sales growth is severely hampered by the unavailability of enough tea tree oil to expand production.

Figure 11.39. One of the Author's Students Collecting Leaves from *Melaleuca cajuputi* trees in Terengganu,

Another company based in the United States EcoSmart Technologies Inc. has developed a number of essential oil based pesticides, herbicides and fungicides. These products are based on the action of essential oils as secondary metabolites, where they block specific pathways of insects and attack the octopamine neuro-receptors that regulate insect movement and behaviour [145]. Essential oils utilised as insecticides include rosemary oil, cinnamon oil, peppermint oil, wintergreen oil and eugenol (ex clove oil). Rosemary, clove and thyme oils are used as fungicides and clove leaf oil as the active ingredient of a herbicide [146].

Natural Anti-Stress Preparations from Betaines and Essential Oils

Degrading soil fertility, salinity, heavy metal residuals in the soil, and the effects of global warming, are subjecting crops in many temperate countries to stress. This has created a market for anti-stress products, which is slowly growing in importance to agriculture. Extracts and essential oils of some trees like *Meleleuca bractea* for example, have been found to substantially reduce the stress of crops [147]. Plant stress levels can be lowered by applying *betaines* produced from *methylated prolines, N-methyl proline, trans-4-hydroxy-N-methyl proline and trans-4-hydroxy-N-dimethyl proline*, extracted from various specifies of *Meleleuca* [148]. A compound *platyphyllol* [149], found in *Melaleuca cajuputi*, a native of Papua and Malaysia, has been identified as having *'UV'* block attributes [150]. This could be used in treatment of plant stress, as one of the major stressors of plants is *'UV'* radiation. None of these natural products have been patented for this application or commercially produced at this point of time.

Essential Oils in Soap Bases

Citronella oil soaps became popular in the 1970's as a way to control insects on flowers and vegetables. This type of product was popular by a select group of nurseries and horticulturalists at the time because of the non-residual properties and low toxicity levels. The efficacy of the product depended on suffocating insects during spraying and causing enough irritation for them to abandon the host plants. Soaps with essential oil additives are quite effective in intensive and confined areas, but of limited use in extensive farming due to the number of repeated applications required to maintain minimal pest infestation. Variations of this product utilising eucalyptus, rosemary, pennyroyal, clove, nutmeg and tea tree oils have come onto the market in recent years. This type of formulation could be considered the forefather of the newer *organic fungicides*, mentioned under the first heading in this section. Table 11.68. shows an insecticidal soap formulation, developed by the author in 1986, which is marketed under the brand *Clensel* in Australia and New Zealand.

Table 11.68. Soap Based Citronella Insecticide Formulation

Ingredient	Percentage
Water	85.04% w/w
Potassium hydroxide	2.02%w/w
Ammonia	1.05% w/w
EDTA	0.0879%w/w
Oleic acid	10.60%w/w
Citronella oil	1.099%w/w
Sodium carbonate	0.8798%w/w

Organic Dusts

Garden dust is a multi-purpose insecticide/fungicide made up with a bulking agent and various synthetic and/or natural plant derivatives. Garden dust is used against plant diseases like powdery mildews, bacterial blights, early blights, fire blight, anthracnose, alternaria blight, leaf spot diseases, brown rot, apple cedar rust, peach leaf curl, peach canker, stem blight, shothole, leafscorch, black rot, scabs and botrytis [151]. Garden dust also provides some repellency against a number of insects. The usual active ingredient is *rotenone*, which is extracted from the roots, leaves and seeds of *Derris elliptica*, locally available in Malaysia [152]. This product can be mixed with water and applied as a spray or sprinkled over plants directly. Although most garden dusts are acceptable as an organic product, it can leave toxic residuals and would be harmful if applied too soon before harvest.

Figure 11.40. Clensel Insecticide Label.

Plant Extracts: Pyrethrums

Pyrethrum based products are rapidly growing in demand for application as a pesticide in agriculture. Under most jurisdictions it is organically certifiable. Pyrethrum is extracted via solvents (usually hexane) from the flowers of *Chrysanthemum cinerariifolium*, which is cultivated in Tasmania, Australia [153]. Natural pyrethrum used to be the major active ingredient in household insecticides before the synthetic pyrethroids, which have much longer residual effects were developed. Natural Pyrethrums are non-toxic to humans and are known as one of the safest pesticides in use [154]. The advantage of natural pyrethrum is that it has a fast knock down effect on insects, through attacking the insect nervous system. However the substance is very unstable in UV light, which breaks it down very quickly. Pyrethrum is usually applied as a spray on crops during the growth and maintenance periods before maturity and harvest.

White Oils

White oil is a name given to oils emulsified in a soap base. Any number of oils including, paraffin, mineral oil, canola, caster, sunflower, can be used. These products are generally used to remove various fungi and scales from plants and trees. Some people add either ammonia or vinegar to the formulation to enhance the efficacy, add some insect repellency and enhance crop greenness before harvest. In general use, these emulsions are sprayed over the plants. For diseased plants, they are manually applied and rubbed around the infected areas of the tree to remove the fungus and scales. There are many variations of this product on the market, with different philosophies and approaches. Mineral oils like paraffin [155] are used in many products. However with the long CH2 chains, 30 in the case of paraffin, brings up potential phototoxicity issues which can be fatal to the plant. In addition these long chain oils may carry sulphur residuals. Also the film created by these oils can block the stomata (intake apparatus of the plant), preventing nutrients being taken up. Some practitioners opt for the vegetable oils and create mild soaps with various additives to assist in killing fungus spores and removing scales, like eucalyptus or tea tree oils.

A simple mild white oil formula with eucalyptus oil as an additive and preservative is shown in the Table 11.69.;

Table 11.69. A Simple White Oil Formula

Ingredients	Percentage
Water	58.0%w/w
Castor Oil	30.67%w/w
Potassium hydroxide	5.78%w/w
Eucalyptus Oil	5.55%w/w

Herbicides

Organic herbicides have been covered in the chapter ten. Some other organic herbicides concepts are based on essential oils that possess phytotoxic effects, which can be utilized to control foliage growth. A number of essential oils like cinnamon, clove, clove leaf, thyme, *Satureja hortensis,* have been found effective in this application [156]. Clove oil has been found to be particularly effective, with eugenol playing and important role [157]. This essential oil is the basis of the product *Matran,* manufactured by EcoSMART Technologies Inc [158].

PHARMACEUTICAL PRODUCTS

Pharmaceutical companies are taking more interest in the potential for the discovery of new compounds from plants. Cosmoceutical and nutraceutical companies are looking for more herbs and other natural products to meet the growing demand for supplementary foods and herbal preventative medicine. The food, cosmetic, herbal and pharmaceutical industries are merging, bringing many new products, which cannot be clearly defined. Within this environment, there are many new companies that are basing their product range and existence around particular technologies and natural active pharmaceutical type ingredients [159].

Today, the pharmaceutical industry can be divided into four areas;

12. Prescription drugs,
13. Over the counter drugs (OTC),
14. Health and food supplements, and
15. Traditional medicines and herbs.

Prescription medicines comprise both patented and generic drugs, where dispensing is restricted to doctors, pharmacists and hospitals. OTC, health and food supplements and traditional medicines may be sold by non-professional outlets and the public.

The nutraceutical sector comprises of herbal, health and dietary supplements which are usually regulated as non-poison over the counter (OTC) or as traditional herbal medicines. These supplements usually take the form of pills, powder, capsules, teas, or beverages. They contain enzymes, vitamins, amino acids and other natural herb extracts. Registration requires proof of efficacy, quality and safety, and production under GMP conditions. Prescription products are stringently tested before registration and undergo random surveillance in the marketplace. Various definitions of product types are shown in Table 11.70..

Traditional systems of therapy including homeopathy, Natropathy, Ayurveda, Sidha, Unani, Chinese traditional medicine (TCM) and various regional Asian traditional medicine disciplines are rapidly growing in popularity. Until now these complementary medicines have not been regulated in South East Asia, but the government regulation is now rapidly being put in place to set down minimum qualifications for practitioners under registration systems.

Table 11.70. Various Health and Herbal Product Definitions

Type	Definition
Nutritional Supplement	Vitamins which are defined as complex chemical substances that are needed for the functioning of the body, but that generally cannot be produced by the body and must therefore be obtained from food or nutraceuticals
Nutraceutical	Is a product isolated or purified from foods and generally sold in medicinal forms not usually associated with food for the purpose of physiological benefits or to provide protection against illness
Dietary Supplement	Includes preparations of vitamins, minerals, amino acids and mixtures of these ingredients as well as herbs and other botanicals
Herbal Medicines	Includes herbs and traditional medicine, which means any product employed in the practice of indigenous medicine, whereby the drugs used consist of one or more naturally occurring substances of a plant, animal, or mineral or part thereof, or in extracted form or non-extracted form, or any homeopathic medicine.
Indigenous Medicine	Is a system of treatment and prevention of diseases involving the traditional use of naturally occurring substances.
Homeopathic Medicine	Any drug in a pharmaceutical dosage form that is used in the homeopathic therapeutic system in which diseases are treated by the use of minute amounts of such substances which is capable of producing in healthy persons symptoms similar to those of the disease being treated.

Table 11.71. Examples of Nutraceuticals and Herbal Medicines

Category	
Vitamins	Vitamin C, B Complex, E, Multivitamins, Folic Acid, Calcium
Nutraceuticals	Evening Primrose oil, Omega 3 Fish Oil, Gingko Biloba, Lecithin, Royal Jelly, Spirulina, Ginsing, Garlic, Chlorella, Bee Pollen
Traditional Herbal Medicine	Tongkat Ali *(Eurycoma longofolia)*, Misai Kuching *(Orthosiphon stamineus)*, Kacip Fatima *(Labisia pumila)*, Bam Gamat, Air Gamat *(various species of the Holothuroidea family)*, Mengkudu/Noni *(Morinda citrifolia)*, Aloe Vera *(Alor vera)*
Western Herbal Medicine	Echinacea, Hawthorne, Garlic, Ginger, Bilberry, Ling Zhi Mushrooms
Essential Oils (Topical Use)	Lavender Oil, Tea Tree Oil, Cajuput oil, Clove Oil, Menthol and Peppermint Oil, Thyme Oils, etc.

Herbal Medicines are very popular in the region with a number of local herbs being aggressively marketed and accepted by consumers. For example in Malaysia, tongkat ali *(Eurycome longfolia Jack)* is currently one of the most popular herbal medicines and is processed into teas, medicines and even coffee. The product is marketed over the country by numerous local companies. According to ethnobotany literature, the herb is believed to be an energy booster, aphrodisiac and anti malaria remedy. kacip fatima *(Labisia pumila)* is another herb used to treat dysentery, rheumatism and women's ailments at birth. Mengkudu or noni *(Morinda citrifolia)* is used to lower high blood pressure and lessen cancer risks.

As there are still a vast number of plants and trees yet to be examined for potential in phyto-medicine, there is currently great interest from government research institutions, private companies and consumers in this area. There are many research paths that can be pursued in the herbal area. However, basic to herbal development is bio-prospecting for potential new plants that can be developed into traditional medicines, pharmaceuticals, phyto-pharmaceuticals, nutraceuticals or flavour & fragrance ingredients. Bio-prospecting is a long term program, where results will only come after systematic prospecting. New screening methods available can cut the time through speedy preliminary assays. Bio-prospecting for potential pharmaceuticals, phyto-pharmaceuticals or traditional medicines is primarily concerned with plants that have efficacy in the following major areas; anti inflammatory, anti microbial, anti-cancer, and anti viral, *e.g. HIV*. Other potential efficacy assays may also be selected for potential cosmetic applications like skin whitening, UV absorbing, or anti aging properties etc, depending on the resources available to the research team. Ethno-botanical monographs provide a guide to the team in selecting what other screening assays should be utilised for selected plants, for example anti-malarial or anti-dysentery.

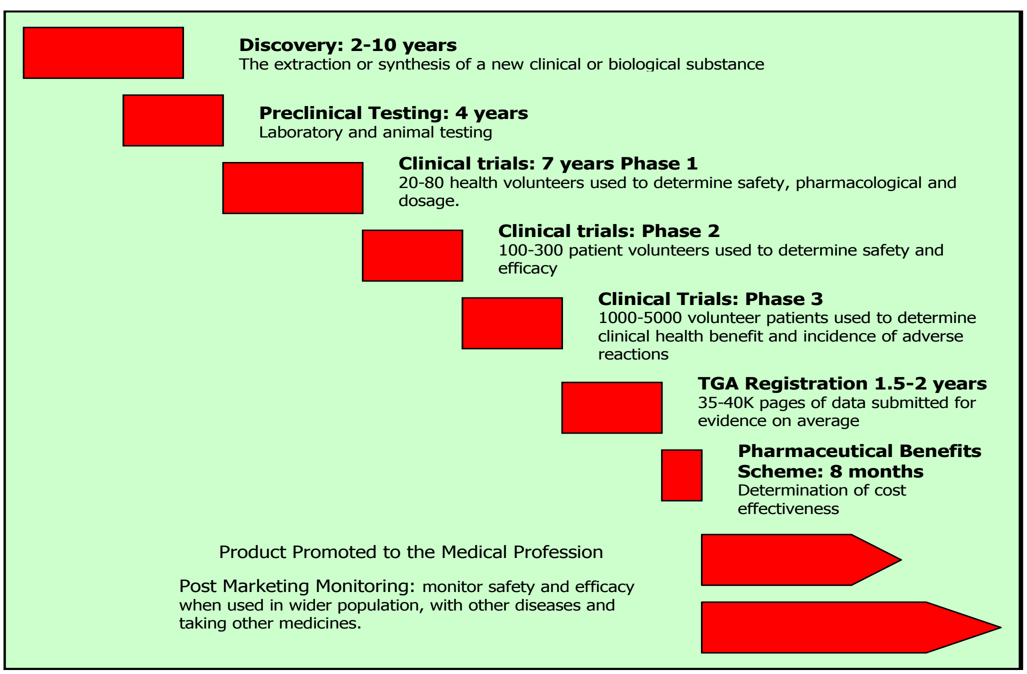


Figure 11.41. The Stages Involved in the Development of a Pharmaceutical Product.

Bio-prospecting is used to find compounds for '*molecular templating'* as was discussed in chapter one. Many companies find it much easier to synthesise a compound rather than cultivate and develop a new crop. For example, a group led by Jay Keasling at the University of California, Berkley, developed the compound artemisinin from the export of artemisimic acid from GM yeast cells, grown in bio-reactors [160]. This decreases the potential to cultivate *Artemisia annua* as a source of artemisinin.

The product development framework for a pharmaceutical product is shown in Figure 11.41.

The development process of a herbal medicine is simpler than for a pharmaceutical, due to less stringent regulation in most countries. The development of a plant extract as a pharmaceutical product will have to go under the same stringent regime as any other pharmaceutical product, taking many years and costing hundreds of million US dollars to complete, as the above figure indicates.

NATURAL ISOLATES AND AROMA CHEMICALS

Essential oils contain aroma chemicals which have value to the flavour and fragrance, cosmetic and pharmaceutical industries as separate materials to their parent essential oils. These may be aroma chemicals that are sold in large bulk for industrial applications, *i.e.*, *d-limonene* or very specialised materials like *nootkatone*, utilised for very specific applications in small quantities. Companies producing large quantities of essential oils may isolate aroma chemicals from their production to sell a greater range of products, like terpeneless oils and terpenes. Terpeneless oils are much more concentrated as the non-oxygenated hydrocarbons and terpenes are removed by fractional distillation. The residue hydrocarbons and terpenes are also sold as separate materials. These are very common with citrus, clove and mint oils. Specialised companies also use essential oils feed stocks to isolate both bulk and minor aroma chemicals for sale. There has been a move of production from Europe and the United States to India and China. New specialised chemical companies are clustering themselves in India and China, where they are beginning to dominate the market over the US and European producers.

Basic aroma chemicals consist of two types, 1. Isolates physically removed from their natural sources through extraction, and 2. Materials that are removed from natural feed-stocks through enzymatic and microbiological methods and modified with similar processes to form new compounds. Previously, natural materials were considered to be those that were isolated from their parent essential oils by physical means, *i.e., distillation, fractionation, and cooling etc*. However materials produced through the use of yeast and enzyme catalysts through fermentation and microorganisms are now also accepted as natural materials. Some examples of natural aroma chemicals isolated from essential oils are shown in Table 11.72.

Table 11.72. Some Examples of Aroma Chemicals Extracted from Essential Oils

Aroma Chemical	**Parent Essential Oil(s)**	**Uses**
Alpha-Phellandrene	Fractioned of *Eucalyptus dives* oil	Used as a stain removal solvent in consumer products. Used in the production of synthetic thymol from piperitone.
Alpha-Pinene	Isolated from turpentine oil	Used to synthesis a large number of aroma materials, i.e., terpineol, terpineol acetate, camphene, dipentene, *p*-cymene, etc.
Alpha-Terpinene	Isolated from orange and eucalyptus oils	Used extensively in perfumery
Anethole	An isolate of basil oil *(Ocimum basilicum)*, also from fennel, star anise oils.	Used as a flavour and fragrance material.
cis-3-hexenol	Obtained as a fraction of *Mentha avensis oil*	Used in perfumery for green floral notes.
Citral	From lemon, lime, mandarin, verbena, lemongrass and *Backhousia citriodora* oils.	The manufacture of ionones, geranial and neral. The manufacture of vitamin A.
Citronellal	Isolated from citronella and *Eucalyptus citriodora* oils.	In soap perfumes.
d-Limonene	Expressed or distilled from orange peels	Used in perfumery and as a solvent in consumer and industrial cleaners.
Eugenol	Usually distilled as a fraction of *bay*, *clove* or *clove leaf oils*	Used in pharmaceuticals as an analgesic, in the production of vanillin and in perfumery.
Gamma-Terpinene	Usually isolated from citrus oils.	Used in food, flavours, soaps, cosmetics, pharmaceuticals, tobacco, perfumes and confectionary
Geraniol	Isolated from citronella and palmarosa oils.	Used in floral fragrances (especially rose type florals), fruit flavours, and insect repellents.
Geranyl Acetate	Isolated from citronella and palmarosa oils.	Rose type floral perfumes.
Hotrienol	Isolated from ho leaf oil.	Used in creating many berry and honey flavours.

Table 11.71. Continued

Aroma Chemical	**Parent Essential Oil(s)**	**Uses**
Iso-Eugenol	Formed by treating eugenol with amyl alcoholic potash	Used in the production of vanillin and perfumery.
Linalool	Can be extracted from *Mentha citratra*, sweet orange oil and palmarosa oil	Used mainly in household product perfumes like cleaners and soaps.Also used to synthesis vitamin E and as a flea repellent.
Linalyl Acetate	Isolated from *Mentha citrate* oil	Used in perfumes, cosmetics and soaps.
Menthol	Crystalisation of *Mentha arvensis* oil and other *Mentha species.*	Used in pharmaceutical topical creams and lotions, perfumery and shampoos to gain a cooling effect. Flavouring material in toothpastes.
Menthone/Isomenthone	Buchu leaf oil *Agathosma betulina* also from a number of *Mentha species*	Used at low levels in rose and lavender compositions in perfumery. Also used in flavour and enzyme synthesis.
Menthyl Acetate	Isolated from oils of the *Mentha species*	In flavours and fragrances, especially cool and fruity notes.
Methyl chavicol (estragole)	Isolated from Basil, tarragon, fennel and bay oils.	In soap and men's fragrances, as a food additive.
Nootkatone	Usually from grapefruit juice and oil	Small quantities in perfumery
Phenyl Acetic Acid	Isolated from Neroli oil	Uses in floral notes for perfumery. Also used in the production of benzylpenicillin (penicillin G)
Phenyl ethyl methyl ether	Available from pandanus oil *(Pandanus odoratissimus)*	Used in floral perfumery for lift.
Terpenin-4-ol	Tea Tree oil *(Melaleuca alternifolia)*	Used in pharmaceutical preparations
Thymol	Isolated from thyme and ajowan oils	Used in dental preparations (mouthwashes) as a fungicide and some shampoos. Also as a mold reducer in book binding. Additive to cigarettes as a throat relaxant.

Turpentine oil is one of the major sources of feedstock for the production and synthesis of aroma chemicals. Turpentine oil is obtained from distillation of the resin from trees mainly of the pine species, including *Pinus halepensis, P. massiana, P. merkusii, P. palustris, P. taeda,* and *P. ponderosa.* The oil is primarily composed of the monoterpenes, *alpha* and *beta* pinene, which is used as the feedstock for the synthesis of pinane, and myrcene (see Figure 2.9). Myrcene can be further synthesized into menthol and geraniol, pinanol into linalool, and then onto citral, citronellal and citronellol. Further methods like hydration of *alpha* and *beta* pinenes into terpin and subsequent dehydration can produce *alpha*-terpineol. Through isomerisation, *alpha*-pinene can be converted into camphene and then estered into isoborneate and isoborneol. Other constituents from turpentine oil like limonene (dipentene), pine oil, estragole, anethole and caryophyllene are also extracted. Turpentine oil is also used as an industrial solvent for paint, varnishes, paint thinner and household products like disinfectants.

A number of aroma chemicals can be derived from renewable plant resources, via various methods. Enzymatic and microbial methods of producing aromatic chemicals are on the increase because they are still considered natural. Many important aromatic alcohols can be derived from methanol produced by wood pyrolysis, and through ethanol and butanol through sugar fermentation. Vegetable oils containing hexanoic, octanoic, decanoic, myristic and oleic acids can be fermented with sugars to form aromatic alcohols as well. A large range of aliphatic aldehydes can be produced through oxidation of corresponding alcohols with alcohol oxidase (AOX), or alcohol dehydrogenase expressing microorganisms. Another group of C6 compounds (z)-3-hexanal, (E)-2-hexanal, hexanal and their related alcohols can be derived through hydroperoxidation and cleavage of linoleuc acid with the sequential action of lipooxygenase and hydroperoxide lyase. These compounds, being naturally derived green notes are highly valued in perfumery.

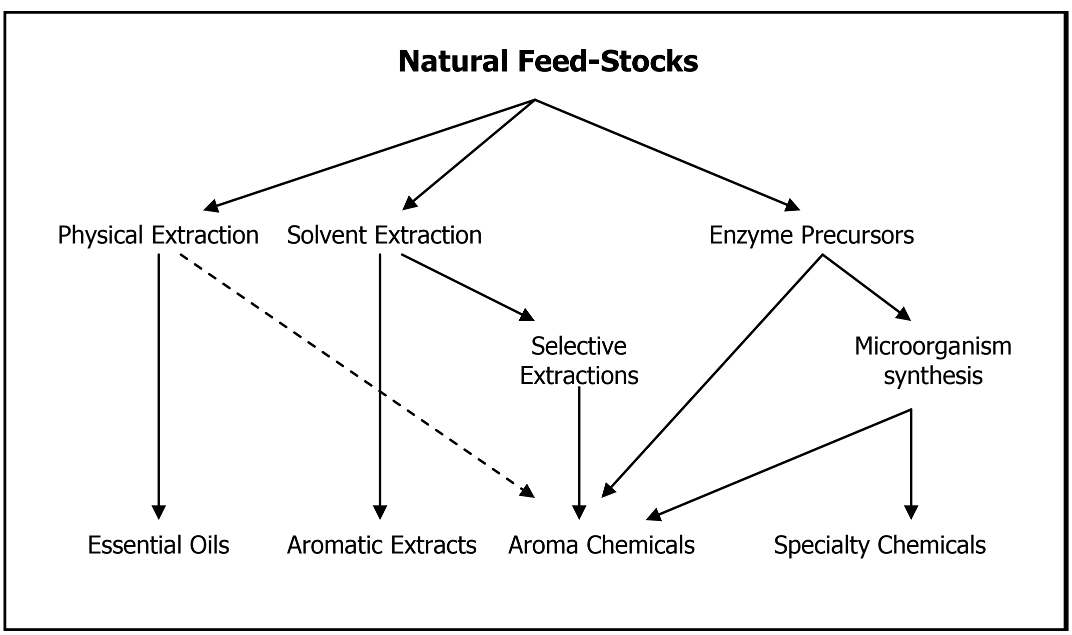


Figure 11.42. A Map of Routes for Natural Aromatic Materials.

Other valued aromatic compounds like raspberry ketone can be produced using *B*-glucosidase catalysed hydrolysis of naturally occurring betuloside, extracted from the bark of the European white birch *(Betula alba)*. The released betuloside can be converted through microorganisms containing secondary alcohol dehydrogenase into raspberry ketone [161]. Specialties like ambergris, as ambergris oxide (Ambrox®), can be produced through a microorganism forming the compound diol from diterpene alcohol sclareol found in *Salvia salarea* oil [162]. Enzyme catalystic methods can be used to produce a wide range of aromatic compounds through microorganisms, which attract prices many times more than their corresponding synthetic equivalents. A map of the allowable routes for natural aromatic materials is shown in Figure 11.42.

The market for individual natural aroma chemicals varies from just a few kilograms a year for some materials, to many thousands of tonnes for other chemicals. It is not uncommon for the total world market for certain materials to be limited to a few hundred kilograms per year [163], so careful study is required to determine which natural materials are of value to the industry.

DISTRIBUTION STRATEGIES

The distribution strategy is one of the most important aspects of a product success. Most companies commence in the domestic market before developing international sales through business models that rely on physical supply chains like retail channels. Porter stated that few industries will ever begin as global industries, but rather evolve over time due to factors promoting globalisation and another set of factors hindering globalization [164]. Thus the path to becoming internationally competitive requires undergoing a learning period to develop the correct products, efficient and cost competitive production processes and chance to gain knowledge of international markets.

There are three basic channels that can be employed as part of any marketing strategy in the domestic market;

a) Distribution through hypermarkets, supermarkets, sundry shops, convenience stores pharmacies and Chinese medical halls (Malaysia),
b) Direct Marketing,
c) Internet marketing, and/or
d) Specialised supply chains.

Distribution through hypermarkets, supermarkets, sundry shops, convenience stores and Chinese medical halls can be undertaken by the following various methods;

a) Directly through own marketing and sales organisation,
b) Through a major national distributor, or
c) Through a network of wholesalers.

Figure 11.43. shows the structure and potential channels of the Malaysian retail market.

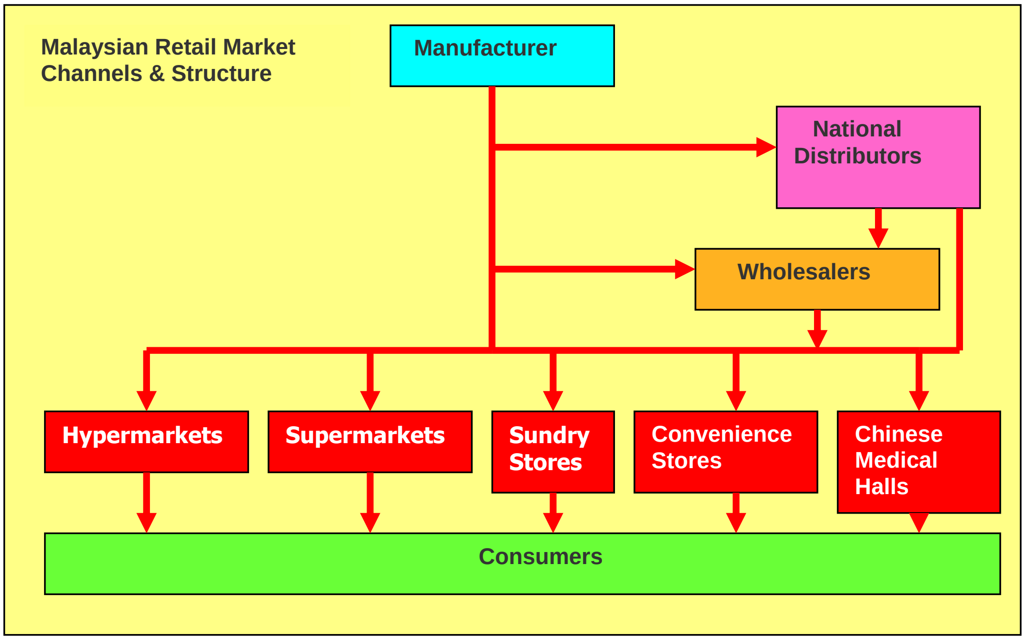


Figure 11.43. The Malaysian Retail Structure.

The difference between Malaysia and other markets throughout the region is the level of concentration of the market. This influences whether sales and marketing focus would be focused at store level in the case of a decentralised market of focused at central buying office level in the case of a centralised market. The degree of centeralisation of some selected markets in the Asia-Pacific region is shown in Table 2.4 in chapter two.

In fragmented markets, the warehouse and distribution function as a service to manufacturers usually taken up by national distribution houses. In concentrated markets like Australia, New Zealand and Hong Kong, the manufacturer may undertake its own sales functions or utilize the services of a sales broker, who will carry out the sales function for the company.

Direct marketing refers to direct mail, telemarketing, and network marketing. Network marketing is common in two forms;

a) Single level marketing is where a marketing company has members who purchase products through other members, called stockists. These stockists are physically located around the country and earn commissions from the members who purchase through them.
b) Multi-level marketing companies utilize a system something between single level and franchising. Customers become associated with the main company on a contractor relationship, where they are compensated for their efforts on achieving sales of products or services for the main company.

Direct marketing companies use a commission plan to motivate and reward those involved in product sales. Many international companies involved in the manufacture of herbal, cosmetic and personal care products utilize some form of the direct marketing system.

Some of these companies include, Amway, Avon, Hebalife, Nuskin, Shaklee, DXN, Elkin, Kaslynet, and Sunrider, etc.

Direct marketing is a very specialised form of marketing and requires a company which is strong in product development (or procurement through contract manufacturers), incentive and motivation of customers/distributors and has created an extensive network of customers. Each direct marketing company has developed particular themes for both the products and sales functions. The companies arrange continual activities for its members, customers and distributors to continue focus on selling their product ranges.

Internet marketing is usually employed as a supportive strategy to reinforce a main strategy of retail distribution and/or direct marketing. Websites are able to be accessed by specific target customer groups who are interested in the types of products marketed by the company concerned. The sites are informative sites as well as offering products for direct sale. Websites allow for maximum conveyance of specific corporate and product images the company has developed to support its marketing strategy.

This method of promotion and marketing is rapidly being taken up by many agro-tourism operations around the world that offer products for sale through various marketing channels. Circular intra-supportive strategies such as agro-tourism supporting the product image and visa versa, are more common now.

Over the last decade, a number of alternative and specialized supply chains have developed with the objective of bringing products produced by selected groups to the international market. These new supply chains usually support community groups and organizations.

One example is the “One Tambon (village sub-district) One Product” in Thailand, which was initiated nationwide by the government in 2001. Products are selected for promotion on the basis of their quality and export potential and have included food items, textiles, woven handicrafts, and non-edible herbal products (etc). The project is supervised by a National OTOP Committee, with regional and provincial level committees. The local committees help not only to identify products by also provide advice on production (e.g. quality control, packaging and designs that make them attractive to domestic and/or export markets). However, as many villagers make products during their spare time (either for their own use or to be exchanged), production capacity and the ability to supply the volume of products required by buyers presents a challenge. The Ministry of Commerce promotes the export of OTOP products through trade fairs, in-store promotions and exhibitions [165].

The original objective of the Thailand “One Tambon One Product (OTOP)” project was to enhance social protection through;

1. Social protection and risk management system with participation from the private sector and the people
2. Sustainability of local handicraft products, social protection and skill development, changes of livelihood and coping strategy in relations to the OTOP project
3. Collaboration modules among public agencies (Ministry of Labour, Ministry of Social Development and Human Security, Ministry of Commerce, Ministry of Industry) and
4. local government organizations for expanding social protection to informal workers

5. Culture: role of producers, consumers and modes exchange Best practices in area-based sufficiency economy, e.g. provincial development or provincial cluster development,
6. and sufficiency economy index/indicators
7. Survey of the application of sufficiency economy in various sectors, e.g. agriculture, industry, tourism, etc. and possibility for expansion in different areas, sectors
8. Fiscal and financial measures to promote green and clean products and technology, and
9. Marketing strategies/plans to promote green and clean products and technology [166].

The Thailand OTOP program is based on the Japanese program. The Japanese One Village One Product Movement (OVOP) **-** The OVOP movement started 1979 in Oita Japan as a means to promote regional revitalization and autonomy. Each community identified one or more products or industry that was locally specific and distinct. Resources were then concentrated on the production of these products, establishing them as local brands, and marketing them to the entire country or beyond. The program is based on the following principles: 1) Local yet global –the development of globally accepted products that reflect pride in the local culture; 2) Self-reliance and creativity; and 3) Human resource development – Rewarding creativity and industry. Villagers found that their local products turned into national brands, which encouraged interest in their local traditions and products – leading at times to an increase in tourism. Publicized through mass media, research and guidance facilities were established to provide technical support to varying industries; a sales and distribution mechanism for OVOP products was organized, and education and training was offered to industrial and regional leaders. A reward system was also set up for those who successfully implemented the program [167].

OTOP Thailand is an umbrella where there are multiple programs set up to enhance product development, skill, technology and marketing through exhibitions, local, regional and international development. OTOP uses a multiple channel strategy framework, utilizing;

1. Regional Retail Outlets
2. Retail outlets in Tourist precincts
3. Exhibitions (regional, domestic and international)
4. Roadshows (domestic and international)
5. Internet Marketing
6. Catalogue marketing
7. Permanent central exhibition centre in Bangkok
8. Through hypermarkets like MAKRO, Carrefour, Tops and Tesco
9. Direct marketing organisation, and
10. International OTOP trade offices

OTOP now covers all product areas including handicrafts, cosmetics, herbs, essential oils, foods, beverages, wine, produce, textiles and clothing, and many other categories. The OTOP program is now in its third strategy phase of developing international markets and is making agreements with international companies and department stores to carry OTOP products in Europe and Japan [168].

Agro-Tourism

Finding a diversification strategy to increase revenue to cover costs is often critical for a small to medium farm. In many cases there is a need to undertake diversification to maintain the family farm [169]. Traditional strategies have included crop diversification, however over the last few decades, agro-tourism has been a potential strategy option, that many farmers have turned to keep farms sound [170].

Agro-tourism probably originated in the wine industries of Canada, the United States, Chile, Argentina, France and Australia during the late 1960s. Community agro-tourism through festivals based on local community social and cultural themes organised around the world also grew. This occurred particularly in rural areas where crops were not primarily cultivated for export and relied on domestic markets. Today, nature, eco and agro-tourism are currently one of the high growth segments of the global tourism industry [171].

Agro-tourism is a way to combine agriculture with one of the Asia-Pacific regions largest industries, tourism. An agro-tourism venture can be defined as a farm that incorporates both a working farm environment, with a commercial tourism component [172]. This would include farms with a farm shop, bed & breakfast operations, camping, properties with boutique restaurants, *u-pick* operations, festivals, farm markets, tours, children's' activities, horse riding, sports-leisure activities, and corporate training, etc. A number of properties with farm like environments now offer alternative therapies with spas to promote health maintenance and prevent disease.

Agro-tourism is probably attractive to people because it provides them with the opportunity of understanding new things, in a rural environment. This appeals to a large range of people. Customers would usually travel as a family, tend to be educated and of predominantly urban origin [173]. They usually gather information about the place they want to visit before traveling, like to avoid mass tourism and interested in maximum connection with nature and relationships with other people. They are also environmentally aware and prefer natural products, including healthy foods. They also seek novel activities and sports and seek genuine local culture [174].

It is important to identify and prioritize personal goals for the venture. This requires a market evaluation to identify potential market and customers. Usually an agro-tourism venture will be targeted at a very specific niche visitor, i*.e., school visitors, so the venture will have an education bias, weekend drivers, so will be orientated towards food, coffee kiosks and product sales, or tourists looking for new experiences, so may orientate towards providing a residential farm experience*. Examining other type of recreation available in the area will assist.

Potts and Rourke suggested that a way to appraise the potential of developing and agro-tourism venture would be by answering the following types of questions to assist in evaluating feasibility and develop an agro-tourism concept for the farm [175]. These questions would include;

What natural resources are available that will entice people to visit?
What services and facilities are available?
What type of tourist is currently visiting the area?
What are your skills?
What are your resources?

To determine how the proposed services will meet potential customer needs and what image is needed to be developed and projected to the potential customer, the following issues must be considered;

What type of experience can be provided to the customer?
What is the image of venture surroundings, décor and equipment (luxury or utility)?
Is the proposed business site adequate or the customer?
Is it in the proper location?
What is the customer really buying? What are the benefits they really seek? e.g., adventure, friendship, excitement, or an understanding of the natural surroundings.
Is it a natural experience?
Does the management possess the right skills and knowledge?

These questions could help lead define what can be offered to the customer, the environment surrounding the venture and its compatibility with the project concepts. It is important to ensure skills and resources match the concept. Compatibility with other enterprises in the region should be evaluated to prevent direct competition with other agro-tourism businesses.

In agro-tourism the personal image that the property and the farmer projects to the customer can mean the difference between success and failure [176]. The products and services provided must be matched with a customer experience.

Promotion can be undertaken through local, regional newspapers and magazines, tradeshows, associations, and tourist organisations. Other methods of promotion will include being member of local civic associations, volunteering to give guest speeches at community events, having open houses with special promotions, networking with local and regional tourist organisations, cooperating with local restaurants, hotels, petrol kiosks, and supermarkets, etc., for promotions and developing a name and logo which is distinctive. Most successful farms would seem to contribute very heavily to both the community and the industry [177]. Eventually, strong word of mouth plaudits from satisfied customers will be the most beneficial and least expensive form of advertising.

Examples of essential oil agro-tourism include the production of lavender oil. Lavender oil production was pioneered in Australia by the Denny family at the Bridestowe Estate near Lilydale in North-Eastern Tasmania. The family developed a hybrid of *L. angustifolia* over a period of many years and built production up to 1200 kilograms per annum. The company currently generates around 60% of is revenue from tourism [178]. Over the 1990s many small farms, ranging from 0.25 to 1 Hectare planted lavender in Victoria and New South Wales, targeting tourism and aromatherapy supply are their main business focus. They are strategically located near major cities, so they can develop their tourist potential. The larger farms offer *"bed & breakfast'*. These farms produce on average 5-10 Kg of lavender oil each per annum and produce a range of lavender based products including fresh cut lavender for flower arrangements, dried lavender flowers, lavender stems for basket weaving, tea, ice cream mustard, lavender honey, bath and shower gels, soap, body lotions, talcum powders, shampoo, candles, perfumes, potpourri, and aromatherapy oil. Similar lavender farms exist in New Zealand [179]. Thursday Plantation, a tea tree plantation near Ballina Northern New South Wales, Australia is a very popular tourism destination [180].

Table 11.73. The Impact of Agro-tourism on the Local Community

Issue	Positive	Negative
Economic	• Increasing incomes • More attractive to invest in area • Employment creation (especially part time) • Earning of foreign currency • Skills development • Opportunity where opportunity did not exist	• Requirement for increase in public expenditure for infrastructure • Increasing local prices • Take people away from other sectors • Foreign exchange used to import things for ventures
Socio-Cultural	• Increase in infrastructure and services • Social advancement • Greater opportunities for cultural exchange • Enhance the sustainability of the local culture	• Change away from traditional lifestyles • Orientation towards leisure • Increase in 'strangers' to locality with undesirable social influences • Outside influence on indigenous culture
Environmental	• Propensity to preserve the environment *(a potential environmental based business)* • Greater environmental awareness • More resources available to preserve the environment	• Traffic congestion, noise and rubbish • Pressure on fragile eco-system

Finally, community Agro-tourism is also growing rapidly and has a number of potential community benefits. It creates revenue from accommodation, catering and leisure activities, as well as promoting sales of local produce and crafts. Agro-tourism also assists in the restoration of architecturally and culturally important places and assists in raising the importance of rural people in the economy. Agro-tourism generally increases the size of the service sector in a geographic area. Agro-tourism can also play a role in developing a minority culture within an area dominated by other cultures. The basic impact of agro-tourism on a local community can be summarised by Table 11.73.

Fairtrade

The Fairtrade movement is a trading partnership based on community dialogue, transparency and mutual respect that seeks to develop trade along an equal and equitable partnership. Fairtrade also strives to contribute to sustainable community development through the improvement of trade conditions. Fairtrade was originally developed through religious groups and NGOs work in developing countries to open up trade links with more equity. The formal Fairtrade movement grew out the 1960s student and activist movements against neo-colonial and multinational companies, where the concept of *"trade not aid"* gained acceptance [181]. Handicrafts during the 1960s were sold through OXFAM stores in the United Kingdom, and eventually volunteer shops opened throughout the rest of Western Europe, and later the United States selling products from the Third World.

During the 1980s the Alternative Trading Organisations (ATO) was formed and widened their scope from handicrafts to focus on the wider issues of commodity trade from South to North. This led to the sale of tea, coffee, fruits, cocoa, sugar, spices, and nuts. Fairtrade also widened its retail scope around Europe and the United States to achieve more than USD 3.6 Billion sales in 2007, increasing at the rate of almost 50% each year [182]. This is still only a very small proportion of total World trade, but according to the Fair Trade 2007 annual report, sales in specific traded product categories represented between 1.0 to 20.0% of total trade in that item in Europe and the United States [183].

The basic principals of the Fairtrade movement are;

- The sharing of a common vision where justice and sustainable development are the basis of trade structures and practices, so that everybody can enjoy a dignified life and develop their full potential,
- That Fairtrade will be a fundamental driver of poverty reduction and contribute to sustainable development, by connecting those in the South who most need change with citizens of the North who seek greater sustainability and justice,

  This will be achieved through;

- Gaining market access for those excluded from the mainstream and value-added markets or those with only access to them through lengthy and inefficient trading chains.
- Encourages the use of traditional forms of production so that social benefits can come back to the community.
- Helps to shorten the trade chain so that more funds will come back to the producers of primary goods, where the basis of the transactions takes account of the costs of production, both direct and indirect, including the safeguarding of natural resources and meeting future investment needs.
- To assist the producer connect with the consumer, so producers can learn concepts of social justice and opportunities for change [184].

The Fairtrade system provides two prices to the producer. The first is the Fairtrade Minimum Price which is a guaranteed price that covers the direct and indirect costs of sustainable production, which moves up and down according to the market. The second price is the Fairtrade Premium which is a separate payment for social and economic development in the producer's community.

In 1988 a Fairtrade certification initiative was developed so Fairtrade products could be sold through wider distribution channels. This led to the formation of the Faitrade Labelling Organizations International (FLO), an umbrella organisation responsible for the setting of Fairtrade standards, support and certification of producers [185]. The first trademark system identified to people products that met agreed environmental, labour and development standards was launched in 2002 under the authority of FLO-CERT. FLO-CERT is a certification body responsible for inspecting the producers and traders, licensing them with authority to use the trademark [185].

Fairtrade standards specify the requirements producers must meet to be certified. These standards specify the improvements that producers must make each year. Two basic standards exist, one for small farmers' organisations and another for hired labour situations. Small farmer organisation standards specify democratic decision making systems and how Fairtrade premiums are invested in the community, as well as requirements for capacity building on both an individual and organisational basis. Standards for hired labour specify that workers receive decent wages and enjoy the freedom to join unions and bargain collectively. Plantations must ensure that there is no forced child labour and occupational health and safety requirements are met. Standards also require that a joint worker-management committee is set up and that premiums be spent to the benefit of plantation workers.

Fairtrade marks are now issued for coffee, tea, rice, bananas, mangoes, cocoa, cotton, sugar, honey, fruit juices, nuts, fresh fruits, dried fruits, canned fruits, quinoa, chutney, muesli, biscuits, jams, sauces, herbs and spices, cakes, wine, beer, cosmetics, baby-food, cotton products, yoghurt, and footballs, etc., sold through department stores, supermarkets and convenience stores in around 50 countries.

Niche Products for Niche Markets

Developing new enterprises requires the process of carefully selecting target markets and developing products in accordance with the wants and needs of potential consumers and customers in that market. One can look internationally, regionally, nationally and within the local market confines of the state. The scope of market definition is very dependent upon the volumes a local or national market can provide and the planned scale of production.

Product niches can be developed through creating novelty. Many new products coming onto markets utilise this strategy and develop large consumer demand very quickly. This is a risky strategy, but can be a successful one at developing competitive advantage. The Japanese were known as 'copycat' manufacturers after World War II and developed into one of the most innovative consumer product marketing countries in the World today.

Another approach is to use the local or national market as a stepping stone to the regional or international market. Alternatively, a selected 'niche' can be defined at the local, national, regional or international level where products cater for the selected consumer demand. Examples of this are producers in Australia supplying produce and manufacturing products for the '*Asian Ethnic market'* in Australia, which is less than 5% of the total population. In New Zealand, some companies survive on supplying products solely for the Korean community there. A number of companies in Fiji survive on manufacturing and exporting products to their expatriate communities in Australia, New Zealand and the United States.

Products are now required to meet a wide range of compliances, standards and certifications. These include valid product registrations with relevant authorities, compliance with GMP, Occupational Health and Safety (OSHA), HACCP and various ISO standards and certifications for *'halal'* and *'Kosher'*, etc. The next few sections will cover these issues.

Good Manufacturing Practice (GMP)

Good Manufacturing Practice (GMP) is a system for the management, quality control, testing of manufacturing facilities for food, pharmaceutical, medical devices, cosmetics and herbicide (in some cases) production. GMP is a total management approach to the operation of manufacturing facilities and laboratories which require documentation practices and procedures to maximize traceability, as a safeguard of the event of any future problems [187].

Table 11.74. Manufacturing Issues Regulated Through Good Manufacturing Practice

1. Quality Management System a) Should be developed with policies and objectives, defining the organizational structure, functions, responsibilities, procedures, instructions, processes, and resources for the implementation of quality management. b) Should be structured and adapted to the company's activities and nature of products. c) Should ensure all necessary samples of starting materials, intermediate and finished products are taken and tested.
2. Personnel Should be adequate number of people with knowledge and experience to fulfill Responsibilities.
3. Organisation, Qualification and Responsibilities a) Production and quality control should be headed by different people b) Head of production should have authority and responsibility to manage production, operations, production personnel, production areas, and records. Responsibilities of key people should be clearly defined. d) Adequate number of trained personnel appointed to execute direct supervision of production and the quality control unit.
4. Training a) Personnel directly involved in manufacturing should be appropriately trained in manufacturing operations. b) Training in GMP should be on a continuous basis d) Records of training and its effectiveness assessed periodically.
5. Premises a) Should be suitably located, designed, constructed and maintained. b) Effective measures should be taken to avoid any contamination from the surrounding environment. c) Household products containing non-hazardous materials and cosmetic products can share same premises and equipment provided due care is exercised to prevent cross contamination. d) Painted line, plastic curtain or flexible barriers can be used to prevent any mix up. e) Appropriate changing rooms should be provided with toilets separated from production. f) There should be defined areas for: • Materials receiving • Material sampling

Table 11.74. Continued

• Incoming goods and quarantine • Starting materials storage • Weighing and dispensing • Processing • Storage of bulk materials • Packaging • Quarantine storage before release of products • Storage of finished products • Loading and unloading • Laboratories • Equipment washing a) Wall and ceiling should be smooth and easy to maintain. b) Floor should be easy to maintain c) Drains should be adequate size and have gully traps, open channels should be avoided d) Air intakes and exhausts and associated pipe-works should be installed in a way to avoid product contamination e) Buildings should be adequately lit and ventilated f) All pipe-work, light fittings, ventilation points and other services in manufacturing areas should be installed in a way to avoid un-cleanable recesses. g) Laboratories should be physically separated from the production area h) Storage places should have adequate space with suitable lighting, good drying conditions and an orderly placement of stored materials and products. i) Storage areas should have separated quarantine, dangerous material, reject material and recall areas. j) Special temperature, humidity and security areas should be provided (if required) Label storage areas should allow for printed material separation to avoid mix ups.
6. Equipment a) Equipment should be designed and located in a way to suit the production of the b) product. c) Equipment surfaces should not be capable of absorbing or reacting to any materials d) Equipment should not affect product through any leakage, etc e) Equipment should be easily cleaned f) Equipment used for flammables should be explosion proof g) Equipment should be placed in a way not to cause congestion h) Water, steam and pressure or vacuum lines should be clearly marked and easily accessible i) Support systems like heating, ventilation, air conditioning, water, steam, compressed air j) and gases should be clearly identifiable.
7. Sanitation and Hygiene a) Sanitation and hygiene should be practiced to avoid contamination of both the premises and products, thus it should cover personnel, premises and equipment. b) Personnel should be healthy to perform their assigned duties c) Personnel should practice good personnel hygiene d) Any person who has an illness that may affect the quality of the products should not

be allowed to work in proximity to any materials or product.

e) Personnel should be encouraged to report to supervisors any conditions that may adversely affect products

f) Direct physical contact with the product should be avoided to prevent contamination. Personnel should wear protective clothing during the duties they perform.

g) Smoking, eating, drinking and chewing is not allowed as it may contaminate the premises and products manufactured within.

h) Suitable locker facilities should be provided to staff for clothing and personal belongings

i) Rodenticides, insecticides, fumigating agents and sanitizing materials must not contaminate equipment.

j) Equipment and tools should be kept clean, vacuum and wet cleaning methods preferred.

k) Standard operating procedures must be designed and followed for cleaning and sanitizing of machines and premises.

8. Production

a) Special attention should be paid to water quality. Water quality should be monitored regularly according to set down procedures.

b) Choice of water treatment, deionization, distillation, reverse osmosis, ozone, UV, silver colloid and/or filtration should be chosen according to the needs of the product.

c) All inwards raw materials and packaging should be checked and verified against predetermined specifications

d) Deliveries of raw materials that do not comply should be rejected

e) All finished products should have production or batch identification numbers with traceable records

f) Weighing should be carried out in defined areas using calibrated equipment

g) All weighing should be recorded and counterchecked

h) All raw materials used should be approved against specifications

i) All manufacturing procedures should be carried out according to written procedures

j) All required in-process controls should be carried out and recorded

k) Bulk and intermediate production materials should be properly labeled until approved by quality control

l) Particular attention should be paid to problem of cross contamination in all stages of processing.

m) Liquids, creams and lotions should be produced in such a way as to protect the product from microbial and other contamination

n) The use of closed production systems is recommended

o) Packaging lines should be inspected prior to operation and seen to be clean and functional.

p) Random samples should be taken and checked.

q) Each labeling and packaging line should be clearly identified to avoid mix-up

r) Excess labels an packaging should be returned to stores and recorded.

s) All finished products should be approved by quality control prior to release.

Table 11.74. Continued

9. Quality Control a) Quality control is an essential part of GMP as it ensures products are of consistent quality and appropriate to their intended use. b) A quality control system should be established to ensure that products contain the correct materials of specified quality and quantity and are manufactured under proper conditions according to standard operating procedures. c) Quality control involves sampling, inspecting, and testing of raw materials, in process, intermediate, bulk and finished products. d) It also includes environmental monitoring programs, review of batch documentation, sample retention, stability studies and maintaining correct specifications of materials and products. e) Methods of reprocessing should be evaluated to ensure that they do not affect the quality of the product. f) Returned products should be identified and stored separately either in an allocated area or by a movable barrier g) Any returned products should be tested before being released again for distribution h) Returned products which do not comply with the original specification should be rejected i) Rejected products should be disposed of according to appropriate procedures. j) Records of returned goods must be maintained.
10. Documentation a) The documentation history should include the complete history of each batch. b) There should be a system for preventing the use of any superseded document c) Document errors should not be erased Where documents carry instructions, they should be written step by step e) Documents should be dated and authorized f) Documents should be readily available to relevant parties g) All specifications should be approved by authorized personnel and include the name of the material, description, testing parameters, any relevant technical drawings, and any special precautions that need to be taken. Specifications should include both bulk and finished products f) The master formula should contain the product name and code, intended packaging materials, storage conditions, list of raw materials, list of equipment used, and in-process controls with their processing limits. g) Batch manufacturing records (BMR) should be prepared for each batch of product. h) Each record should contain, the name of the product, batch formula, brief manufacturing process, batch number, date of start and finish of process, identity of each major equipment, records of cleaning of equipment used for processing, in-process control and laboratory results, packaging clearance inspection records, any investigations of failures. i) Records for each quality assurance test should record the date of the test, identification of the material, supplier name, date of receipt, original batch number, quality control number, quantity received, date of sampling, quality control results.
11. Internal Audits

An internal audit consists of an examination and assessment of all or part of a quality system with the specific purpose of improving it. An internal audit may be conducted by outside or independent specialists. Such internal audits may also be extended to suppliers and contractors.
12. Storage a) Storage areas should be sufficient capacity to allow orderly storage of each category of material. b) Storage conditions should be clean, dry and well maintained c) Receiving and dispatch areas should protect materials and products from weather. d) Upon the receipt of goods, each itme should be checked against the relevant documentation and physically verified and surveyed for damage. e) Records should be maintained for all receipts and issues of products f) Good stock rotation rules should be used
13. Contract manufacturing and Analysis The conditions of contract manufacturing and analysis should be clearly defined and controlled, so as to avoid any misunderstandings. All work should be undertaken according to agreed standards. There should be a written contract between the principal and the contract manufacturer to clearly establish the duties and responsibilities of each party.
14. Complaints a) A person responsible for handling complaints and deciding the measures to be taken should be appointed. b) There should be written procedures describing the action to be taken in the case of a complaint. c) All details and information should be recorded d) Other batches should be checked if fault is found with a similar batch. e) Where necessary, appropriate follow up such as a recall should be undertaken after investigation and evaluation of the complaint.
15. Product Recalls a) There should be a system of recall from the market of products known to be defective. b) A person should be appointed who will be responsible for the execution of the recall. c) Written procedures for the recall should be established d) Primary distribution records should exist for assisting in the recall e) A written instruction should be established to ensure recalled products are stored securely in a segregated area while awaiting decision.

GMP requires that all equipment be suitable for use according to specific specifications, operated according to certain procedures which would include pre-operational, operational and post-operational practices. Under a GMP system, raw materials utilized in the manufacturing process have set guidelines concerning sourcing, preparation, use and testing. Personnel deployment and standard of training is also defined in GMP, as is the documenting of each operational step in the facility. The issues regulated through GMP are listed in Table 11.74.

GMP is mandatory for specified products under respective national jurisdictions. GMP compliance is usually a pre-requisite for a product to be allowed in the marketplace, if pre-launch registration is not required. A manufacturing plant's GMP status is the result of an inspection before certification and regular follow-up inspections to maintain certification [188].

HAZARD ANALYSIS AND CRITICAL CONTROL POINTS (HACCP)

HACCP is a preventative method of food and pharmaceutical safety assurance, taking a holistic or *"soil to table"* approach. HACCP analysis assesses the biological, chemical and physical hazards involved in production. Although primarily relating to the food industry, HACCP is also applied to the pharmaceutical industry in some jurisdictions and finding a role in the cosmetic industry, on a voluntary basis. The HACCP approach seeks to identify and evaluate potential hazards in the production and supply chain and develop solutions or protocols to deal with each potential hazard, in contrast to traditional quality assurance methods which rely upon post production inspection.

The basic process of the HACCP framework involves;

- The conduction of a hazard analysis of biological, chemical and physical aspects along the production chain that may render food or products unsafe for human consumption and determine the preventative measures that can control these hazards.
- Identify the critical control points in the production process where particular measures can be taken to prevent, eliminate or reduce any hazard to an acceptable level.
- Establish a critical control points monitoring process with maximum and minimum tolerance limits at each control point and specify the monitoring procedure.
- Establish the critical control point monitoring methods necessary to ensure the production process is under control.
- Establish what corrective actions are required when monitoring a critical point detects a deviation from the accepted critical limits.
- Establish the necessary record keeping procedures to maintain documentation of the monitoring of critical points, limits the process reach, and handling of process deviations, and
- Establish a system to ensure that the HACCP system is working as intended [189].

The verification of the total system requires a plan to continually review hazards, critical points and preventative measures, so that the system will remain intact and work effectively. The system also requires validation with samples taken and assessed for the accuracy of the system. HACCP falls under ISO 22000.

HACCP is not without its criticisms. The scientific foundation of the effectiveness of a preventative system is questioned. HACCP is process rather than outcome orientated and therefore difficult to assess its benefit [190]. Major criticisms also arise from SMEs because of the bureaucracy, paperwork and costs involved to implement and operate the system [191].

STANDARDS

Over the last few decades the issues of standards have emerged in most industries, including the essential oil, cosmetic, household, and pharmaceutical industries. Standards apply to these industries in three main areas, 1. For raw materials, their processing, handling and properties, 2. For finished products, and 3. For organization or enterprise procedures, processes and operations.

Standards exist for essential oils in both various country pharmacopoeia like the Indian, Japanese, British, European, Chinese and US pharmacopoeia, and the International Organization for Standardization. Some essential oils that are specifically indigenous to a particular country may have a national standard, if various pharmacopoeia and ISO don't yet have a standard. Pharmacopoeia are standards set for therapeutic and pharmaceutical materials, specifying composition, acid and ester levels, optical rotations, refractive index, specific gravity, purity parameters, consistency limits, olfactory profiles, and methods of analysis. Pharmacopoeias specify a standard that is usually acceptable for pharmaceutical use, but may be too high and expensive for other uses like household and agro-chemical applications.

The International Organization for Standardization (ISO) has a technical committee responsible for developing standards for the methods of analysis and specification for essential oils (TC 54) [192]. At the time of writing, Technical Committee 54 had issued 127 standards for essential oils covering the areas of general rules for labeling and marking of containers, sampling, determination of relative density, determination of refractive index, optical rotation, ester and acid values, freezing point, preparation of test samples, etc., as well as specific standards for a number of essential oils, including bay, grapefruit, ylang-ylang, petitgrain, Australian eucalyptus, sweet orange, litsea cubeba, nutmeg, lemongrass, lavender, sassafras, cananga, cinnamon leaf, Spanish sage, citronella, caraway, and Melaleuca (terpenin-4-ol type) oils [193].

There are standards for a number of cosmetic products to resolve specific issues relating to their substance. The International Organization for Standardization (ISO) and through respective national standard organizations. ISO has a technical committee (194) concerning cosmetic products and has issued standards concerning analytical methods, microbiology, detection of micro-organisms, packaging and labeling, in-vivo determination of SPF, etc [195].

National standard organizations have traditionally developed standards for products that have potential public risk and performance. For example Australian Standards AS 1792 and later 4351.1, were developed because many surfactants were not readily biodegradable and began clogging the world's waterways in the 1970s [196]. National standards at this stage are much more product comprehensive than ISO, covering all general cleaning, personal care and cosmetic categories. There is no legal requirement for manufacturers to comply with standards, although consumers are often aware of standards marking on the packaging.

A number of standards exist for organizational processes and operations. These standards are usually developed and set by various committees comprising representatives of national organizations for the International Organization for Standardization (ISO). Although the standards themselves are not compulsory, some are set into regulation in various local jurisdictions, for example, in the areas of food and pharmaceuticals, etc, (GMP and HACCP).

Other standards like quality systems *(ISO 9001)* become accepted industry standards, where there is a belief that accreditation will bring a company a number of benefits, such as better quality management, better staff awareness of quality, increased staff motivation, improved profits, improved productivity, reduced wastage and lower product costs leading to competitive advantage over competitors [197]. ISO standards are criticized for increasing the expense of business without bringing measurable tangible results [198]. Many companies, particularly in South-East Asia obtain ISO accreditation as a promotional aid for showing company and product quality, even though standards like ISO 9001 does not directly involve issues relating to product quality. A list of the main standards applicable to the food, cosmetic and pharmaceutical industries is listed in Table 11.75.

Table 11.75. A Summary of Process and Operational Standards Relevant to Manufacturing Industries

ISO Number	Name	Purpose
ISO 65	Fairtrade: Process and Compliance	Used for certification of Fairtrade producers and traders.
ISO 9001:2000 (2008)	Quality management system	Usually used by manufacturing and trading based companies. Focus on seven principals: *Customer focus, leadership, involvement of people, process approach, systems approach, continual improvement, factual approach to decision making, and mutually beneficial supplier relationships.* Some pharmaceutical manufacturers may certify under **PS 9000**.
ISO: 9235:1997	Aromatic Natural Raw Materials - Vocabulary	Defines natural
ISO 14001:2004	Environmental Management System	A standard that provides a framework for environmental management covering development of environmental policy, implementation, monitoring and evaluation of policy effect and continual improvement of environmental performance.
ISO/IEC 17025:2005	Testing and Calibration Laboratories	The certification required for operating a laboratory. Covers the scope of the laboratory, normative references, terms and definitions, and both management and technical requirements.
ISO 18146:2007	Cosmetics-Microbiology-Detection of *Candida*	Standard intended to reduce human infection from cosmetic products

	albicans	through a series of microbiological examination standards.
ISO 21148:2005	Cosmetics-Microbiology-General Instructions for Microbiological Examination	Standard intended to reduce human infection from cosmetic products through a series of microbiological examination standards
ISO 21149:2006	Cosmetics-Microbiology-Enumeration and detection of aerobic mesophilic bacteria	Standard intended to reduce human infection from cosmetic products through a series of microbiological examination standards.
HACCP/ISO 22000:2005	HACCP Food Safety Management System	The ISO standard for HACCP certification.
ISO 22715:2006	Cosmetics-Packaging and Labeling	
ISO 22716:2007	Good Manufacturing Practice (GMP) – Guidelines on Good Manufacturing Practice	Sets out GMP requirements and specifications.

Organic and Ecological Product Certification

Over the last decade, consumer interest in natural, organic, environmentally safe and ethically sourced products has increased greatly. The worldwide organic cosmetic market was estimated at USD 5.5 Billion in 2007 with a 20% growth over 2006 [199]. Another estimate puts sales at around USD 7.0 Billion [200]. The European market is the leader in organic cosmetic products, with 50% of the sales of organic cosmetics attributable to European countries, growing around 12% per annum. This boom in organic cosmetics is not restricted to Europe and the US, as the Australian market is also showing around 20% growth per annum [201].

In addition, consumer concern about toxicity of products to both themselves and the environment and issues of sustainability are also driving sales of ‘green’ products and services, which are estimated to be around USD 250 Billion per annum and set to double over the next couple of years [202]. At the same time, many companies are finding ways to build ethical reputations. Treatt’s are developing community essential oil production in India, with the objective of building ethical supply chains [203], S.C. Johnson’s are switching to ‘green energy’ and philanthropy with a philosophy of *“the right thing to do*” [204] and a number of companies are sourcing ethical ingredients for their products as a strategy [205].

These trends have resulted in “natural’, “green” and “organic” products finding a mainstream place in the market and positioned on the shelves of major supermarkets, department stores and pharmacies, as well as their traditional distribution channels through markets and health stores. Many companies have joined the ‘bandwagon’ and labeled their products with often misleading phrases like ‘environmentally’, ‘natural’, ‘pure’, ‘renewable’, recycled’, ‘chemical free’, ‘100% natural based actives’, ‘no animal testing’, ‘sustainable forestry’, ‘good environmental management’, and ‘CFC free’, etc. These claims are obscure, misleading, without proof, straight out false giving wrong impressions or irrelevant information, creating great confusion to the consumer [206].

Part of this problem is caused because the various certification bodies are unable to develop agreeable definitions of organic and environmentally friendly products, due to the number of interests of various industry, consumer and regulatory groups. In addition, the United States FDA has not developed a definition for organic cosmetics. Legally only companies in the United States that meet USDA Certified Organic Standards for food could carry the "USDA Organic" logo on their products. This was difficult as the USDA organic certification only applies to products with 95% organic ingredients, excluding water, usually the main ingredient of a cosmetic [207]. This program by the USDA for cosmetics was totally abandoned in 2005 in a policy reversal, leaving a total cosmetic certification vacuum in the United States [208].

This is creating a number of issues in the industry. Absence of organic ingredient certification has allowed large companies which don't necessarily use natural and organic ingredients in their products to dominate the market through large advertising campaigns at the cost of the smaller companies who have traditionally specialized in this niche market [209]. Worse, some companies are knowingly manufacturing products containing carcinogens, claiming they are green, taking advantage of the lack of regulation in this area [210]. The trend towards natural products has also encouraged companies to incorporate obscure herbs with little or no safety information, which could be potentially hazardous to health. Thus any organic certification is not necessarily a certification of health [211].

Table 11.76. Organic Cosmetic Certifying Bodies around the World

Country	Certifying Body	Comments
USA and Canada	Certech Registration Inc., Toronto, Canada	International organic standard for natural and natural organic cosmetic certification, launched in 2008
UK	Soil Association	Health and Beauty Care Standard, launched in 2001
Germany	BDIH	Certification for natural cosmetics, was the first cosmetic certification launched in 1986.
France	EcoCert	Natural and organic cosmetics standards, launched in 2003
Italy	Italian Organic Farming Association (AIAB)	Guidelines for natural and organic cosmetics.
Belgium	Eco Garantie	Natural, organic and environmentally friendly
Australia	Biological Farmers of Australia	Draft for cosmetics and skin care products for addition to AOS 2008 released [212].

Europe has taken the lead and a number of private certification bodies have developed organic certification standards and certification systems. These certifications to some extent have been harmonized, with a similar standard in Australia also available. At the beginning of 2008 a standard for cosmetics similar to the French Eco-cert Standard has been developed in North America [213]. Private organic cosmetic certification bodies around the world are listed in table 11.76.

At present no European wide system exists and various certification schemes differ. For example The EcoCert system recognizes both natural and organic, which provides some flexibility to manufacturers. However the UK certification system applies the same stringent standards to organic cosmetics as it does agriculture. The German certification system recognizes natural but not organic [214]. The EcoCert system is very popular among manufacturers for organic certification, as it has a number of subsidiaries in a number of countries *(Brazil, Canada, Colombia, Ecuador, Germany, Japan, Portugal, South Africa and Spain)*. The main aspects of the certification criteria include [215];

1. Two certifications:
   a) Ecological cosmetic where 5% of organic certified ingredients of the total, where 50% are vegetable based ingredients, and
   b) Ecological and organic cosmetic where 10% minimum of certified organic ingredients of the total, where 95% are vegetable based ingredients. Both labels require 95% of all ingredients to be of natural origin.
2. Products of natural origin can only be transformed by approved processes, which include physical processes like grinding, distillation, blending, natural drying, expression, filtration, etc., and chemical processes like condensation, hydration, neutralization, hydrolysis, saponification, esterification, etherification and sulphatation, etc. This excludes bleaching, ethoxylation, sulfonation and irradiation, etc. The allowable 5% of synthetic ingredients are for the purpose of preservation and processing. There is a restrictive list which includes synthetic fragrances and dyes (nature identical not allowed), silicones and glycols, carbomers, parabens, phenoxyethanol, quaternary ammonium compounds, and products derived from synthetic fatty alcohols and acids.
3. Ingredients used must be prescribed on a positive list (appendix III) and not prohibited by the standard.
4. Raw materials used must be pure without specified heavy metals and other toxins and traceable from source to finished product
5. Clauses exist to ensure that the manufacturer complies with environmental and waste disposal regulations, and what cleaning chemicals can be used during plant cleaning.

Organic standards have not been without criticism from various quarters. Organic standards do not eliminate the total use of petrochemical based surfactants as materials like cocoamidopropyl betaine, which is still allowed. The standards only require 50% and 95% ingredients of natural origin in the final formulation, of which only 5% and 10% require organic certification. The maximum 5% synthetic ingredients, still allows the use of synthetic preservatives [216]. Mr. Stuart Thomson on his Gaia Organics website claims that organic certifications have more to do with marketing than a commitment to natural and organic cosmetic chemistry [217]. Another confusing point to consumers is the number of standards available with their differing definitions of what is natural and organic [218].

Like the voluntary organic standards, there are a number of standards and certifications available for *'product environmental responsibility'* like the *Green Seal* [219] program in the US, Environmental Choice Program *(Ecologo)* in Canada [220], *Blue Angel* in Germany [221] and the *Ecolabel* programs in the European Union [222] and Australia [223]. The standards cover the extraction of raw materials, manufacture, distribution, use and disposal of the product, and primarily cover personal care, cleaning products and detergents. Again the environmental standards are only voluntary and certified by a private organization. The major parts of compliance for the *Australian Ecolabel Standard* include [224]:

- Definitions of cleaning product ingredients
- Excluded products that would be covered under other legislation like disinfectants.
- Environmental Performance Criteria
  a) level of performance for specified application
  b) applicable standards
  c) if no relevant standard, must demonstrate efficacy
  d) product must contain only specified materials allowable by the standard
  e) restricted substances
  f) surfactants and enzymes must be biodegradable and micro-organisms in enzyme production must not be detectable in final product
  g) solvents – must not contain more than 5% of volatile organic solvents.
  h) Product should not contain carcinogenic substances
  i) Compounds should not be listed within the top 200 most toxic compounds in the Australian pollutant inventory (otherwise not more than 1.0% in formulation)
  j) The total amount of environmentally hazardous compounds should not exceed 2.0%
  k) Aerosol propellants and solvents should not be capable of deleting atmospheric ozone.
  l) Fragrances must be produced in accordance with IFRA and European Council directive 76/768/EEC
  m) Restrictions on claims that can be made on packaging and Labeling
  n) plastics must be appropriately marked in regards to recycling status
  o) packaging must not be coated or labeled in any way that would prevent recycling
  p) cardboard packaging must contain 70% recycled pulp
  q) Packaging should clearly state ingredients, disposal instructions, etc
- Manufacturer should comply with all environmental regulations
- Manufacturer should comply with all labour, anti-discrimination and safety regulations
- The manufacturer should show evidence of compliance through audit, assessments, and laboratory testing.

With carbon dioxide levels increasing in the atmosphere and the world primarily reliant on fossil fuels, there is little doubt that global warming is occurring. Sea levels are rising, forcing the relocation of Pacific communities from their island nations and threatening major population centres like London, New York, Jakarta and Bangkok. Mountain glaciers are retreating, snow cover in alpine areas residing, melting icecaps in the Artic region, Greenland and Antarctica, droughts occurring more often in Africa and Australia, and more adverse weather like typhoons, hurricanes and heat waves, are occurring. While Governments have reacted through the Kyoto Accord, many scientists say enough is not being done. Global warming has become a major consumer issue.

Current organic and environmental standards only very lightly touch the issue of global warming through the requirement of companies to meet local environmental regulations, yet this is a major issue of concern to consumers. Carbon rationing is seen as a part solution to the problem where Government, businesses and consumers will allocated a certain amount of carbon to use in everyday life and be compelled to purchase carbon credits, should they require more carbon consumption. Everybody, an individual and corporate entity has a carbon footprint – *the amount of carbon an entity consumes over a period of time (usually a year)*. Carbon usage is usually directly related to our energy use and can be calculated out. A large number of carbon calculators appear on the internet [225].

The carbon footprints of major companies are already being measured [226]. It is not too much to imagine that very soon, companies will put their carbon footprint scores on the labels of their products, as Tesco is planning [227]. Whether existing organic and environmental standards will incorporate the carbon footprint into their standards or new certification systems like the Carbon Trust [228] will emerge, is yet to be seen.

Jeremy Hollows in addressing the most significant market trends of the decade believes that ethical consumerism is having far reaching impacts on the market [229]. These trends originated by NGOs concern for major issues and then pushed by consumers who feel guilty and under social pressure, have made an impact. Governments reacted through responding to consumer concerns and the supply chain, made up of manufacturers and retailers saw the potential brand benefits and profits through association with these issues. The consumption of natural and organic products is rapidly rising through consumer health concerns and to express their social and political concerns. However opportunities are not realized as consumers are confused with labeling and skeptical of many products. With Government seeing the need, more regulation is being put in place to promote a ‘greener’ value chain. This effects the choice of materials, where both ethical purchasing, safety and effect on the environment come into play, manufacturing and processing where environmental, waste issues and labour rights and standards are important, logistics where choices of packaging and transport are issues and finally profits, whether companies put their profits back into the community.

Halal and Kosher Certifications

With the growing awareness of Islam, more Islamic consumers are knowledgeable about the concept of *halal*. *Halal* simply means what is permitted under Islam and is important to a Muslim’s life and spiritualism. The guiding laws of Islam are the *Syar’iah*. Central to the *syar’iah* are the concepts of *halal* and *Toyyibaan*, which govern all the economic activities of man in wealth production and consumption of wealth, where certain means of gaining a livelihood are declared unlawful [230]. *Halal* means lawful or permitted for Muslins [221], a concept that is much wider than just issues of food. It concerns whether things are undertaken according to the *syar'iah* [232]. *Toyyibaan* is a much wider concept, which means good, clean, wholesome, ethical in the Islamic concept. In nutrition, *toyyiba*an is a much wider concept than *halal*, as food must also be clean, safe, nutritious, healthy and balanced [233]. *Toyyibaan* would also mean that agriculture must be undertaken within sustainable practices [234], and in business, where things should be done with good intentions [235].

Increasing globalism means that new product choices are available to consumers from companies and service providers which they do not know and are yet to trust. Through advances in biotechnology, new ingredients are being formulated into products. It is important to the majority of the Muslim community that some system is in place to assure them that the products they purchase and consumer are lawful under Islam. There are a number of ingredients which Muslims cannot consume in any form, which include;

a) Pork or pork by-products,
b) Animals that are dead or dying prior to slaughter
c) Blood and blood by-products
d) Carnivorous animals
e) Birds of Prey
f) Land animals without external ears
g) Alcohol, and
h) Animals killed in the name of anything other than *Allah* (God).

The Muslim living as a minority in a non-Islamic society will have a number of problems identifying what items are halal and haram (forbidden in Islam), without product certification. For example, gelatine, lard and tallow can be either in a halal or non-halal, depending upon their source and method of processing. Cross contamination is a major problem in stores and particularly restaurants, where pork is also served. Therefore from the Muslim consumer standpoint; 1. Products must be produced without any forbidden ingredients, 2. Products must be proved to be in the interests of the consumers' health and wellbeing, 3. Products must be clean and hygienic, have supply chain integrity [236], 4. Products must benefit those who produced them, 5. Products must benefit the community they came from and 6. Products and the materials that make up these products must be traceable from the origin, to have total confidence. The halal certification system attempts to verify these issues.

The Halal certification process involves;

a) Halal accreditation should be done with an Islamic Association with a good international reputation,
b) All processes must comply with requirements under the syar'iah
c) All ingredients must be checked as to their suitability to be certified halal. All ingredients must be certified halal before the product can be certified halal
d) Any haram (unlawful products) must be processed in separate facilities and never come into contact with halal certifiable products.
e) Halal and products considered haram can never be stored together.

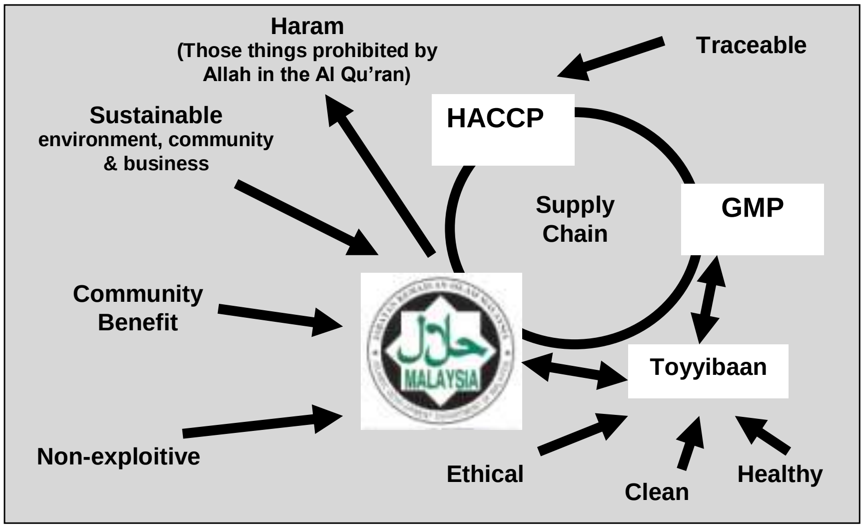


Figure 11.44. The Concept of Halal in Relation to HACCP and GMP.

The certified *halal* market is currently estimated to be worth USD 400 Billion per annum [237]. There are two major parts of the potential *halal* certified market, country markets where the Muslim population makes up the majority and country markets where Muslim consumers are a minority group. This represents around 20% of the World population. The major countries in these two markets are shown in the next two tables.

The markets shown in the Table 11.77. vary greatly in their stage of development and as a group are very heterogeneous due to individual country tastes and preferences, although specific markets will tend to be homogeneous due to similar cultural, historical and social consumption traits. Markets like Indonesia, Pakistan, Bangladesh, Nigeria, Iraq, Sudan, Uzbekistan, etc, have low per capita incomes, where aggregate consumption of many consumer items would be very low, until some further development takes place. Some research also shows that approximately 20% of Muslim consumers do not look for *halal* certifications when purchasing a product and that the majority of consumers will buy products that do not have the logo if there are no alternatives [238]. More research is required in this area.

The top countries where the Muslim population is the minority are also potentially substantial markets for *halal* certified products, representing large market segment potentials (Table 11.78.). The US, Russia, China, France and Germany rank among the top group of Islamic economies with their aggregate Islamic GDP figures. Recent reports indicate that *halal* sales in the US are increasing around 80% per year, where a number of new retail outlets specializing in *halal* products are opening up. A&P, Loblaws, Food Basics and Wal Mart are allocating space for halal products in their stores [239]. Many of the other countries down the list represent very small markets. However, in Europe and the Middle East per capita consumption of cosmetics is high [240]. Possibilities exist that some countries may be potentially lucrative niches.

Table 11.77. Markets Where the Islamic Population is the Dominant Group *(Ranked by Muslim GDP at Purchasing Price Parity)* [238]

Rank	Country	Total Population	% Muslim Population	Muslim Population	Muslim GDP USD (PPP)	GDP Per Capita USD (PPP)
1	**Turkey**	71,892,808	99%	71,173,879	879.12 B	12,900
2	**Indonesia**	237,512,352	88%	207,000,105	771.075 B	3,725
3	**Iran**	65,875,224	98%	64,557,719	737.94	10,624
4	**Saudi Arabia**	28,146,656	100%	28,146,656	564.6 B	23,243
5	**Pakistan**	172,800,048	97%	167,616,046	397.7 B	2,600
6	**Egypt**	81,713,520	90%	73,542,168	363.6 B	5,500
7	**Algeria**	33,769,668	99%	33,431,971	222.5 B	6,500
8	**Malaysia**	25,274,132	60.4%	15,265,575	215.9 B	13,316
9	**Bangladesh**	153,546,896	90%	138,192,206	186 B	1,300
10	**U.A.E.**	4,621,399	96%	4,436,543	160.6 B	37,300
11	**Nigeria**	146,255,312	50%	73,127,656	146.35 B	2,035
12	**Morocco**	34,343,220	99%	33,999,787	124 B	4,100
13	**Kuwait**	2,596,799	85%	2,207,279	110.5 B	39,305
14	**Albania**	3,619,778	70%	2,533,845	13,94 B	6,300
15	**Iraq**	28,221,180	97%	27,374,544	99.23 B	3,600
16	**Kazakhstan**	15,340,533	57%	8,744,103	95.5 B	11,100
17	**Syria**	19,747,586	90%	17,772,827	78.3 B	4,500
18	**Tunisia**	10,383,577	98%	10,175,905	75.4 B	7,500
19	**Libya**	6,173,579	97%	5,988,371	72.5 B	12,300
20	**Azerbaijan**	8,177,717	95%	7,768,831	62.2 B	7,700
21	**Oman**	3,311,640	93%	3,079,825	57.3 B	24,000
22	**Sudan**	40,218,456	70%	28,152,919	56.5 B	2,200
23	**Uzbekistan**	27,345,026	88%	24,063,622	56.45 B	2,344
24	**Yemen**	23,013,376	90%	20,712,038	46.8 B	2,336
25	**Qatar**	824,789	78%	643,335	45 B	80,870
26	**Afghanistan**	32,738,376	99%	32,410,992	34.6 B	1,000
27	**Jordan**	6,198,677	95%	5,888,743	26.6 B	4,886
28	**Lebanon**	3,971,941	60%	2,383,164	25.4 B	11,270
29	**Mali**	12,324,029	90%	11,091,626	12,12 B	1,031
30	**Turkmenistan**	5,179,571	89%	4,609,818	23.78 B	5,200
31	**Bahrain**	718,306	81%	581,827	19.85 B	32,604
32	**Senegal**	12,853,259	95%	12,210,596	19.57 B	1,700
33	**Brunei**	381,371	67%	255.518	13.16 B	51,005
34	**Tajikistan**	7,211,884	97%	6,995,527	11.46 B	1,800
35	**Guinea**	9,806,509	85%	8,335,532	9.08 B	1,100
36	**Burkina Faso**	15,264,735	50%	7,632,367	8.6 B	1,300
37	**Chad**	10,111,337	52%	5,257,895	8.26 B	1,700
38	**Niger**	13,272,679	90%	11,945,411	8.0 B	700
39	**Kyrgyzstan**	5,356,869	75%	4,02,651	7.87 B	2,000
40	**Mauritania**	3,364,940	99.9%	3,331,290	5.9 B	2,008

Table 11.78. Markets Where the Islamic Population is a Minority Group
(Ranked by Muslim contribution to GDP at Purchasing Price Parity)

Rank	Country	Total Population	% Muslim Population	Muslim Population	Muslim GDP USD (PPP)	GDP Per Capita USD (PPP)
1	**USA**	303,824,640	3.5%	10,633,862	487 B	45,800
2	**India**	1,147,995,904	13.4%	153,831,451	415.3 B	2,700
3	**Russia**	140,702,096	10.5%	14,633,017	215.1 B	14,700
4	**China**	1,330,044,544	3.0%	39,901,336	211.5 B	5,300
5	**France**	64,057,792	7.5%	4,804,334	159.5 B	33,200
6	**Germany**	82,369,552	3.7%	3,047,673	104.2 B	34,200
7	**Thailand**	58,851,357	14.0%	8,239,190	65 B	7,900
8	**UK**	60,943,912	2.7%	1,645,485	57.75 B	35,100
9	**Japan**	125,449,703	1.0%	1,254,497	42.1 B	33,600
10	**Italy**	57,460,274	2.4%	1,379,047	41.92 B	30,400
11	**Philippines**	74,480,848	14.0%	10,427,319	35.4 B	3,400
12	**Netherlands**	15,568,034	5.4%	840,674	32.4 B	38,500
13	**Singapore**	3,396,121	17.0%	577,477	28.7 B	49,700
14	**Canada**	33,212,696	1.9%	631,041	24.2 B	38,400
15	**Israel**	5,421,995	14.0%	759,079	19.58 B	25,800
16	**Spain**	40,491,052	1.5%	607,365	18.3 B	30,100
17	**Angola**	10,366,031	25%	2,591,508	14.5 B	5,600
18	**Austria**	8,205,533	4.5%	369,248	14.2 B	38,400
19	**Kenya**	28,176,686	29.5%	8,312,122	14.13 B	1,700
20	**Belgium**	10,258,762	3.6%	369,315	13 B	35,300
21	**Poland**	38,633,912	2.0%	772,678	12.6 B	16,300
22	**Hungary**	10,106,017	6.0%	606,361	11.5 B	19,000
23	**Australia**	21,007,310	1.5%	315,109	11.4 B	36,300
24	**Sweden**	9,800,000	3.1%	303,000	11.0 B	36,500
25	**Argentina**	37,384,816	2.1%	785,081	10.4 B	13,300
26	**Bulgaria**	7,707,495	11.9%	914,880	10.34 B	11,300
27	**Switzerland**	7,283,274	3.1%	225,781	9.27 B	41,100
28	**South Africa**	41,743,459	2.0%	834,869	8.2 B	9,800
29	**Ghana**	17,698,271	30%	5,309,481	7.43 B	1,400
30	**Cyprus**	744,609	33.0%	245,721	6.7 B	27,400
31	**Belarus**	10,350,194	5.0%	517,510	5.64 B	10,900
32	**Macedonia**	2,104,035	30%	631,211	5.35 B	8,500
33	**Czech Rep.**	10,264,212	2.0%	205,284	4.96 B	24,200
34	**Greece**	10,538,594	1.5%	158,079	4.62 B	29,200
35	**Mozambique**	17,877,927	29%	5,184,599	4.1 B	800
36	**Denmark**	5,352,015	2.0%	107,056	4.0 B	37,400
37	**Burma**	41,994,678	4.0%	1,679,787	3.2 B	1,900
38	**Madagascar**	13,670,507	20%	2,734,101	3.0 B	1,100
39	**Ireland**	3,840,838	2.0%	76,817	2.98 B	38,800
40	**Georgia**	5,219,810	11.0%	574,179	2.7 B	4,700

Under Jewish law, the Kashrut specifies what can and cannot be eaten and how the materials can be prepared. The work *Kosher* describes what meets the Kashrut specifications and can be consumed. The term *Kosher* can also be applied to non-food items to describe that they do not contain any forbidden substances. *kosher* certification generally requires the submission of the ingredients to one of the many certifying bodies. Each individual ingredient will be checked for its status, usually with an inspection of the manufacturing facilities. *Kosher* certifications are important in the United States as there are around 10 Million Jewish consumers. Australia and Europe, as well as Israel are important markets where *Kosher* certification is important.

Environmental Compliance

Facilities where products are manufactured are usually subject to environmental regulations. These will usually cover;

- Regulations concerning the discharge of exhaust and waste gases into the atmosphere. These regulations will primarily be concerned with the discharge of ozone depletion chemicals and other gases that may pose a danger to human health.
- Regulations controlling the injection of wastes underground to ensure the cleanliness and safety of underground water tables. These regulations may also be concerned about water bacteria as well as chemical residues.
- Regulations concerning solid and liquid waste disposal in off site locations, including rubbish tips. What materials can be disposed of and where they can be disposed of are specified. These regulations usually also concern the transport of waste materials.
- Regulations controlling the discharge of waste materials into streams, rivers, lakes, dams, the sea and other waterways.

Usually specific effluent regulations do not exist for the perfume, cosmetic and household product industries. In these cases, a manufacturing plant is assessed for the potential threat to the environment by the nature and volume of its annual discharges. Other jurisdictions would have a set of specific guidelines for specified industries, requiring specific flow controls to be installed, subject to the issue of a discharge license [241]. Various jurisdictions will have different planning, surveillance, monitoring, record keeping, audit, reporting, contingency and emergency response activities and other procedural requirements according to their acts and regulations. Meeting environmental requirements can increase the cost of setting up manufacturing facilities around 5-10%, depending on the emission threat and product manufactured.

Occupational Health and Safety (OSHA)

Occupational health and safety (OSHA) is of vital concern to both the basic production of essential oils and manufactured products. Occupational Health and Safety not only covers issues relating to chemicals and packaging, but it is a comprehensive set of standards and practices relating to the workplace and equipment used in manufacturing processes.

OSHA had its beginnings at the International labour Organisation (ILO), formed in 1919, which endeavors through study and consultation to set international standards for worker protection. Many ILO standards and recommendations are reflected in laws and regulations enforced by local authorities around the world.

This has many implications to the production of essential oils and value added products. Regulations cover [242];

1. *Safety, Health and Technical Equipment*
   a) Workplace risks,
   b) technical equipment,
   c) lifting equipment,
   d) safety precautions for machinery,
   e) tools and equipment,
   f) electricity and its risks,
   g) welding,
   h) boilers and pressure vessels,
   i) general workplace housekeeping,
2. *Workplace Climate, Lighting and Noise*
   a) Heat stress,
   b) Heat protection,
   c) Cold Environment,
   d) General lighting,
   e) Noise,
   f) Vibrations combined with noise,
   g) Methods of noise control,
   h) Hearing protection,
3. *Chemical Risk to health*
   a) Atmospheric pollution (workplace)
   b) Gases,
   c) Liquids and vapours,
   d) Metals and other hazardous chemicals,
   e) Occupational skin diseases,
   f) Ventilation,
4. *Ergonomics*
   a) Work positioning,
   b) Strenuous work,
   c) Design of controls and tools,
   d) Signal displays and panels,
5. *Work Organisation*
   a) Quality of working life,
   b) Work organisation and work content,
   c) Hours of work,
   d) Rest and leisure time,
   e) Shift work, and

f) Supervision, workplace committees, inspections, record keeping.

Usually stringent regulations apply to boilers and pressure vessels concerning explosion and accident risks, because of their high internal pressure. Regulations in most jurisdictions will cover installation and operation, periodic inspections and will usually specify that this equipment is operated by qualified persons. Machines used in planting, maintenance and harvesting as well as those used in the production of products have many regulations concerning the safety requirements for each type of machine, safety equipment workers must use when operating these machines, machine servicing, safety devices on machines, and the required training personnel must be given before they can operate any machine without close supervision. Regulations also restrict the way chemicals are handled, including worker exposure limits, ventilation, storage, labelling and disclosed information.

Most chemicals and manufactured products require a material safety data sheet (MSDS) to be produced by the manufacturer to disseminate important information about a product from the safety point of view. A summary of the information required on a material safety data sheet is in Table 11.79.

Table 11.79. The Contents of a Material Safety Data Sheet (MSDS)

1. **Product Identification** Company name, address and contact details (telephone, etc.) Chemical name Synonyms CAS No. Chemical formula Product codes
2. Composition of Product/Ingredients Ingredient CAS No. Percentage Hazard assessment (Y/N format)
3. **Hazard Information** A general hazard statement like …..*Danger: An extremely flammable liquid and vapour. Vapour may cause fire. Harmful if swallowed or inhaled. Causes irritation to skin, eyes and respiratory system. Potential to affect nervous system.* **Potential Health Effects** Inhalation Ingestion Skin contact Eye contact Chronic exposure Aggravation of Pre-existing conditions **Advice to doctor**
4. **First Aid Measures** Inhalation Ingestion

	Skin contact Eye contact Chronic exposure Aggravation of Pre-existing conditions
5.	**Fire Fighting Measures** Fire: *Flash point, Auto-ignition temperature, Flammable limits* Explosion Fire Extinguishing Media Special information
6.	**Accidental release Measures**
7.	**Handling and Storage** Storage Transport Spills Disposal
8.	**Exposure Controls/Personal Protection** Airborne exposure limits Ventilation Systems Personal Respirators Skin Protection Eye Protection
9.	**Physical and Chemical properties** Appearance Odour Solubility Specific gravity pH Boiling Point Melting Point Vapour Density Vapour Pressure (mm Hg) Evapouration rate
10.	**Stability and Reactivity** Stability Hazardous decomposition products Hazardous Polymerization Incompatibilities Conditions to avoid

THE HOLISTIC AND FOCUSED ENTERPRISE

Strategy will depend upon the views of the enterprise management, whether they see themselves in a close knit and narrowly defined business or whether they want to expand and take opportunities in horizontal, vertical, and/or undertake complementary activities. Diversification may be necessary for market reasons, such as developing product differentiation through branding. Expansion from the core business involves some risk. Peters and Waterman in their book "In Search of Excellence" strongly advise that companies '*sticking closely to the knit'* will more likely be the ones that succeed [243].

Starting up and/or growing an enterprise presents a number of challenges in primary production, processing, marketing and administration, as shown in Fgure 11.45.

The above problems must be solved for each potential entrepreneur to be successful and to assist the business develop strategically. Agriculture and agriculture processing by its very nature will require complex strategy expansion in order to gain new markets. This requires basic market identification and product development to exploit potential identified niches. Thus the four basic strategies (generic) in produce development are figured in Figure 11.46.

As covered in some detail this chapter, the new product development process will be the key tool firms must use to develop their strategic position in the market. New product development is not a process well appreciated by even managers in large firms, let alone, new entrepreneurs. Even crude essential oils require the same development process, in the same way as a manufactured product, so the final product meets market expectations in terms of chemical constituents, odour profile, colour, appearance, etc. A summary of the steps required in the new product development process are shown again in Table 11.80.

Problems Facing New Entrepreneurs
Technology: Acquisition, knowledge, understanding, application, experience, troubleshooting
Finance: Availability, management, cash-flow, variance due to highs and lows in sales
Management: General skills, personnel skills, developing order of process
Legal: General understanding of business & company codes, contracts, licensing
Production: Understanding production processing, developing efficiency, quality control
Purchasing: Sourcing, financing, purchasing at lowest cost/highest quality, supply management
Accounting: Costing, cash flow control, general accounting, taxation
Marketing: Product development, gaining channel access, understanding of basic principals of marketing, strategy, promotion, distribution, international marketing, selling

Figure 11.45. Expected Problems that will be faced by New Entrepreneurs.

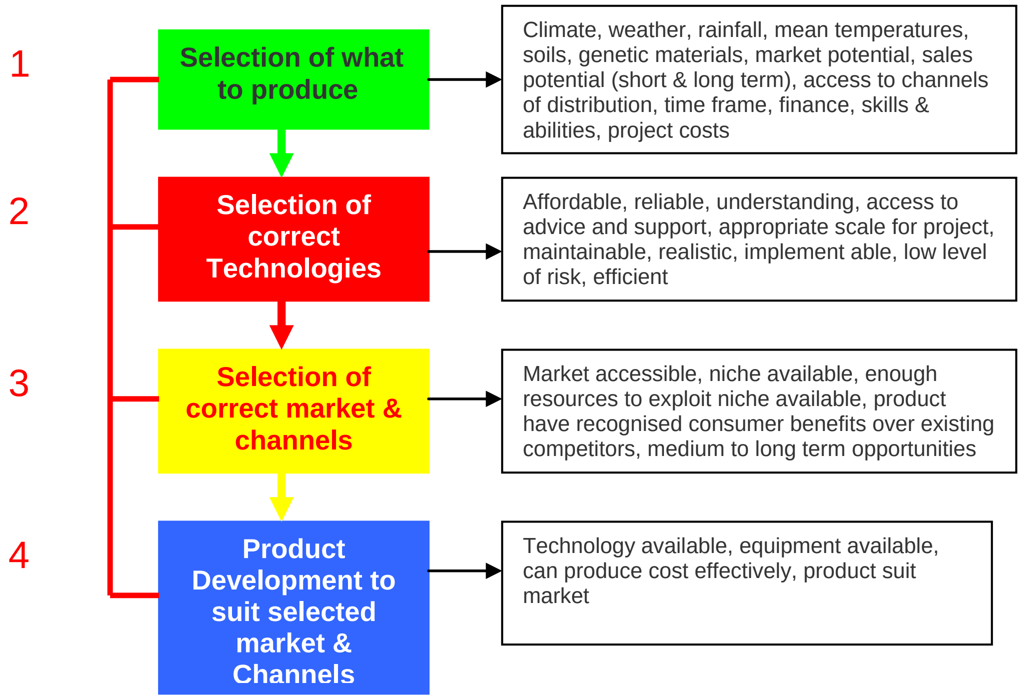


Figure 11.46. The Four Basic Produce Strategies.

Finally, the strategies outlined within this chapter will need to be developed in an individually tailored way for each product and enterprise, as their own situation in regards to product, market, capabilities and competencies and opportunity will be unique. The state of the entrepreneur's skills, abilities and vision will set restrictions as to how far strategy can be developed and integrated in transforming a basic producer into a value added producer.

Table 11.80. A Summary of the Steps in the New Product Development Process

Stage	Requirements
Ideation	*The process of conceptualizing a new idea for manifestation into a new product*
Developing Product Specifications	To develop an idea into a list of criteria that can be developed into a tangible product
Market and Product Planning	a) Branding (image) b) Packaging c) Product d) Budget projections advertising, promotion, sales e) Source of Production f) Product compatibility with branding g) Review of existing products in market - both in terms of benefits they offer the consumer and standard of product

	h) Formulation compatibility with packaging i) Logistic considerations and effects on product
Concept and Prototype Generation	Concept and Prototype Considerations a) Can the product meet organisational expectations? b) If not, what compromises are acceptable? c) Where can I source raw materials and obtain good technical support? d) What type of product system is best suited to the application? e) Can product objectives be achieved within company unit cost expectations? **What is realistic?** Period of negotiation and explanation Where can I source raw materials and obtain good technical support?
Product Registration	New products will require some efficacy testing for presentation to the marketing arm of the organisation and in many cases (Thai & Vietnam FDA's) product registration. If the product is a cosmetic or insecticide, efficacy information will have to be submitted at registration – Depending on the product, different tests are required. – Sometimes we have to invent our own methods for unusual products like ant and cockroach repellents and then convince the FDA to accept the results.
Packaging Design	– As during the MPP phase the same considerations apply, but these must be tested for stability using various techniques – Formulation is compatible with proposed packaging *Considerations here for the formulator are:* *a. Is the nature of the product compatible with the proposed packaging?* *b. What product bulk densities will be required?* *c. Can the product be filled efficiently during production?* *d. Will the proposed packaging affect product stability?*
Further Formation and Recipe Development	– PVC materials are extremely susceptible to high alkalis and solvents – Some formulations that release gases over time (bleach) must have some an outlet to equalise pressure with the atmosphere – Syneresis can occur in gels and create moisture leakage – Clear packaging will change some overtime dyes by allowing constant UV light to effect product
Manufacturing System Design	– Major Issues – Is the proposed manufacturing process compatible with the formulation? – Will a new process need to be engineered and developed? – What modifications to the product formula will have to be made, if any? – What type of filling equipment is needed? – GMP is a set of guidelines for the manufacture of pharmaceutical and cosmetic products

	– Manufactured and imported products have to comply with set standards and procedures – HACCP
Review Packaging and Formulation	A full process review of development to date
Marketing Review	– This is the time when target markets are focused upon and minor modifications to packaging or formulation may be made because of panel testing
Test Market (optional)	– Test Marketing in a domestic market is very rare today: - concentration of retailers - companies tend to have regional or - global product strategies Test markets tend to be in a region or number of countries before a regional or global launch is made
Refining of Product Before Major Launch	– When products have been tested in a single country or region, there will be final refining of the product before major launch – These refinements have more to do with different markets, than technical issues – Fragrances may be modified to suit a particular market – Packaging changes may be modified – Branding may be changed – Some raw materials may be changed due to local regulations or availability or cost factor
Major Launch	Evaluate all product and market parameters
Post Launch Product Refinements	Make any adjustments to product formula, packaging, branding and/or marketing aspects of the launch.

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Chapter 12

ENTERPRISE VIABILITY AND NEW CROP POTENTIAL

Chapter Twelve, as the final chapter in this book, briefly re-examines the opportunity concept and the importance of the form of enterprise in crop viability. The importance of both personal and enterprise goals in the determination of enterprise objectives and strategy is also re-discussed. The chapter briefly outlines the process of how community development projects should be developed. Potential essential oil screening criteria are summarized before listing a number of aromatic plants that have ethno-botanical significance and a number of small monographs on essential oils of interest to the author.

INTRODUCTION – A RE-LOOK AT OPPORTUNITY AND PERSONAL GOALS

An essential oil crop with potential for success is not enough; the enterprise business model must also be viable for the project to succeed. A good essential oil project with potential customers for the product may fail to materialize because of the application of the wrong enterprise model or some deficiencies within the enterprise. Good projects have failed because of partners and shareholders not sharing the same vision and holding different views of how things should be done. Others fail because of politics, particularly ventures which have a government or corporate organization involved in the shareholding. Still other ventures fail because of lack of capital and patience to see the project through, with the stakeholders becoming overwhelmed with the risk perceptions of what they are doing. All these problems are the result of lack of planning and staged implementation in a manner this book has espoused. Essential oil commercialisation depends as much on a solid enterprise base, as it does on a viable market and sound technical platform to develop it.

There are perhaps two major aspects that lead to a successful foundation of an essential oil business. One is passion and the other is opportunity. No new essential oil can be developed without these two ingredients.

Passion is needed to drive the project through the long period of time needed to bring gestation from paper concept to field and market reality. Passion can be a positive driver to get things done and it can also be a negative influence because it can block objectivity, which can lead to failure.

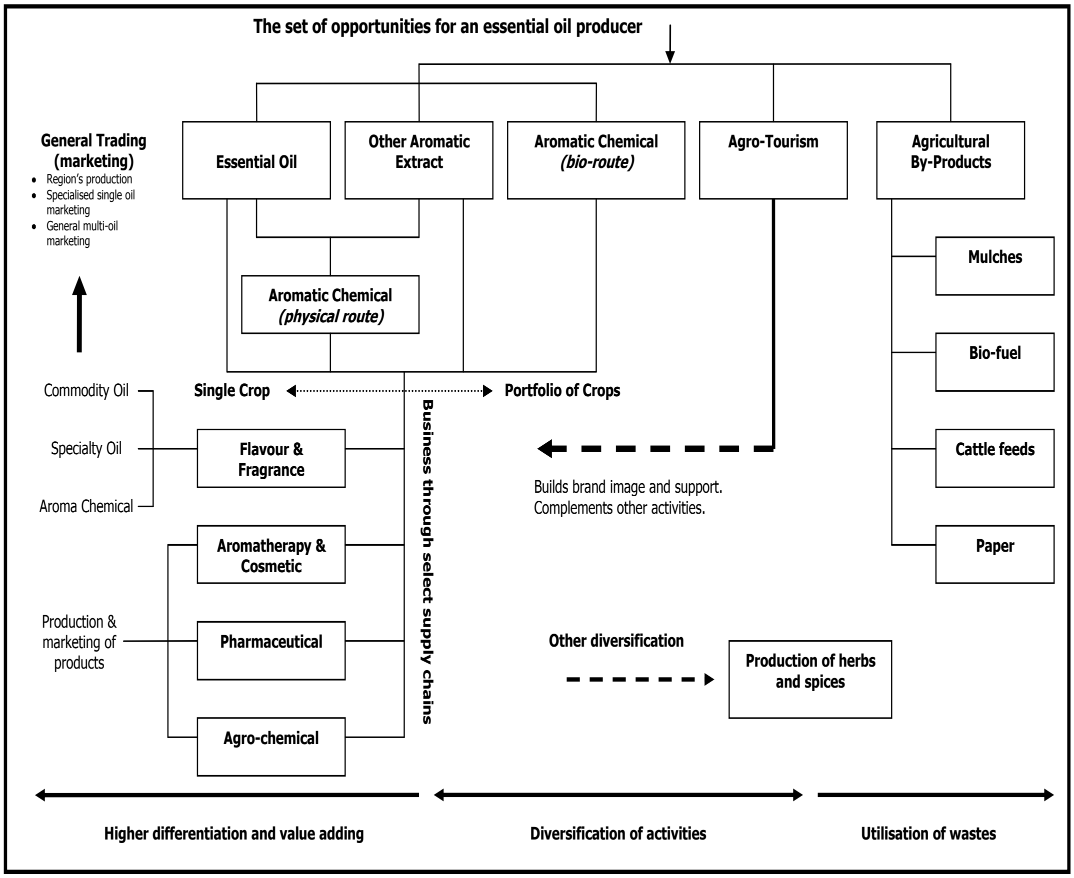

Figure 12.1. The Set of Potential Opportunities for an Essential Oil Producer.

The elements of opportunity were outlined in the last chapter and each element must be present for success to prevail. There must be some experience, knowledge, aspirations and skill present to perceive the idea of producing essential oils. A linkage between the idea and the potential to develop and market the product must exist, *i.e.*, *there should be a group of potential customers with potential uses for the product*. Developing innovative methods of production will enhance efficiency, for example, *field and harvesting equipment and extraction plant should be built to the right and appropriate scale*. The right and necessary skills must be identified, acquired or developed. There must be a network to the customer and to sources of needed technology for technical and market realization. Implementing a product/market strategy requires the correct resources to be available. Then only an opportunity can really exist. The scope of potential opportunities for an essential oil producer is shown in Figure 12.1.

Dorland and Rogers outlined a number of product success stories [1], all based on opportunities exploited by entrepreneurs at the time. Their stories about the successes of *Coty's Rose Jacqueminot, Yardley's Lavender, Shulton's Old Spice, Coca Cola* and *Wrigley's Chewing Gum*, to name a few, were all based on exploiting an opportunity. Likewise Dorland and Rogers descriptions about the emergence of the US mint industry in Massachusetts, New York and Ohio, between 1812 to 1835, exploiting the popularity of mint oil produced in the

UK by John Ray, in 1796, was about the taking up of another opportunity. The book goes on to describe the development of the US flavour and fragrance industry, all based on exploiting opportunities created from external events.

Many other essential oil industries grew out of opportunities created from external events and careful competency development. For example, the growth of the lemongrass industry in the Western Hemisphere, namely Guatemala, Haiti and Brazil, described by Guenther, was the result of supplies from India being cut off during World War II and the development of mechanization and box type distillation systems, which enabled them to compete with the rest of the world [2]. Citronella oil become popular in soaps over Europe, only after it was promoted at the London and Paris World fairs in 1851 and 1855 [2]. Taiwan's early citronella industry was the result of the passion of Kiyoshi Iwamoto in the early 1900s [2]. Citronella was developed by the Tela Railroad Company in Honduras during the Second World War because of the inability to ship bananas to the US and need to keep labourers working on the plantation [2].

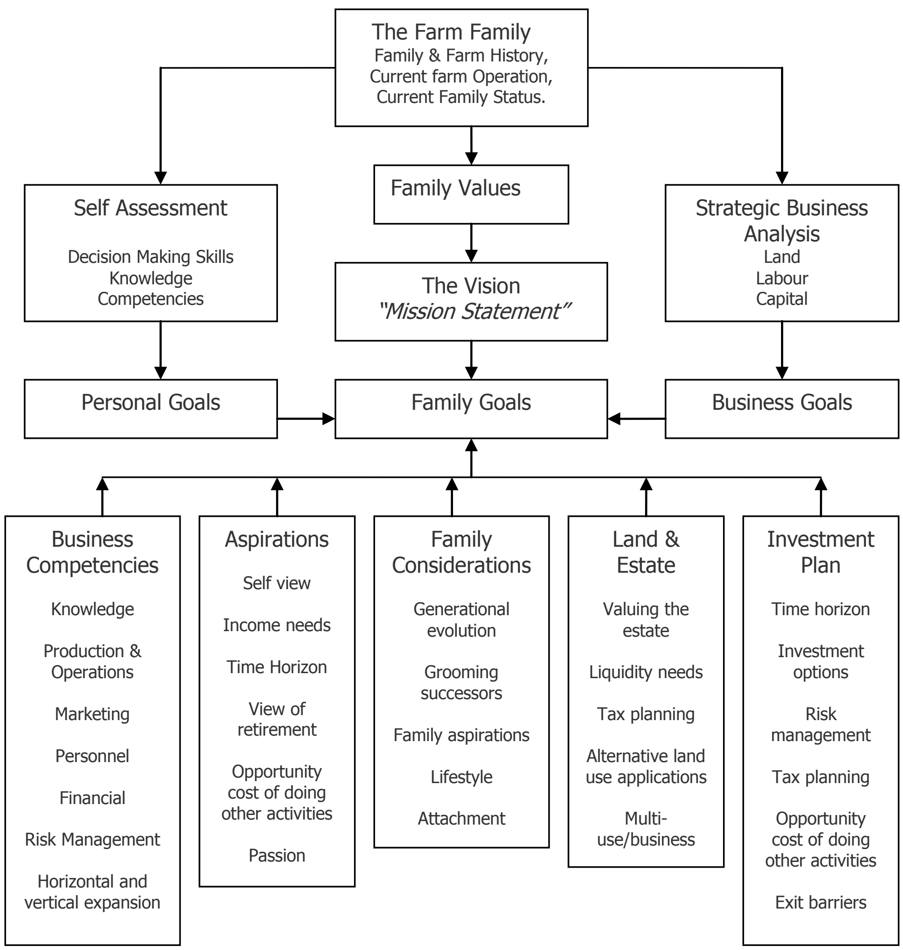

Figure 12.2. A Taxonomy of Business and Personnel Goals.

The Denny family in the 1920s realized the possibility of producing good French lavender oil in Tasmania, Australia, through seeing that Tasmania had a similar latitude to Southern France in the Northern Hemisphere. Likewise Joseph Bosisto, a Melbourne pharmacist built the first distillation plant for the extraction of eucalyptus oil near Melbourne, beginning the eucalyptus industry [3]. Bosisto promoted the oil as a medication for the treatment of a wide range of ailments, which over the next 20 years became internationally accepted [4]. Eucalyptus oil played a role in developing rural Victoria, where farmers could easily distil wild eucalyptus trees for oil, which could be quickly sold for cash.

As such, the development of new essential oil crops and industries is as much about personal goals, as it is about family or company goals. Therefore it is important in enterprises that the personal goals of the main stakeholders are compatible, if not the same. The taxonomy of goals and objectives is a complex one, influenced by numerous interrelated factors, such as the business competencies, aspirations, family considerations, land and estate, and investment plan. This is shown in Figure 12.2. [5].

Although essential oils as often analysed by industry consultants in terms of aggregate demand and supply, as small scale commodities [6], it could be argued that essential oil production is more about meeting niche markets through overcoming barriers to entry, *i.e., acquiring the correct knowledge, technology and capital costs,* and networking with the buyers. If this is the case market entry depends upon how well the new enterprise deals with the *"market forces"* displayed in Figure 8.1., chapter 8. The different scale and enterprise models that produce essential oils outlined in chapter 2 have various levels of viability and strengths and weaknesses. It is worth briefly summarizing them again before concluding this book, followed with a look at some interesting and potential essential oils.

WILD COLLECTION

As mentioned in chapters one and two, there are still a number of oils produced from wild plant collection. The wild collection of plants from forests, jungles and bush landscapes for small holder income is still very important in some communities. Wild collection in many cases has not moved onto domestication and cultivation due to; 1. The short term orientation of current collectors in the industry, who are mainly subsistence farmers, 2. The long period of time before the crop reaches harvest maturity, 10-50 years from planting to harvest for some trees, 3. The costs involved, and 4. Lack of research and development support. This leads to the propensity of over-harvesting and potential extinction of the species [7]. Users faced with shortages of supply will seek alternative materials to formulate products, as discussed in chapter one.

Generally, although there are a few exceptions, wild plant collection is a subsistence activity and individuals and enterprises engaged in this activity are weak in financial and market terms. They tend to act according to demand from other parties higher in the supply chain, rather than directly with end users. Local regulations (if adhered to) and limited physical populations restricts supply and growth of any industry based on wild collection.

This is not to say that all wild plant collection is not sustainable. Some companies in New Zealand collect and process manuka bushes *(Leptospermum scoparium)* from the wild and distill the essential oil for supply as a specialty material to the cosmetic and pharmaceutical industries [8].

A general SWOT analysis showing the general issues for the wild plant harvesting for essential oil production is shown in Table 12.1.

SUBSISTENCE FARMING

As with wild plant collection, there are a large number of essential oils produced through the subsistence farming sector. Most essential oil production within the Asian region is through the subsistence sector. Subsistence farming is a very important generator of income for many poor farmers, who inhabit marginal land with traditional farm arrangements in developing countries. The size of subsistence farming land holdings face pressure each generation, as parents pass down their small land holdings to their children through inheritance, thus dividing up the holding. In recent decades, land just becomes idle as children become educated and take jobs in the cities. Land may now have more valuable alternative uses in housing or industrial development. Subsistence farmers usually lack knowledge, technology and capital to grow. All these issues threaten the subsistence farming sector, which will threaten medium to long term supply and put upward pressure on prices.

Table 12.1. SWOT Analysis Showing the General Issues for Wild Plant Harvesting for Essential Oil Production

Strengths	Weaknesses
• Relative ease of entry and exit into the business • Product well known by users • Low production costs	• Fragmented production taking power away from the producer in favour of the buyer • Product quality and consistency unacceptable to industry • Distribution structure prevents farmers from getting "good and sustainable" pricing for product.
Opportunities	**Threats**
• Developing Fairtrade markets • Organic (although not certified) • Product value adding • *"Native plant"* niche markets	• Increasing regulation on cosmetic, pharmaceutical, cosmetic and other chemicals with probability of no organization, or an organization with no funding to defend challenges to product toxicity • The question of sustainable collection • Government restriction on collection • Heavy market scrutiny of wild collected products

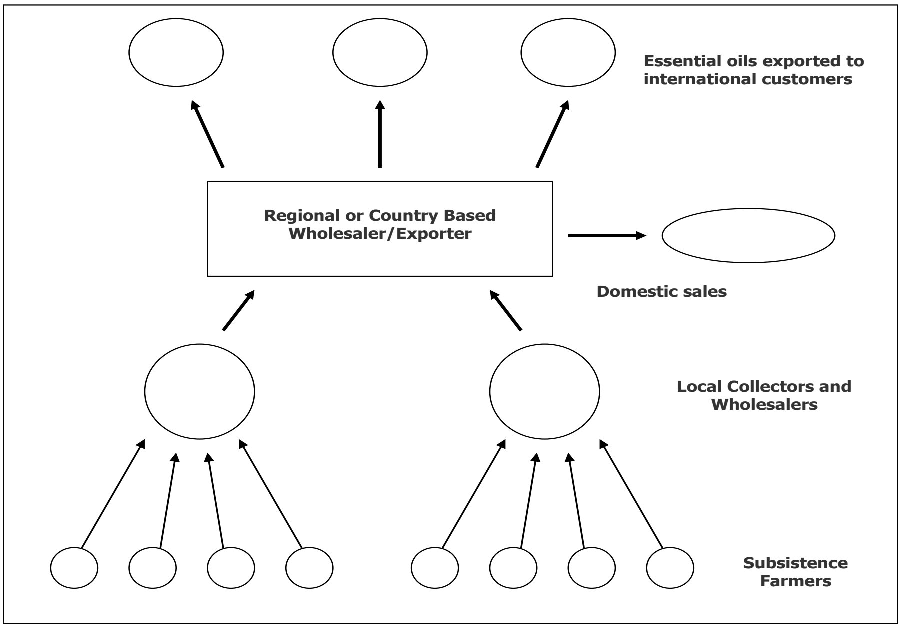

Figure 12.3. A Flowchart of the Market for Subsistence Farmers.

Table 12.2. A SWOT Analysis for a Subsistence Farm

Strengths	Weaknesses
• Relative ease of entry and exit into the business • Can easily switch to the cultivation of essential oil crops, if the price is high enough (also can easily switch out of essential oil production) • Product well known by users • Low production costs • Very adaptive to demand changes	• Fragmented production taking power away from the producer in favour of the buyer • Farmer is remote from the buyer and end user • Product quality and consistency unacceptable to industry • Lack knowledge, technology and capital for growth • Support for development weak • Sustainability of farm questionable • Lack of growth opportunities
Opportunities	**Threats**
• Developing Fairtrade markets • Earning revenue above costs when prices are high • Organic (but not certified) • New markets developing for essential oils	• Increasing regulation on cosmetic, pharmaceutical, cosmetic and other chemicals with probability of no organization, or an organization with no funding to defend challenges to product toxicity • Break up of land holdings through inheritance • Land worth more in other use such as industrial development, housing, etc. • Heavy competition in export markets • Almost impossible to get HACCP certification

The subsistence farming sector has historically been an inconsistent supplier of essential oils because of the sector's position as a price taker, and the low barriers of entry and exit from the crop. This is particularly the case with grass and semi-perennial crops. Therefore in most cases farmers will choose to cultivate the crop that gives them the maximum return. In times of rapid increases in demand, farmers have little ability to increase production immediately, which leads to shortages and high prices, until new farmers entering the market have their first harvest. If more farmers have switched to the essential oil crop than there is demand for, there will next season be an over supply situation and a drop in price. This has sometimes been worsened by the over-expectations of new producers. The prices of essential oils produced through subsistence farmers are generally the most price volatile of all essential oils.

Oil quality from subsistence farms can also be inconsistent due to a number of factors. There is still a lot of adulteration going on, where either farmers or others, higher in the supply chain, add adulterants to the oil. A flowchart of the subsistence farmer market is Figure 12.3.

Figure 12.3. shows a typical market structure for subsistence farmers in countries like Indonesia, India, Sri Lanka and Indo China. Subsistence farmers are usually visited by local collectors who pick up and pay cash for any oil produced. It is generally through these collectors that subsistence farmers receive market information. Local collectors bulk the oil together and sell it to a major wholesaler in the city, who is the usual exporter of the oil. The regional or country based wholesaler may blend the oils for quality consistency. These wholesalers will also supply major customers in the domestic market. The production of citronella, patchouli, lemongrass, cinnamon, vetiver, cananga, cajuput and many other tropical oils is handled in a similar manner. Many wild collected oils are also handled through a similar structure. A SWOT analysis showing the major issues facing subsistence farmers is shown in Table 12.2.

Many industry commentators have pointed out that the survival of small holder subsistence farming will depend upon developing better management practices [9] to improve sustainability, improve yields and achieve long term survival. There have been efforts from a number of international development agencies to create entities which can assist small holders group together in community projects and cooperatives to produce essential oils. However these have been new groups with little or no exposure to essential oil production, rather than exiperienced producers.

COOPERATIVES

Sometimes subsistence farmers in the developing world and farmers in developed countries like Australia and New Zealand are able to create collaborative agreements with other farmers to form cooperative organizations that perform some or all of the following functions;

a. Undertake some planning of planting, maintenance and harvesting as a group,
b. Engage in research and development with outside groups like local universities on issues important to farm productivity,

c. Share planting, harvesting and distillation equipment, and
d. Market the essential oil as a single entity to maximize price and financial returns.

The formation of a cooperative requires funds to finance the building of centralized facilities. This is usually done through either Government grant or the members themselves making a contribution to set up the infrastructure. Some cooperative agreements allow farmers to sell and market their own product, utilizing the cooperative for harvest and distillation purposes only. Sometimes more elaborate arrangements are made where the member is paid an amount for the oil and a second amount is dispersed after all sales have been made, reflecting cooperative profit. This type of arrangement is modeled on some of the US mint producing cooperatives. The North Queensland Essential Oils Co-Operative (NQEO) made up of a number of farmers with land holdings between 2 and 20 hectares, was set up in 1993 along a similar model [10]. Another co-operative the Tasmanian growers under the Natural Plant Extracts Cooperative Society Ltd [11], also follows this model. Figure 12.4. shows a model for a cooperative enterprise.

One of the major issues in agriculture is how to concentrate marketing of farmers' products into one organization, so that the seller's bargaining position over the buyer is enhanced. In the past, trade organizations have favoured the international traders over the farmers. Statutory bodies that are semi-government are not politically favoured [12].

The cooperative model is a way to bind producers' product together in a collective marketing arrangement. Under such a clustering arrangement, growers can operate their own enterprise, but combine the marketing, under an umbrella marketing effort. Variations of this model include a brand franchise arrangement, where the brand name is shared by a number of producers operating their businesses separately, but utilizing the same brand goodwill developed. The brand is trademarked and the producer agrees to follow a set of guidelines, set down by the cooperative. This is similar to a franchise arrangement. Cooperatives can form strategic alliances with groups, such as Oxfam Fairtrade Shops with a supply contract where a closed supply chain is developed.

Another variation on the cooperative model is when a single company owns the distillation facilities. VICMINT, a company in North-East Victoria was set up back in the early 1990s where it built a distillery. The company purchases the peppermint oil from the farmers on a contract basis with an outright purchase to fulfill supply contracts the company has made with customers. This is called contract farming.

Some of the major problems facing cooperatives are;

- the struggle to find profitable markets for their product,
- Inability to compete with large established companies,
- inability to enter large retail chains,
- lack of capital at farm and cooperative level,
- the government not taking the cooperative seriously,
- don't gather the momentum to take off,
- don't have the ability and networks to market well, and
- lack resources and the personnel to make things happen.

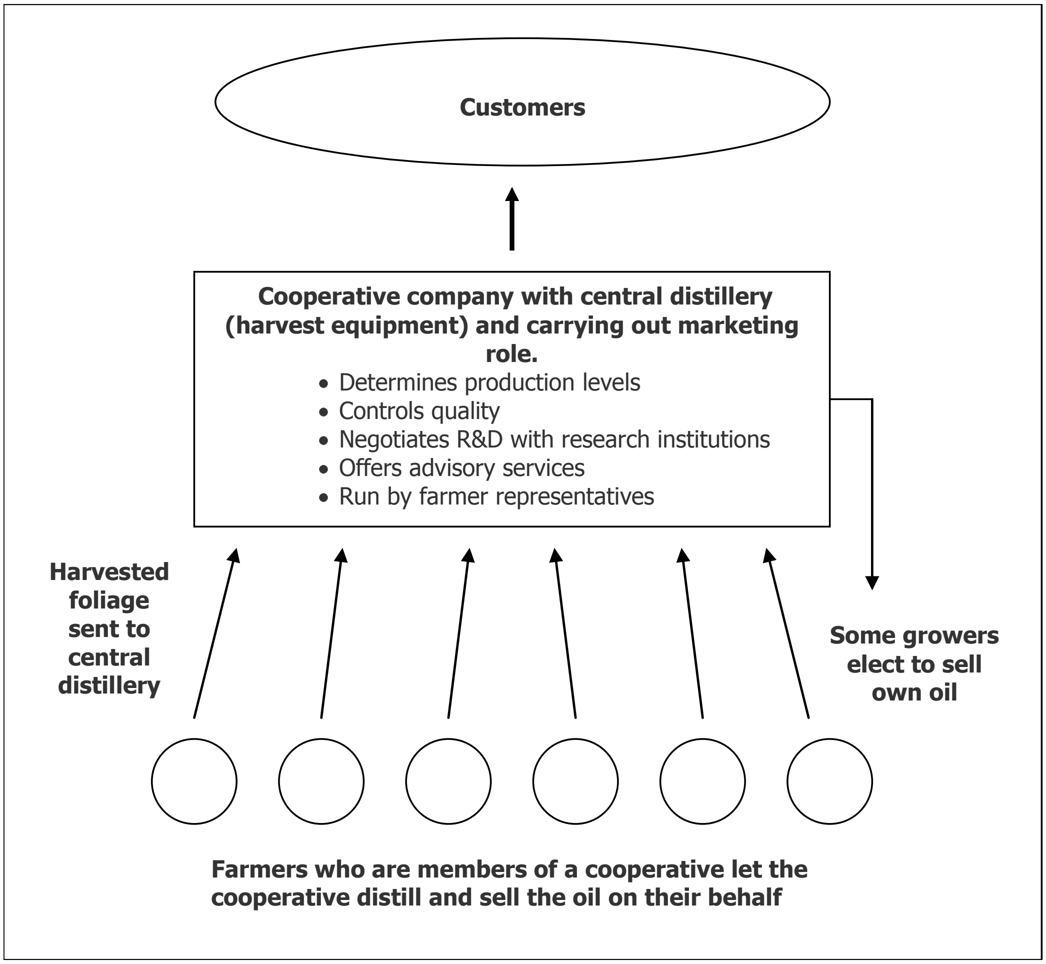

Figure 12.4. Flowchart of a Cooperative Enterprise.

A SWOT analysis showing the major issues facing a cooperative essential oil enterprise is shown in Table 12.3.

COMMUNITY DEVELOPMENT PROJECTS

Over the last decade, there has been some effort by many development authorities and NGOs to initiate community development projects based on essential oil production. A number of projects have been initiated from Africa to the Asian region. Some projects are building upon what was already there in terms of a small industry [13], while other projects involve finding a niche opportunity for the community and championing the project [14]. A SWOT analysis of the issues facing a community venture in a developing country would be similar to Table 12.4.

Table 12.3. A SWOT Analysis Showing the Major Issues Facing a Cooperative Enterprise

Strengths	Weaknesses
• Central distillation facilities can provide small holders with the economies of scale to compete against larger producers • Products are marketed in a more professional manner • Cooperatives in better position to raise funds • Quality assurance is much improved • Mutual sharing and support within group	• Cooperative may not be large enough and the situation of fragmented production still takes power away from the producer in favour of the buyer • Central production may not necessarily mean better efficiency, if move from non-salaried to salaried costs • A cooperative is no guarantee of knowledge, technology and capital for growth • Cost structure can be higher if cooperative makes a profit margin
Opportunities	**Threats**
• Able to seek better prices through larger volumes and eliminate *'middlemen'* • Able to invest in market development • Able to collaborate with research institutions • Able to finance trials for new crops • Community/value added products	• Increasing regulation on cosmetic, pharmaceutical, cosmetic and other chemicals with probability of little resources to handle issues • Small land holdings may make it difficult to achieve any economies of scale • Land worth more in other use such as industrial development, housing, etc. • Heavy competition in export markets • Disagreement between members on critical issues • Members leaving cooperative

Table 12.4. A SWOT Analysis Showing the Issues Facing Community Development Projects

Strengths	Weaknesses
• Initial assistance in setting up a conceptual venture • Marketing assistance by *"experts"* • Some financial assistance • The ability of members of the community to learn new skills in a supportive environment	• Lack of long term assistance • Lack of ongoing R&D assistance once "assistance" ends • Project may not be sustainable • Continued reliance on outside assistance • Lack of local management skills • Lack a local *"champion"* to take over • Sustainability
Opportunities	**Threats**
• Fairtrade • Value added community products	• Lack of technology to progress • Heavy international competition • Following people who have little industry/product understanding • Political interference

Community projects should be business and market orientated, with clearly identified value-added product and service opportunities with supply chain goals established. There should be product/service points of differentiation that provide the community organization with sources of competitive advantage. The operational process should have some participatory decision-making mechanisms established, with a focus on developing local skills. There must be real consensus and joint aspirations about the project from the participants to be successful. The project must be socially, economically, financially, culturally and environmentally sustainable, with equal opportunities for all members.

The community approach to agricultural project development would follow similar steps to the roadmap outlined below;

1. *The selection of the area and target group*
   a) Area selection
   b) Establishment of a working group
   c) A bio-physical analysis of the area
   d) Profiling of client groups
   e) Risk analysis
   f) Development of collective action plan
   g) Joint planning among stakeholders
2. *Identifying Market Opportunities*
   a) The identification of opportunities
   b) The evaluation of each opportunity
   (Compare each opportunity to population and skills resources and bio-physical conditions)
3. *The design of the community business model*
   a) Participatory supply chain analysis
   b) Analysis of resource and competency gaps
   c) Development of plans to enhance skills, strengthen competencies, obtain required resources and network with critical stakeholders
   d) Design business model to suit cultural, social, business, and financial needs
4. *Identifying and developing support infrastructure*
   a) Identify support services needed, research and development, education, finance and skills
   b) Development of support infrastructure

SMALL TO MEDIUM FAMILY FARMS

Small to medium family farms are usually professional farms dedicated or partly dedicated to the production of one or more essential oil crops. These enterprises over a long period of time have developed site and crop specific expertise, which gives them some comparative advantage in the production of those crops. These enterprises sometimes also value-add through the production of by-products and end consumer products. Farm sizes range from 20 hectares to many thousands of hectares, depending on the crop. Some small to medium farms specialize in the production of specific medium-high value low volume products, like lavender, while others specialize in medium-high volume, low-medium value products like mint oils, and depend upon mechanization to gain competitive advantage in production. Many farms have diversified into home-stay and agro-tourism to supplement their incomes. These supplemental activities may provide the majority of income for the farm.

One of the problems with agro-tourism in some localities is when a number of farms develop along the same theme and compete, rather than cooperate with each other. All become reliant on a limited potential income at the farm-gate from the same potential customers.

Many farms handle their own marketing, dealing with both international traders and end users. A SWOT analysis of the issues facing small to medium family farms is shown in Table 12.5.

LARGE SCALE FARM/PLANTATION

Large scale farms and plantations are usually extensive operations cultivating crops that are suited to mechanically planting, maintenance and harvesting methods. Some intensive crops that require manual harvesting also exist, although usually as an exception to the rule. As a mono-cropping arrangement, these farms are mostly operated using conventional farming methods. Large scale farms and plantations are usually professionally and/or family operated organizations. Enterprise expansion usually occurs through the development of larger acreage, purchasing and selling other farm’s oil, the development of specialized products such as extracts and isolates and the development of a professional marketing organization. Large scale farms and plantations can be very vulnerable to long periods of low prices, where the financial strains caused can lead to bankruptcy. This is why many large scale farms cultivate a secondary crop to reduce risk from falling prices.

PRODUCING ESSENTIAL OILS AS A BY-PRODUCT

Both the citrus and certain timber industries produce essential oils as a by-product of their core production. These are usually very capital intensive operations, and the essential oil extraction process is usually on-line as part of the production process or processed in a near by location. Most citrus, pine, cedarwood and some eucalyptus oils are produced in this way. Revenue from essential oil production is a supplementary, rather than a main source of revenue. A SWOT analysis for a by-product manufacturer is shown in Table 12.7.

Before moving onto the final section of the book, it is worth looking at the SWOT analysis for an organic essential oil producer, a plantation/marketing company and a research and development based company. These models all exist among producers in the industry.

Table 12.5. A SWOT Analysis Showing the Issues Facing Small to Medium Family Farms

Strengths	Weaknesses
• The small to medium family farm has developed expertise and its own proprietary technology over a period of time • Specialized in a single or small number of crops with a reputation over a number of years. • Characteristics of product and market well known • Products are marketed in a more professional manner • Products ‘accepted’ by industry • Breeding and cultivar development	• Scale may be too small to develop any competitive advantage • May be difficult to exit the industry • May be too narrowly focused on a single product • May not be in a suitable location for agro-tourism activities, etc • Lack of opportunities for growth without diversification
Opportunities	**Threats**
• To consolidate product reputation as a benchmark product (if long established business) • Able to diversify into other related ventures like end consumer products, aromatherapy and agro-tourism, etc • Able to diversify into non-related crops and markets • Able to finance trials for new crops • New markets developing • Scope for better farm and field management	• Increasing regulation on cosmetic and pharmaceutical products • Product produced may be affected by regulation, cutting down demand for product • May be subject to price fluctuations, making it difficult for cash flow • Heavy competition in export markets • Rising land costs and alternative uses

Table 12.6. A SWOT Analysis Showing the Issues for Large Scale Farm/Plantations

Strengths	Weaknesses
• Intense specialization on single or related group of crops • Very efficient production relative to small holders • Breeding and cultivar development in place	• Entry and exit difficult into industry • Difficult to adjust production according to demand • Difficult to change crops • Enterprise can be financially strained during downturns
Opportunities	**Threats**
• Increasing need for accreditations (i.e., HACCP, Halal, Kosher, etc) • Production of value-added by-products • New uses for essential oils	• Increasing regulation • Lower costs of production from more competitive countries • Failure to protect proprietary knowledge and know-how

Table 12.7. A SWOT Analysis Showing the Issues for By-Product Processors of Essential Oils

Strengths	Weaknesses
• Able to marginally cost the product • Can withstand low price periods as not main part of business • High capital costs creates barrier to entry so monopoly or oligopoly in country of processing • Very efficient technologically based processing	• Not in the industry, so not necessarily attuned or interested in potential opportunities • Inelastic supply
Opportunities	**Threats**
• Creation of extra revenue • Production of value added isolates and fractions	• Changing trends • New technology • Regulation

Table 12.8. A SWOT Analysis Showing the Issues for a Certified Organic Farmer

Strengths	Weaknesses
• Lower cost of production due to lower cost of inputs (this could be disputed in developed countries)	• Limited production volume • Require very careful management
Opportunities	**Threats**
• Able to sell into certified organic market at 'premium' prices (for some oils) • Organic market is growth market • Opportunities for value-adding with the production of consumer products • Opportunities for value-adding through agro-tourism	• Higher prices can lead to higher and inefficient cost structures and enterprise finds it difficult to keep costs under control during times of low prices • Organic market becoming more competitive • The number of organic certification schemes and terms could confuse the consumer and make them lose confidence in organic essential oils • Consumers abandoning organic products during times of recession • Too high a price premium for organic oils • Organic certification schemes do not insist on the use of organic essential oils in products

Organic essential oil producers are a variation on small to medium farms. There are two types, those subsistence farmers that don't use chemical inputs and are not certified organic and those organic producers that are certified. Certified producers service niche markets in low volume/high value range and medium value/high volume essential oils, where premium prices for organic oils exist. Organic farms, located near tourist centres will most likely also cater for agro-tourism and produce end products like cosmetics and aromatherapy products like sachets, lotions and soaps. There is likely to be a slow and steady growth of this type of enterprise, although groups of farmers *'jumping onto the bandwagon'* in Victoria and New South Wales, Australia can create an oversupply of a particular oil very easily. A SWOT analysis for a certified organic farmer is shown in Table 12.8.

Some family farmers and plantations expand their roles to become general essential oil marketing companies, or add selected essential oils from their region to their marketing efforts. This amortizes their marketing costs over a greater volume of sales to the same or similar customers already covered by the company. Companies would sign up other producers to gain access to larger volumes of oil to sell, in an attempt to gain more power over the buyer. As a service to end users in an effort to develop customer loyalty, some of these companies would also assist end user companies in product development. A SWOT analysis for an essential oil marketing company is shown in Table 12.9.

Some companies have put their expertise into organizing research and development and utilizing the benefits in the industry. One example of this type of model is Essential Oils of Tasmania, which utilised research undertaken by the University of Tasmania and applied it to the development of the Tasmanian industry. The company's operation involves contracting out farming to local farmers, where it undertakes the extraction and processing. With the increase in biotechnology development, it would be expected that more companies follow this type of model in the future. A SWOT analysis for an R&D based company is shown in Table 12.10.

Table 12.9. A SWOT Analysis for an Essential Oil Marketing Company

Strengths	Weaknesses
• Easy exit from industry • Utilise existing developed network of customers • Focus on product/application specialisation	• Multi-national markets requiring multi-national approaches, which may exclude small to medium regional companies • Technical and market expertise • Need to finance larger stock holdings for long periods of time
Opportunities	**Threats**
• Entry into markets where high value product opportunities exist • High market growth in a number of sectors which are 'non-traditional' • Move from production to marketing where much higher profit opportunities exist • The development of value-added proprietary products for particular industries, i.e., terpinen-4-ol from tea tree oil for pharmaceutical use	• Regulation and cost of compliance and certification • Cyclic price fluctuations increase risk of carrying stocks • Large multi-national companies enter market segments

Table 12.10. A SWOT Analysis for a Research and Development Company

Strengths	**Weaknesses**
• Strong research base can build up specialized IP • Well planned IP development portfolio • Monopolistic supply of successfully developed products	• The high cost of product development • The difficulties of realizing research into tangible product and business enterprise • The time lag involved
Opportunities	**Threats**
• Very specialized niche areas highly profitable • Very little competition in some niche areas • The development of value-added proprietary products for particular industries, i.e., terpinen-4-ol from tea tree oil for pharmaceutical use	• Revenue does not cover research and development costs • Regulation, certification and compliance costs

NEW ESSENTIAL OIL CROPS

Finding new essential oils can be assisted through studying ethno-botanical commentaries and studies. Mankind's use of plants for medicinal, cosmetic and flavour purposes goes back thousands of years, when flora was the only source of medication [15]. This information has been well documented from Chinese Traditional Medicine, Ayurvedic, European, American and African modes of medicine. According to Farnsworth, 74% of new plant derived products were already known before they were developed [16], so referring to this data is invaluable and will potentially save a lot of resources. Once potential plants have been identified, they can be further searched for any specific studies as to medical efficacy, cosmetic potential or flavour and fragrance potential. Extractions can be made from the physical plant and the essential oil screened and assayed for relevant properties by some preliminary form of bio-assay. However it should be noted that different bio-assay methods will deliver different results, where some methods can be unreliable, under certain conditions [17]. Therefore it is necessary to evaluate the strengths and weaknesses of each method before committing to them. Important essential oil efficacies screening areas would include;

- *Anti-microbial*: Plant derived anti-microbial oils have been largely ignored since the development of antibiotics. With the increase of incidence of drug resistant micro organisms, interest in natural anti-microbial agents is increasing. Other interesting applications for essential oils exist for anti-fungal and anti-viral agents for pharmaceutical, cosmetic and agricultural applications. Approximately 15% of cosmetic products utilize anti-microbial agents in their formulations [18]. Phenolic and terpenoid compounds are common in essential oils and generally possess anti-microbial activities. Some essential oils with anti-bacterial activity are listed in Table 12.11.

- *Anti-inflammatory:* Anti-inflammatory oils are those that will contain analgesic properties and assist in reducing pain and inflammation. Mostly, essential oil applications will be concerned with topic use, although clove oil is used internally to relieve tooth and gum pain and inflammation. Essential oils are used for anti-inflammatory applications in aromatherapy, cosmetics or cosmoceuticals and pharmaceuticals.
- *Anti-cancer:* Plant derivatives are being thoroughly examined for potential treatments of cancer and other major aliments. This is a wide area due to different efficacy at different stages of cancer growth and the number of different types of cancer.
- *Anti-oxidant:* Phytochemicals have become very important in diet to prevent coronary heart disease and cancer [19]. Research has also shown anti-oxidants are effective against photo-aging [20], degenerative diseases [21] and free radicals [22] that are in some way believed to be connected to many diseases. The potential of anti-oxidants to treat numerous conditions, particularly age related conditions is under a lot of investigation [23]. Anti-oxidants are incorporated into a growing number of cosmeceuticals, nutraceuticals and functional foods. Many cosmetics with anti-oxidants are marketed as anti-aging treatments. Anti-oxidants are also utilized in processed foods as ingredients to reduce deterioration caused by the oxidation of unsaturated lipids in the product. Synthetic food ingredients are less favourable by consumers, so natural anti-oxidant materials may have market opportunities. Essential oils that contain phenolic compounds are most likely to contain anti-oxidants [24].
- *Anti-aging:* People over thousands of years have been concerned about aging and utilized herbs, drugs and foods and cosmetic surgery to maintain the appearance of being young. Ethno-botanical literature is rich in describing plants used for this purpose. Modern anti-aging products are now a major product segment within the cosmetic industry. Anti-aging products are segmented, either directly or indirectly, as a preventative or treatment measure and include vitamins, antioxidants, UV-blocking materials and anti-wrinkle materials.
- *UV Absorbers and Blocks:* Sunscreen products are an important cosmetic product used either as a sun protection product or as a sunscreen incorporated into another product as a secondary function. Sunscreen products usually contain a chemical like oxybenzene that absorbs UV light and/or compounds which settle on the skin in small particles like titanium dioxide and zinc oxide that reflect or block UV light. Most materials used as sun protection factor (SPF) agents are synthetic, except for titanium dioxide and zinc oxide which are minerals. A European company now offers an extract of *Kaempferia galangal* as a sun block agent [25]. Cosmetic companies are also looking for natural products that act in synergy with existing SPF agents to boost their performance [26]. Companies are studying plants which have developed survival mechanisms under stress for new active ingredients in this area, which include extracts of *Senna alata* and *Curcuma longa* [27]. Besides cosmetic application, UV absorbers and blocking agents will possibly find application in plant anti-stress products.

Table 12.11. Some Essential Oils with Anti-Microbial Activity

Name	Botanical Nme	Compound	Activity
Allspice	*Pimenta dioica*	Essential oil	General anti-microbial
Ashwagandha	*Withania somnifernum*	Lactones	Bacteria and fungi
Bael Tree	*Aegle marmelos*	Essential oil	Fungi
Basil	*Ocimum basilicum*	Essential oil	*Salmonella*
Bay	*Laurus nobilis*	Essential oil	Bacteria, fungi
Betel pepper	*Piper betel*	Essential oil	General anti-microbial
Black pepper	*Piper nigrum*	Piperine	*Lactobacillus, Micrococcus*, fungi
Buchu	*Barosma betulina*	Essential oil	*Gneral Anti-microbial*
Buttercup	*Ranunculus bulbosus*	Lactones	*Genral Anti-microbial*
Calamus	*Acorus calamus*	Essential oil	Enteric bacteria
Caraway	*Carum carvi*	Coumarins	*Bacteria, fungi and viruses*
Cinnamon	*Cinnamomum verum*	Essential oil	*M. tuberculosis, S. typhimurium, S. aureus,* and helminths
Chamomile	*Matricaria chamomilla*	Essential oil	*Viruses*
Clove	*Syzygium aromaticum*	Eugenol	General anti-microbial
Coriander	*Corianmdrum sativum*	Essential oil	Bacteria, fungi
Dill	*Anethum graveolens*	Essential oil	Bacteria, viruses
Eucalyptus	*Eucalyptus globulus*	Essential oil	Bacteria, viruses
	Rabdosia trichocarpa	Terpenes	*Heliobacter pylori*
Kanuka	*Kunzea ericoides*	Essential oil	*Gram positive bacteria*
Lawsonia	*Lawsonia spp.*	Quinone	*M. tuberculosis*
Lemon verbena	*Aloysia triphylla*	Essential oil	*E. coli, M. tuberculosis, S. aureus*
Manuka	*Leptospermum scoparium*	Essential oil	*Gram positive bacteria*
Nutmeg	*Myristica fragrans*	Essential oil	General anti-microbial
Orange	*Citrus sinensis*	Essential oil	Fungi
Pao d'arco	*Tabebuia spp.*	Essential oil	Fungi
Peppermint	*Mentha piperita*	Menthol	General Anti-microbial
Rosemary	*Rosemarinus officinalis*	Essential oil	General Anti-microbial
Tansy	*Tanacetum vulgare*	Essential oil	Helminths, bacteria
Tarragon	*Artemisia dracunculus*	Essential oil	Viruses, helminths
Tea tree	*Melaleuca alternifolia*	Terpenin-4-ol	Viruses, fungi, bacteria
Thyme	*Thymus vulgaris*	Thymol	Viruses, fungi, bacteria
Valerian	*Valeriana officinalis*	Essential oil	General Anti-microbial

- *Skin whitening:* Skin whitening products are important in both Africa and Asia. They are also used in European countries for skin blemish treatments. Some skin whitening products also contain UV blocking materials to prevent the sun darkening the skin.
- *Flavour and fragrance application:* Any new essential oil for flavour and fragrance application should meet the criteria set out in Table 7.4., of chapter 7. The issue of regulation will be the largest barrier to industry acceptance. Extracting individual constituents of essential oils and selling them as a separate product, is a way of avoiding necessary dossier compilation for a new material, required in the EU, if the individual constituent is already approved [28]. Aromatic materials isolated from essential oils will have immense value to the flavour and fragrance industry, if they are not already extracted from other natural sources or from currently available from sources with very low yields, less efficient to extract than from the new potential source [29]. Compounds with useful odours to perfumers with extremely low threshold concentrations may have value, as they can be used in very small quantities to get fragrance effect (see cost/price performance ratio in Chapter seven).
- *Aromatherapy application:* The aromatherapy industry has a number of producers promoting "new" essential oils. Their recommended usage is usually supported by ethno-botanical literature and/or folklore. Examples of essential oils that have become popular over the last few years in Australia include blue cypress oil *(Callitris intratopica)*, linked to the medicinal uses that the aborigine people utilized the plant for, lemon tea tree oil *(Leptospermum petersonii),* Australian Kunzea *(Kunzea ambigua),* Anise scented myrtle *(Backhousia anisata),* and cypress leaf oil *(Callitris glaucophylla)*. Essential oils also exist in special grades for aromatherapy, where for example tea tree oil can be purchased as *'tea tree bush still'*, *'tea tree organic'*, '*tea tree wild collection'* and *'pharmaceutical grade tea tree oil'*. Thai entrepreneurs are also marketing a number of local oils for aromatherapy including blue lily *(Nymphaea caerulea),* plai oil *(Zingiber cassumunar)* and various species of cinnamon. Many oils available for aromatherapy may have only a few producers with small local 'niche' markets.
- *Agricultural application:* The development of agrochemicals from essential oils has increased over the decade, creating a new generation of agricultural and horticultural fungicides, pesticides, anti-phytovirals and to a lesser degree herbicides. Use of these products has been discussed in chapter 10 and their production in chapter 11. Continued growth and innovations in this area should be expected. Interest is also growing in the area of plant stress, which will become a large issue due to climate change.
- *Feed-stocks for biological product transformations:* Constituents of essential oils can be utilized as feed-stocks for bio-transformation into other useful chemicals via a number of physical, chemical and biological routes. The use of micro-organisms to convert chemicals has great potential for growth and in the future it will be expected that a number of new essential oils will be cultivated for this purpose, as new biological transformation processes will replace chemical transformation routes that are less environmentally sensitive.

Some of the potential applications for essential oils overlap, especially in the cosmetic domain, where a single ingredient could become an anti-microbial, anti-inflammatory, anti-oxidant and anti-aging agent and also contribute to the fragrance of the product. Cosmoceuticals is a rapidly growing market where important categories include anti-wrinkle treatments, products to promote microcirculation, sunscreens, analgesics and products promoting hair growth are important [30]. A list of plants from the Asia-Pacific that have a volatile oil and ethno-botanical usage by indigenous communities are shown in Table 12.12.

Table 12.12. Some Plants with Volatile Oils Where Usage by Indigenous Communities is Recorded [31]

Plant	**Location**	**Traditional Use**	**Potential Application**
Acacia farnesiana (Acacia)	Widely distributed around the world	Used for gum and eye treatment	Flowers for perfumery
Adenosma caeruleum	Warmer parts of Asia	As a medicine for bowel complaints and rheumatism	Aromatherapy
Aegle marmelos (Bel fruit tree)	Throughout Asia from India to Philippines	As a medicine against dysentery and cholera, as a fish poison.	Citrus like oil in leaves and rind, some potential for aromatherapy/cosmetic use.
Aglaia odorata, Aglaia odoratissima	Throughout Asia and parts of the Pacific	Tall forest timber tree where flowers were used a fragrance after childbirth and for a treatment against venereal disease. *A. odoratissima* is a much smaller tree.	Flower oil as a jungle perfume. Wood oil also possible.
Ailanthus malabarica	India and South-East Asia	Resin used as an incense	Resin for incense
Albizzia saponaria	South-East Asia	Wood used as fragrant timber, pods as a flavour in Java. Bark also used as a soap.	As a flavour material and cosmetic ingredient.
Altingia excelsa	South-East Asia	General tonic and stimulant, particularly good for chest complaints.	Aromatherapy, cosmoceuticals
Amomum kepulaga	Indonesia, Malay Peninsula	Cough and colds, freshen breath, rheumatism and liver disease	Aromatherapy and cosmoceuticals
Annona squamosa L.	Thailand, Malaysia	For treatment of head lice	Agricultural Pesticide
Boesenbergia pandurate	South East Asia	Anti-fungal, treatment of colic, diuretic, aphrodisiac	Agricultural fungicide, aromatherapy, cosmetics
Cassia alata L.	South-East Asia	Laxative, antibacterial, anti-tumor, treatment of skin diseases	Aromatherapy, pharmaceutical, cosmetic
Centella asiatica	South-East Asia	For treatment of wounds, anti-bacterial, anti-fungal, anti-cancer, anti-inflammatory, muscle relaxant, insecticidal,	Agricultural pesticide and fungicide, aromatherapy, cosmetics

		cooling, diuretic	
Andropogon odorata	India, Pakistan	Used for unspecified medicinal purposes	Aromatherapy and cosmoceuticals
Annona muricata	Asia	Skin complaints, coughs and rheumatism	Cosmetics
Aromadendron elegans	Indonesia	Reduce swelling	Anti-inflammatory
Baeckea frutescens	Australia and Asia-Pacific	General woman's tonic and tea flavouring	Nutraceutical
Blumea balsamifera	South-East Asia	As a source of camphor	Aromatherapy
Blumea balsamifera	South-East Asia	As a source of camphor	Aromatherapy
Camella sinensis	Highlands of Asia, China and India	Tea	Oil stimulant and antioxidant
Cedella odorata, C. calantas	Asia	Aromatic timber	Aromatherapy
Citrus hystrix (leaves and fruits)	South-East Asia	Washing and ointments	Aromatherapy and cosmetics
Citrus maxima (Pomelo) Fruit, rind and flowers (enfleurage)	South-East Asia	Fragrance and medicinal use	Fragrance and aromatherapy
Curcuma domestica (turmeric)	South-East Asia	Oil applied to bruises and to smooth out rough skin in India	Cosmetics
Dacrydium elatum	Malaysia to Pacific area, highland tree in tropical areas	Used for wood	As a possible alternative to cedar wood oil
Desmos chinensis	Southern China and South-East Asia		As a floral oil
Echites scholaris L.	Thailand, Malaysia, Laos	Anti-Malarial, Anti-diabetic, remedy for liver and intestinal problems	Armoatherapy
Ervatamia coronaria	Indonesia, Malaysia and Thailand	As a cooling material in medicine	Cosmetics
Eryngium foetidum	American herb introduced around the World	Substitute for coriander in flavouring	Aromatherapy and flavouring
Eugenia michelli	Introduced from South America	Stomach remedies	Aromatherapy
Eupatorium triplinerve	Malay Peninsula	Respiratory remedies	Aromatherapy
Evodia hortensis	Pacific, Indonesia and Malaysia	Floral	Aromatherapy
Excoecaria agallocha	Africa to Australia	Timber	Aromatic wood
Gaultheria procumbens	New Zealand and Tasmania	Methyl salicylate	
Gonystylus maingayi	Malaysia	For incense	Aromatherapy

Table 12.12. Continued

Plant	Location	Traditional Use	Potential Application
Hibiscus sabdariffa	South-East Asia	Anti-bacterial, anti-fungal, laxative, diuretic	Agricultural fungicides, aromatherapy
Hyptus suaveolens	South-East Asia	A weed in the tropics	Agro-pesticide
Illicium verum	China, Asia, Japan	Similar to dill oil in leaves	
Ipomoea pes-caprae	South-East Asia	Antihistaminic for jelly fish	
Languas galanga	South=East Asia	Medicinal, food flavouring (leaf and rhizome oil)	Aromatherapy, cosmetics
Lawsonia inermis L.	South-East Asia	Anti-fertility, anti-fungal, anti-bacterial, anti-tumor, anti-spasmodic, for treatment of skin diseases, herpes, boils, etc.	Cosmoceuticals, aromatherapy, agricultural fungicide
Leonurus sibiricus L.	South-East Asia	Diuretic, uterine relaxant	Aromatherpay
Lindera pipericarpa	Indonesia and Malaysia	Citronella type oil, fruits citral like oil	
Lysimachia foenum-grecum	Temperate Southern Hemisphere	Odour of fenugreek used in hair scenting	Cosmetics
Magnolia kobus	Asia	Leaves and twigs	Aromatherapy
Mimusops elengi	India and South-East Asia	Used as an infusion for use after bathing	Fragrant water for aromatherapy
Monodora myristica	Africa and Madagascar	Similar to nutmeg oil	
Murraya crenulata	Australian, Southern Asia, Philippines	Treatment for rheumatism	Aromatherapy
Ochrocarpus lonifolius	Tropical Africa and Asia	Essential oil in buds	Cosmetic
Persea americano (Avocado)	Americas and Mediterranean	Essential oil in leaves and bark	
Phoenix dactyifera (Date Palm)	Africa and Asia	Flowers contain essential oil	Aromatherapy
Pistacia lentiscus	East Asia	Oleo-resin used as perfume	
Pittosporum pentandum	Philippines	Bark oil a perfume	
Psidium guajava L. (Guava)	South-East Asia	Anti-bacterial, anti-viral, hypoglycaemic, astringent for skin diseases, anti-diarrheal, deodorant	Agricultural fungicides, aromatherapy, cosmetics
Ruta graveolens	Indonesia, Malaysia, Thailand	Infusion as a diaphoretic in fevers, relaxant	Aromatherapy
Vitex trifolia L.	South-East Asia	Insecticide, anti-bacterial	Agricultural pesticide
Zanthoxylum ovalifolium	Asia	Safrol source	

Another way to search for useful essential oils is to examine individual compounds with known bio-active qualities. Literature can be searched quickly for interesting compounds that will lead onto a more thorough investigation of the plant and/or individual constituent bio-activity. A number of aromatic compounds and their potential bio-active properties are listed in Table 12.13.

Table 12.13. Some Aroma Chemicals and Potential Bio-Active Properties [32].

Aroma Chemical	Potential Bio-Active Properties
***Cis*-ascaridole**	Analgesic, ancylostomiicide, anthelmintic, antiflatulent, fungicide, nematicide, pesticide, sedative
Bornyl acetate	Antibacterial, antifeedant, antispasmodic, antiviral, expectorant, flvaour, myorelaxant, pesticide, sedative
Camphor	Allelopathic, analgesic, anesthetic, antiacne, antidiarrhetic, antidysenteric, antifeedant, antifibrositic, antioxidative, antiseptic, antispasmodic, CNS-stmulant, cancer preventative, counterirritant, decongestant, expectorant, fungicide, herbicide, insect-repellent, nematicide, pesticide, respirastimulant
Capilene	Seed germination inhibitor
carvone	Allergenic, antiseptic, CNS-stimulant, cancer-preventative, flavour, insecticide, motor-depressent, nematicide, perfume, pesticide, sedative
B-caryopyllene	Aldose-reductase-inhibitor, antiacne, antiasthmatic, antibacterial, anticariogenic, antidemic, antifeedant, anti-inflammatory, antispeasmodic, antistaphylococcic, antitumor, flavour, fungicide, irritant, perfume, pesticide, sedative, ant repellent
1,8-cineole	Allelopathic, allergenic, anesthetic, anthelmintic, antiallergic, antibacterial, antibronchitic, anticariogenic, antifatigue, anti-inflammatory, antirheumatic, antiseptic, antispasmodic, antiulcer, CNS-stimulant, counterirritant, decongestant, dentifrice, ademagenic, expectorant, flavour, fungicide, herbicide, hypotensive, nematicide, neurotoxic, perfume, pesticide, sedative, spasmogenic, surfactant
Estragol	Anesthetic, anticonvulsant, genotoxin, myorelaxant, hepatocarcinogen
***a*, *b*-, *Ύ*-eudesmols**	Fixative for perfumes (non-bioactive)
***b*-ocimene**	Ant repellent
Farnesol	Bacteriacide
a-Phellandrene	Hyperthermic, irritant, spasmogenic, tumor-promotoer
Piperitone	Antiasthmatic, flavour, herbicide, perfume, pesticide
***a*-Thujone**	Abortfacient, antibacterial, emmenagogue, epileptogenic, insecticide, larvicide, pesticide
***b*-Thujone**	Abortfacient, antibacterial, emmenagogue, epileptogenic, pesticide

SOME INTERESTING CROPS

Finally, the last section of this book lists some essential oil plants that have attracted the author's interest over the last few years. These are not in any order of priority or necessarily of great potential. Potential is a relative concept that has a lot to do with our interest, passion, scale and market. Each small plant monograph presents some basic information for the reader to follow up from other sources, should there be further interest, as there is a lot of specific plant information available.

As a final note in this book, the viability to commercialise an essential oil or aromatic extract many come from the ability to produce it more efficiently and cost effectively than existing producers, without sacrificing any quality considerations. This could arise out of the utilization of new technology. For example Phura Natural Oils Ltd. in Thailand (see chapter 3 and 5) employs an extraction technology, many times more cost effective than solvent extraction, thus lowering the company's relative production cost structure, compared to traditional producers. Technology breakthroughs in the future will alter the relative comparative advantage of producers, giving some advantages over others. New technology introduction may be the key factor in maintaining the viability and profitability of essential oil production.

Plant Common Name: Ambrette Seed Oil and Absolute

Botanical Name: *Hibiscus abelmoshus (moshatus)*

Location and Climate Range: Available around India, South-East Asia and as far south to Australia.

Natural Habitat: Warm tropical woodlands.

Description: *Ambrette abelmoshus* is a herbaceous plant growing up to 2 m in height. It has an underground tuber which the plant dies back to in the dry season, emerging again at the beginning of the wet season. Its leaves are toothed and seeds grow in okra from the stems. It has yellow flowers with crimson centres.

Ethno-botanical Use: As a general tonic, stimulant, kidney and intestine treatment, demulcent for gonorrhoea, and dysuria, and as an agent to freshen clothes in storage.

Economic and Potential Uses: In perfumery

Part of the Plant Containing Oil: Dried seeds

Method of Extraction: An essential oil is obtained from the dry powdered seeds by steam distillation with yields between 0.3-0.5%. Further solvent extraction will obtain an absolute free of the fatty acids in the seeds. As an alternative to solvent extraction, the fatty acids can be saponified and separated from the volatile materials [33].

Agronomy –

Propagation: by seeds or cuttings, should be planted on well drained soil, planted at the beginning of the rainy season.

Cultivation: Usually on fertile, well drained soil.

Harvesting: Harvesting of okra from plant for seeds, approximately 4-6 months after planting.

Known Production: India

Chemical Constituents: Contains a macrocyclic lactone ambrettolide that has a distinct musky odour. Also contains decyl acetate, and dodecyl acetate around 7%, A number of other lactones exist displaying powerful notes [34]. Also contains the sesquiterpene, farnesol.

Olfactory Description: A very persistent musky odour with a cognac note.

Any Standards or Threats: On GRAS List

Assessment of Potential: Ambrette seed oil was once greatly appreciated for its musk notes, but was superseded by the development of synthetic musks. It may have potential again if demand for natural products continues to grow and attention is placed on natural fragrances,

Plant Common Name: Anise Scented Myrtle

Botanical Name: *Backhousia anisata* Recently renamed *Anetholea anisata* [35].

Location and Climate Range: A rare tree that grows up to 25 m in height in the sub-tropical rainforests of Northern New South Wales, Australia.

Natural Habitat: A rainforest tree among other trees.

Description: A hardy evergreen tree with flush of leaves.

Ethno-botanical Use: Anti-fungal, sedative, insect repellent (according to some websites)

Economic and Potential Uses: Aromatherapy and cosmetics, some potential in flavours and fragrance.

Part of the Plant Containing Oil: The leaves and terminal stems.

Method of Extraction: Steam distillation

Agronomy –

Propagation: Fresh seed or plant cuttings. Plant cuttings will keep stock genetically the same. Likes indirect sunlight at the nursery stage.

Cultivation: Fertile, well drained soil.

Harvesting: For essential oil, harvest tree once 2 m height as a shrub, so coppice develops.

Known Production: Some trial plantings and some small amounts of oil coming out of North Coast of New South Wales.

Chemical Constituents: Exists in two chemotypes, E-anethole type (up to 95%) and Z-anethole 0.05% and methyl chavicol type [36].

Olfactory Description: Oil has a smooth, clean aniseed note.

Any Standards or Threats: Should avoid *cis*-anthole chemotype.

Assessment of Potential: Some very small production from small plantations. According to Cropwatch the tree is an endangered species [37]. Some potential in cosmetics and aromatherapy.

Plant Common Name: Artemisia annua (sweet sagewort or sweet wormwood)

Botanical Name: *Artemisia annua*

Location and Climate Range: Found throughout the World in temperate regions.

Natural Habitat: Grassland, woods, forest, field ridges, etc.

Description: A single stem shrub up to 2 m high that has fern like alternating leaves with bright yellow.

Ethno-botanical Use: Used to treat fever from a tea made from dry leaves.

Economic and Potential Uses: Used for the extraction of artemisinin for the treatment of malaria [38]. Perfumery and aromatherapy.

Part of the Plant Containing Oil: Leaves

Method of Extraction: Steam distillation

Figure 12.5. *Artemisia annua* at the Author's Property in Perlis, Malaysia.

Agronomy – Wild collection
Propagation: Tissue culture and cuttings
Cultivation: Transferred to field at high densities (50-100K plants per Ha.)
Harvesting: Seasonal harvesting during Autumn months of whole plant.
Known Production: Bulgaria
Chemical Constituents: *Alpha*-pinene 0.032%, *beta*-pinene 0.882%, β-caryophyllene, Camphene 0.047%, camphor 0.6%, artemisia ketone 66.7%, linalool 3.4%, myrcene 3.8%, germacrene, D, 1,8-cineole 5.5%, borneol 0.2%, terpinen-4-ol, and artemisia alcohol [39].
Olfactory Description: A herbaceous camphorous odour.
Any Standards or Threats: Use of linalool in cosmetics subject to EC Directive 76/768/EEC
Assessment of Potential: Known to have anti-cancer properties against breast and prostate cancer and leukemia [40]. Potential in cosmetics and aromatherapy. Possible use in agriculture for fungal control. Potential as a natural herbicide [41].

Plant Common Name: Cajuput subsp. *"Platyphylla"*
Botanical Name: *Melaleuca cajuputi* (there are a number of well defined chemotypes)
Location and Climate Range: Found along the coast lines of tropical South-East Asia, as far north as Bangkok, Throughout Indonesia, New Guinea and the Pacific Islands. The sub species *"platyphylla"* is widely distributed among the general population.
Natural Habitat: The tree prefers sandy soils along the coast line and also thrives in coastal swampy areas.

Description: A woody bark tree that grows up to 15 metres high with a single main, but windy trunk. The branches contain small erect dark green leaves that are oval in shape with a sharp other edge.

Ethno-botanical Use: Used by indigenous populations in Asia, the Pacific and Australia for muscle pains and inhaled through vapour for chest relief.

Economic and Potential Uses: The essential oil of the cajuput tree *(Platyphylla type)* contains β-triketone constituents platyphyllol *(6,6-dimethyl-2-acylohex-4-en-1,3-dione, 1-acetyl-4-methoxy-3,5,5-trimethylcycohex-3-en-2,5-dione, etc.)* that have UV block characteristics.

Part of the Plant Containing Oil: The leaves around 0.05-0.3%

Method of Extraction: Steam distillation

Agronomy –

Propagation: By seed, vegetative propagation not very successful.

Cultivation: Rarely cultivated except as ornamental trees

Harvesting: Cutting down of upper and middle leaves and branches during wild collection

Known Production: No known commercial production of this sub species

Chemical Constituents: Two chemotypes, chemotype 1: alpha-copaene 0.5%, beta-caryophyllene 0.6%, alloaromadendrene 0.1%, humulene 0.6%, spathulenol 9.0%, platyphyllol 71.0% and cajeputol 2.3%. Chemotype 2: alpha-pinene 67.9%, beta-pinene 1.3%, 1,8-cineole 0.3%, gamma-terpinene 0.4%, para-cymene 0.3%, terpinolene, 0.2%, beta-caryophyllene 1.9%, aromadendrene 1.3%, allomadendrene 0.3%, humulene 0.9%, viriflorene 1.0%, alpha-terpineol 1.1%, beta-selinene 1.0%, alpha-selinene 0.6%, palustrol 0.1%, caryophyllene oxide 1.5%, viridiflorol 0.9% and spathulenol 2.1% [42].

Figure 12.6. A Natural Stand of *Melaleuca cajuputi* along the Coast of Southern Thailand in Pattani Province.

Olfactory Description: A powerful eucalyptus like odour, except not as sharp.

Any Standards or Threats: No standards for this chemotype

Assessment of Potential: Patented for use in sunscreens and as a bacteriacide and fungicide by Joulain and Racine in 1994 [43]. Could be used as a plant anti-stress agent in agriculture and horticulture, and an anti-aging material in cosmetics, due to it's SPF properties.

Plant Common Name: Caraway

Botanical Name: *Carum carvi*

Location and Climate Range: All over Europe and Asia

Natural Habitat: Widely distributed on all types of terrain in Europe

Description: A small biennial herb growing up to 60 cm tall with finely divided leaves in a featherlike arrangement, growing on 20-30 cm stems. The plant has small white flowers in umbels. The fruits are crescent shaped achenes, approximately 2-3 mm long with five ridges.

Ethno-botanical Use: Used to treat colic, stimulate the appetite and improve digestion.

Economic and Potential Uses: Used in flavours, mouthwashes, medicines and aromatherapy

Part of the Plant Containing Oil: Dried fruit or seeds and leaves. Seeds contain between 4-7% volatile oil.

Method of Extraction: Steam distillation of the crushed seeds.

Agronomy –

Propagation: by seeds

Cultivation: Caraway prefers a warm, sunny location with well drained soils.

Harvesting: Fruits harvested and dried.

Known Production: UK, Holland, Germany, Finland, Poland, Russia, Norway, India and Morocco (but mainly for food use).

Chemical Constituents: *Beta*-pinene 0.04%, limonene 9.75%, terpinolene 0.20%, myrcene 0.06%, *para*-cymene 0.06%, caryophyllene 0.11%, *trans*-dihydrocarvone 0.59%, cis-dihydrocarvone 0.11%, carvone 80.17%, cuminaldehyde 0.08%, *cis*-perillyl alcohol 0.14%, *trans*-carveol 0.10%, *cis*-carveol 0.14%, dihydrocarveol, and cuminyl alcohol 0.02% [44].

Olfactory Description: Intense warm, spicy odour, reminiscing of cumin.

Any Standards or Threats: Use of limonene in cosmetics subject to EC Directive 76/768/EEC

Assessment of Potential: Carvone is an insect repellent, a suppressant of sprouting in stored potatoes and for inhibiting the growth of some fungi. Caraway could be used in agro-fungicides to suppress *gano derma* and other fungi, as well as a mold suppressant in household cleaning. perillyl alcohol is undergoing trials against various cancers [45].

Plant Common Name: Volatile fraction of coconut oil

Botanical Name: *Cocos nucifera*

Location and Climate Range: Throughout the tropics

Natural Habitat: Sandy soils, but adaptable to many other types along with a wide variety of coastal vegetation. Does not like waterlogged soils.

Description: A palm tree with a major trunk that rises up to 40 metres in height. Palms form an "X" shaped canopy at the top in an almost horizontal position. The coconut tree has both male and female flowers that grow from woody sheathes under the palms. The fruits, coconuts grow from under the palms in bunches.

Ethno-botanical Use: Numerous uses from food, to dyes, tannins, ropes, building materials, copra, santan, coconut oil (fixed).

Economic and Potential Uses: Flavour material, cosmetics, and aromatherapy.

Part of the Plant Containing Oil: The coconut oil

Method of Extraction: steam distillation of the coconut fatty oil

Agronomy –

Propagation: Solely propagated by the seed falling and seedling growing from it.

Cultivation: In the wild, grow naturally with the seed developing roots that anchor it to the soil.

Harvesting: Collection of coconuts from the top of the tree or waiting for them to fall.

Known Production: Unknown

Chemical Constituents: *d*-2-nonanal, *d*-2-hendecanol, methyl *n*-amyl ketone, methyl *n*-heptyl ketone, methyl *n*-nonyl ketone, methyl *n*-undecyl ketone [46].

Olfactory Description: Cocount santan fatty type odour.

Any Standards or Threats:

Assessment of Potential: Also coconut flower scents are obtained through infusion of the flowers.

Plant Common Name: Cryptocarya cunninghamii

Botanical Name: *Cryptocarya cunninghamii* Meisn. (also a number of close spp. In Asia)

Location and Climate Range: Across Northern Australia and New Guinea.

Natural Habitat: Shallow rocky soils and sandstone gorges.

Description: A small evergreen tree growing to around 25 metres in height, with alternate leaves.

Ethno-botanical Use:

Economic and Potential Uses:

Part of the Plant Containing Oil: Bark, wood, fruits and leaves. (leaf yield 0.7-1.5%)

Method of Extraction: Steam distillation

Agronomy – A forest tree

Propagation: Unknown

Cultivation: Unknown

Harvesting: Unknown

Known Production: Not known

Chemical Constituents: Bark: Linalool 0.9%, borneol 0.7%, C-10 massoia lactone 64.8%, β-bisabolene 1.4%, C-12 massioa lactone 17.4%, benzyl benzoate 13.4%, wood: massoia lactone 68.4%, *gamma*-decalactone, C-12 massioa lactone 27.7%, C-14 massioa lactone 1.4%, Fruit: *alpha*-copaene 2.1%, β-elemene 1.3%, β-caryophyllene 12.9%, *alpha*-

humulene 2.2%, *E*,*E*-α-Farnesene 1.3%, C-10 massoia lactone 1.4%, *alpha*-cadinene 1.2%, benzyl benzoate 68.3% [47]. Other analysis shows bicyclogermacrene (C2 massoia lactone) 78-88% in the leaves [48].

Olfactory Description: Bark odour of apricots and coconuts.

Any Standards or Threats: Unsustainable harvesting

Assessment of Potential: A potential source of lactones.

Plant Common Name: Eucalyptus Oil (Blue Mallee)

Botanical Name: *Eucalyptus polybractea*

Location and Climate Range: This species of eucalyptus occurs in Central Victoria and Western New South Wales, Australia. It is primarlily suited to a temperate, but semi-arid climate with a mild winter, although summer period temperatures can range into 40°C+ for long periods of time. The plant can also withstand long periods without water.

Natural Habitat: Red-brown and sandy loam soils in bushlands.

Description: A 6-10 m high smooth bark tree with branches aerating out from the main trunk with clumps of green long narrow-lanceolate leaves, 6-10 com long and 0.5-1.0 cm wide.

Ethno-botanical Use: Used by indigenous population to treat wounds as an antiseptic. Also for treatment of colds and nasal congestion when boiled with water to make steam for inhalation.

Economic and Potential Uses: *Eucalyptus polybractea* is the major eucalyptus tree used for the production of high-grade medicinal oil.

Part of the Plant Containing Oil: Leaves, oil yields vary between less than 1.0% to up to 5.0%

Method of Extraction: Steam distillation

Agronomy –

Propagation: Wild collection is common in Australia, plantations are produced through seed propagation. The tree requires a fertile and well drained soil that can retain moisture.

Cultivation: Seedlings planted into the field after a number of months in the nursery. The tree requires some care to grow in most conditions.

Harvesting: The tree is well suited to mechanical harvesting where it coppices after each cutting.

Known Production: In central Victoria and Western New South Wales, Australia.

Chemical Constituents: The dominant constituent is 1,8-cineole which is about 90-93%, other constituents include *alpha*-pinene 1%, limonene 1%, *para*-cymene 2%, *beta*-pinene 0.2%, and sabinene 0.2% [49].

Olfactory Description: Powerful and pungent fresh uplifting cineole type odour.

Any Standards or Threats: Standards for eucalyptus oil exist in most pharmacopeia. SCCP (EU) identified oil as toxic and subject to restriction in use.

Assessment of Potential: Many people believe the olfactory characteristics of *Eucalyptus polybractea* are superior to *Eucalyptus globulus. E. polybractea* yields are much higher than *E. globulus* is cultivation if this crop can be managed.

Plant Common Name: Eucalyptus dives oil *(broad leafed peppermint gum)*

Botanical Name: *Eucalyptus dives*

Location and Climate Range: Grows naturally from Melbourne, Victoria along the Great Dividing Range through Canberra and the Snowy Mountains, to Central-East New South Wales. Likes Temperate and dry conditions.

Natural Habitat: Prefers foot-hills and open conditions in fields and plateaux.

Description: *Eucalyptus dives* is a midsized range tree that grows to a height of around 20m. Branches with clumps of broad-lanceolate browny-green leaves, 7-20 com long aerate out from the main trunk. The branched areas grow fruit buds with seeds measuring approximately 4-6 mm long and 3-5 mm across.

Ethno-botanical Use: Unknown

Economic and Potential Uses: Previously the piperitone rich chemotype was used as a source of *l*-piperitone for the synthesis of *l*-menthol.

Part of the Plant Containing Oil: Leaves up to 4.5%

Method of Extraction: Steam distillation

Agronomy –

Propagation: Through seeds.

Cultivation: Prefers well drained soil in low rainfall temperate, semi arid regions. Can be harvested within two years after planting and subsequently harvested on an annual basis.

Harvesting: Can be harvested mechanically and coppice grows after subsequent cuttings.

Known Production: Some in Africa and Western new South Wales.

Chemical Constituents: Piperitone 50%+, *alpha*-pinene 1%, *beta*-phellandrene 2%, *alpha*-phellandrene 20%, *alpha*-terpinene 2%, *gamma*-terpinene 1%, *para*-cymene 3% and terpinolene 2% [49].

Olfactory Description: piperitone chemotype has a herb-mint type odour, cineole rich oil has a blunt cineole type odour.

Any Standards or Threats: N/A

Assessment of Potential: Phellandrene is a proven stain removal solvent in laundry applications and demand for this oil could increase if this application is marketed.

Plant Common Name: Galanga

Botanical Name: *Alpinia Galanga*

Location and Climate Range: Found in tropical climates throughout South-East Asia.

Natural Habitat: Found within the grasses in open jungle areas, especially along banks and ridges.

Description: Galanga is a perennial tall herb growing up to 2 m tall, with a rhizome base under the soil. The leaves are glabrous and arranged distichously. The green leaf blades are linear and elliptical along the whole broadside, with an acuminate apice and sheathing base. Flowers grow on terminal panicles, approximately 10-15 cm long.

Ethno-botanical Use: Used in traditional medicine for rheumatism, fever, bronchitis, dyspepsia and diabetes. Also widely used as a spice.

Economic and Potential Uses: potential for flavour and aromatherapy usage. Also as a plant anti-stress agent with reported UV-blocking characteristics (see chapter 11).

Part of the Plant Containing Oil: Rhizomes yield about 0.2-0.5%

Method of Extraction: Steam distillation

Agronomy –

Propagation: Easily propagated through the division of rhizomes

Cultivation: Thrives on rich loamy soils in semi shaded conditions. Grows very poorly under waterlogged conditions.

Harvesting: Rhizomes

Known Production: Small quantities in Thailand

Chemical Constituents: 1-acetoxychavicol acetate, 1-acetoxyeugenol, 1-acetoxyeugenol acetate, ascorbic acid, bassorin, camphor, cardinene, cineole, beta-carotene, caryophyllene oxide, caryophyllenol-1, caryophyllenol-11, eugenol, (E)-8-β-17-epoxylabd-12-ene-15,16-dial, galangol, galangin, isorhamnetin, kaempferide, kaempferol, methylcinnamate, niacin, phlobaphen, D-pinene, quercetin, quercetin-3-methyl ether, riboflavin, terpinen-4-ol, thiamin, trans—3,4-dimethythoxycinnamyl alcohol, trans-4-hydroxycinnamaldehyde, trans-4-methoxycinnamyl alcohol.

Olfactory Description: A mild but sweet gingery odour

Any Standards or Threats: N/A

Assessment of Potential: Some potential as a small herb oil and for aromatherapy. Some potential as a plant anti-stress agent in agriculture.

Plant Common Name: Hedychium spicatum

Botanical Name: *Hedychium spicatum*

Location and Climate Range: Found in forest clearings between, 5000-8000 Ft ASL from the Himalayas to East Asia.

Natural Habitat: Found within clearings.

Description: A perennial rhizome herb of the Zingiberaceae family, growing up to 1.5 m height with leaves spreading out from the main trunk about 30 cm in length. Inflorescence is spiked. The flowers are ascending with a bright deep yellow colour. A rhizome exists below the ground.

Ethno-botanical Use: Anti-bacterial, anti-fungal, vasodilatory effect on blood vessels, antispasmodic, mild tranquilizing effect [50], anti-inflammatory, analgesic, treatment of nausea, asthma and bronchitis.

Economic and Potential Uses: potential for flavour and aromatherapy usage. Dried roots used for incense.

Part of the Plant Containing Oil: Rhizomes yield about 0.13-0.16%

Method of Extraction: Steam distillation

Agronomy – Wild collected

Figure 12.7. Wild *Alpinia galangal* Growing in Ranong province, Southern Thailand.

Propagation: Easily propagated through the division of rhizomes, also from seed propagation.

Cultivation: Thrives on rich loamy soils in sunny conditions in temperate to sub-tropical environments. Can withstand frosts.

Harvesting: Rhizomes

Known Production: Small quantities wild collected in India.

Chemical Constituents: *b-phellandrene, para*-methyl cinnamic acid and its esters, linalool, *b*-eudesmol, *d*-cadinene, *d*-sabriene, cineole, pentadecane methyl *para*-cumarine acetate [51].

Olfactory Description: A very pungent odour of hyacinths, with some orris type notes.

Any Standards or Threats: N/A

Assessment of Potential: Some potential for aromatherapy, if cultivated as listed as an endangered species by IUCN.

Plant Common Name: Kesom (Vietnamese mint)

Botanical Name: *Polygonum odoratum (Persicaria odorata* (Lour.) Sojak.)

Location and Climate Range: The plant is cultivated in Australia for a number of years. Literature searches reveal very little about the origin, but most probably introduced into Australia by immigrants from South-East Asia. *Polygonum minus* Huds is spread across South-East Asia, where the taxonomy is very similar to *P. odoratum*. Both varieties are very similar, except *P. odoratum* has a broader leaf. The chemotaxonomy of both varieties is very similar [52].

Natural Habitat: Along river and dam banks.

Description: A perennial herb which has stems with joints from where the leaves protrude. The stems are usually green with some tinges of red. The lance shaped leaves are deep green with a red-green crescent marked on the upper side. The herb blossoms with tiny pink flowers when the stems become woody and terminal. The herb grows up to 1.5 m in height. During the winter in Southern Australia, the herb becomes dormant for about 2 to 3 months.

Ethno-botanical Use: Unknown

Economic and Potential Uses: As a source of natural aliphatic aldehydes, as a flvouring material and for natural aldehydic notes in perfumery.

Part of the Plant Containing Oil: Levaes and to a lessor extent, the stems. Yields of *P. odoratum* oil in North-East Victoria are higher than yields in Northern Malaysia, which is probably due to the milder climate in Victoria [53].

Method of Extraction: Steam distillation

Agronomy –

Propagation: Vegetative propagation

Cultivation: Requires plenty of water especially on hot days, where lack of water and heat will stress the plant. Soil should be well draining but able to maintain moisture.

Harvesting: Can be mowed and scooped up into distillation charge bins in the same way mint is harvested.

Known Production: Unofficial reports of experimental plots in Malaysia and Vietnam.

Chemical Constituents: 1-decanol (alcohol C10) 3-4.0%, 1-dodecanol (alcohol C12) 5-12.0%, decanal (aldehyde C10) 20-25.0% and dodecanal (aldehyde C12) 45-50.0% [54].

Olfactory Description: An overpowering aldehydic odour, predominately of dodecanal.

Any Standards or Threats: Essential oil not on GRAS list and not registered under REACH in EU. Individual constituent aldehydes are on GRAS list and registered under REACH.

Assessment of Potential: There is a small market as a natural flavour material like many savory oils. There is also a market for the individual aldehyde isolates, but it is not large enough for a large number of producers. This is a straight forward crop to cultivate and process, except for weed control strategies.

Plant Common Name: Lemon Myrtle

Botanical Name: *Backhousia citriodora*

Location and Climate Range: A native tree of the sub-tropical Queensland rainforests.

Natural Habitat: A secondary rainforest tree.

Description: A perennial tree that can reach 20 m in height, lush glossy green opposite lanceolate leaves, 5-14 cm long and 2-3 cm wide. The flowers are white and 5-7 cm in diameter, in clusters around the ends of branches, throughout summer.

Ethno-botanical Use: Used as both a medicine and a flavouring by the indigenous people of Australia.

Economic and Potential Uses: Leaves used in dry form to flavour tea, also in Australian 'bushfood' as a lemon scented herb. As an essential oil for fragrance. Anti-microbial activity reported [55].

Part of the Plant Containing Oil: Leaves contain approximately 1-3% oil.

Method of Extraction: Steam distillation

Agronomy –

Propagation: Through seeds, cuttings or micro-propagation. To maintain the same genetic characteristics (cloning). Seeds usually propagate genetically diverse populations. Only fresh seeds will germinate.

Figure 12.8. A harvest of Kesum *(Polygonum odoratum)* growing at the Ovens Research Station, Myrtleford, Victoria (Photo courtesy of Mr. Fred Bienvenu)

Cultivation: Grows slowly and is usually maintained around 1.5 m to create a bush for easy management and harvesting.

Harvesting: Usually leaves harvested so coppice re-growth occurs.

Known Production: Northern New South Wales and North Queensland.

Chemical Constituents: Oil contain between 85-95% citral.

Olfactory Description: A sharp clean but sweet lemony/citrus odour.

Any Standards or Threats: Australian Standard AS 4941-2001. Use of citral in cosmetics subject to EC Directive 76/768/EEC.

Assessment of Potential: There is not enough production to allow much growth in demand for this essential oil. Establishing a plantation requires some effort in propagation and establishment.

Plant Common Name: Lemon Tea Tree

Botanical Name: *Leptospermum petersonii*

Location and Climate Range: Grows naturally in parts of the Great Dividing Range in Southern Australia.

Natural Habitat: Tends to grow on open fields and ranges on well drained soils.

Description: A shrub or small tree up to 4 m high with green leaves are arranged in rosettes, with small linear leaf blades, approximately 3-4 cm long and 4-5 mm wide. The shrub produces small white flowers in Australia during December and January, which exhibit a fresh, crisp lemon odour.

Ethno-botanical Use: Unknown

Economic and Potential Uses: Potentially as a fragrance ingredient, although not common, in aromatherapy and as an insect repellent. Some experimentation as a preservative in shampoos [56].

Part of the Plant Containing Oil: Leaves around 1.2-1.5%

Method of Extraction: Steam distillation

Agronomy –

Propagation: Usually by seed, also can be propagated by cuttings. Prone to pests in the nursery and field, from various species of caterpillars

Cultivation: Full sun and well drained soil required (does not like waterlogged soil).

Harvesting: Tree cut down during harvest so it can coppice.

Known Production: On small plantations in New South Wales and Queensland, Australia

Chemical Constituents: The oil primarily contains Citral, as neral around 20-25.0% and geranial 38-34%, citronellal 22-27.0%, pinene 05-1.0%, myrcene 0.5-4.0%, linalool 0.5-3.0%, eugenol 0.2-0.6%, caryophyllene 0.1-0.5% and pathulenol 0.4%.

Olfactory Description: A strong lemony odour with citronella background.

Any Standards or Threats: Use of citral in cosmetics subject to EC Directive 76/768/EEC.

Assessment of Potential: Has some potential as a minor essential oil in some cosmetic formulations and in aromatherapy.

Plant Common Name: Manuka

Botanical Name: *Leptospermum scoparium* Foster

Location and Climate Range: An abundant large bush found throughout New Zealand

Natural Habitat: Usually found in forest ranging up to 1000 metres in altitude. Capable of growing on all types of soils.

Description: A conical shaped bush or shrub that grows to around 4.0 metres in height. A barky shrub with whitish-reddish wood. The shrub is covered with small lanceolate shaped leaves with spiky ends. White flowers around 10 cm across during May-June.

Ethno-botanical Use: Used in a number of Maori remedies [57].

Economic and Potential Uses: Currently produced for cosmetic and aromatherapy applications.

Part of the Plant Containing Oil: Leaves, yield around 0.2-0.8 of dry leaf.

Method of Extraction: Steam distillation

Agronomy –

Propagation: Usually by seed, also can be propagated by cuttings (not undertaken commercially).

Cultivation: Mostly wild harvested in the North Island of New Zealand.

Harvesting: Tree cut down during harvest so it can coppice and re-harvest every 2-3 years.

Known Production: North Island of New Zealand

Chemical Constituents: A very wide variance in the chemistry due to location. Can be classified into a number of chemotypes. Diiferent types contain *a*-pinene, myrcene with a number of sesquiterpenes, (β)-caryophyllene and (α)-humulene and a number of sesquiterpenes, a geranyl acetate type, a triketone type, a linalool type and another sesquiterpene with elemene and selinene.

Olfactory Description: A bitter clove terpene like resinous, herbaceous with some fruity undertones.

Any Standards or Threats:

Assessment of Potential: Long periods of distillation and fractionation are required to extract and isolate β-triketones from the oil. CO_2 extraction may make the process more economical. β-triketones have been found to be present in excess of 20% of some oil compositions. β-triketone oils are claimed to be highly effective anti-microbial agents, effective against herpes (HSV-1) and (HSV-2) [58], sedative and antidepressant properties, insecticidal properties, effective against proteases implicated in muscle wasting diseases like muscular dystrophy [59], anti-dandruff effects and as a plant regulator in herbicides [60].

Plant Common Name: Marsh Honey Mrytle
Botanical Name: *Melaleuca teretifolia* Endl.
Location and Climate Range: South Western Australia.
Natural Habitat: Tends to grow in moist and poorly drained soils and swampy areas.
Description: A medium size shrub growing 1-3 m high, with linear rounded in cross section, 40-60 cm long, with long curved leaves (5-8cm x 3mm), with white flowers.
Ethno-botanical Use: Unknown
Economic and Potential Uses: None reported
Part of the Plant Containing Oil: Leaves around 1.0-1.5%
Method of Extraction: Steam distillation
Agronomy –
Propagation: Usually by seed, also can be propagated by cuttings.
Cultivation: Hardy in a wide range of soils, preferring direct sun and humid conditions.
Harvesting: Tree cut down during harvest so it can coppice.
Known Production: No known production
Chemical Constituents: Two chemotypes: 1,8-cineole type: cineole 84%, alpha-pinene 1.8%, p-pinene 1.2%, myrcene 1.0%, limonene 3.1%, terpinen-4-ol 1.8%, and alpha=terpineol 3.3%. Citral Type: neral 28.7-30.0%, geranial 38.7-38.8% (citral content approx. 68%), myrcene 9.8%, limonene 0.3-1.7%, citronellal 0.2-1.7%, terpenin-4-ol 0.1-6.7%, alpha-terpineol 0.1-1.6%, citronellol 0.6-1.2%, geraniol 1.7-2.5%, nerol 0.2-2.0%, isoneral 1.3-1.8%, isogeranial 2.1-21.7% and exo-ctral 0.3-0.5% [61].
Olfactory Description: A strong lemony odour with citronella background.
Any Standards or Threats: Use of citral in cosmetics subject to EC Directive 76/768/EEC.
Assessment of Potential: Potential for aromatherapy and cosmetics outside of EU.

Plant Common Name: Melaleuca bracteata
Botanical Name: *Melaleuca bracteata*
Location and Climate Range: Widely distributed from the East coast to the West coast of Australia.
Natural Habitat: Growing along water courses in heavy textured soils and clays.
Description: A large shrub 5-10 metres in height, with the capability to reach 20 m, depending upon the environment. It has small prickly leaves and dark-grey hard bark.
Ethno-botanical Use: Used as an antiseptic through applying the leaves to cuts by the indigenous population of Australia.
Economic and Potential Uses: As an essential oil for aromatherapy (some small production).
Part of the Plant Containing Oil: Terminal twigs and leaves 0.2-2.5%
Method of Extraction: Steam distillation

Agronomy –

Propagation: Seed

Cultivation: Prefers fertile and well drained soil. Can be harvested with 18 months of planting and coppiced for annual harvesting.

Harvesting: Cut down tree for coppicing

Known Production: Some wild collection in Australia.

Chemical Constituents: Four known chemotypes, 1. elemicin type, elemicin 57.4%, β-caryophyllene 21.4%, alpha-phellendrene 3.5%, 2. E-isoelemicin, E-isoelemicin 45.4%, alpha-phellendrene 12.7%, β-caryophyllene 6.8%, 3. E-methyl isoeugenol, E-methyl isoleugenol 75.9%, methyleugenol 17.5%, and 4. methyl eugenol type, methyl eugenol 45.7%, E-methyl isoeugenol 43.0%, E-methyl cinnamate 8.6% [62].

Olfactory Description: A medicinal/clove like odour with floral notes.

Any Standards or Threats: Methyl eugenol suspected carcinogen by IFRA.

Assessment of Potential: Can be used as a synergist with insecticides [63]. Tree by-product betaine potential for the treatment of plant stress [64].

Plant Common Name: Swamp Paperback (Rosalina)

Botanical Name: *Melaleuca ericifolia*

Location and Climate Range: Tasmania, North to Queensland

Natural Habitat: Woodlands and forest valleys, swamps and coastal areas.

Description: A small tree up to 3 metres high resembling a tea tree (*M. alternifolia)*

Ethno-botanical Use: Unknown

Economic and Potential Uses: Aromatherapy

Part of the Plant Containing Oil: Terminal stems and leaves.

Method of Extraction: Steam distillation

Agronomy –

Propagation: Through seed or by cuttings.

Cultivation: Grows well in moist soils in open sunlight.

Harvesting: Cutting and coppicing

Known Production: Wild collection in Southern Australia

Chemical Constituents: Linalool 56.2%, *alpha*-pinene 6.6%, 1,8-cineole 13.3%, limonene 1.9%, *alpha*-terpineol 2.7%, linalool oxide 1.8%, andgeranial 0.7%, aromadendrene, 2.0%, globulol 1.7%, spatliulenol 1.0%, β-caryophyllene, allo-aromadendrene, viridiflorene and *alpha*-copaene in traces [65].

Olfactory Description: A floral-medicinal like odour.

Any Standards or Threats: Use of linalool in cosmetics subject to EC Directive 76/768/EEC.

Assessment of Potential: Potential agricultural use as an anti-fungal agent [66]. Wild harvesting maybe unsustainable, plantation cultivation desirable.

Plant Common Name: *Melaleuca quinuenervia* Broad Leafed Paperback

Botanical Name: *Melaleuca quinuenervia*

Location and Climate Range: East coast of Australia, Southern Papua New Guinea

Natural Habitat: Occurs along waterways and swamps on peat humic soils.

Description: A medium sized tree ranging between 8-12 metres tall. Stiff leather like lanceolate-elliptic leaves and multi-layered whitish papery bark.

Ethno-botanical Use: Used against lice and as an insect repellent (?).
Economic and Potential Uses: As a fragrance in cosmetics and aromatherapy.
Part of the Plant Containing Oil: Leaves
Method of Extraction: Steam distillation
Agronomy –
Propagation: From both seeds and cuttings
Cultivation: Adaptable to most soils and weather conditions. Thrives in tropical areas.
Harvesting: Whole tree cut down during first year and allowed to coppice for further harvests.
Known Production: Small Production in Australia through wild harvesting
Chemical Constituents: Two chemotypes: Chemotype 1: E-Nerolidal 95.0%, (niaouli type) and chemotype 2: 1,8-cineole 64.9%, *alpha*-terpineol 9.9%, limonene 6.8%, globulol 3.4%, viridiflorene 1.5%, aromadendrene 1.7%, β-caryophyllene 1.3%, and myrcene 1.2% (nerolina type) [67].
Olfactory Description: Niaouli type: sweet, fresh medicinal odour, Neroline type: Herby-woody floral lavender, medicinal type odour.
Any Standards or Threats: N/A
Assessment of Potential: Aromatherapy and cosmetics.

Figure 12.9. A "Very Young" *Melaleuca quinuenervia* Crop Plant at the Author's Property in Perlis, Malaysia with the Distillery Shown Behind.

Plant Common Name: Onion
Botanical Name: *Allium cepa.* Many other spp.
Location and Climate Range: Worldwide, but a Mediterranean climate with hot dry summers is optimum.
Natural Habitat: One of the earliest plants cultivated by humankind.
Description: An perennial evergreen bulb plant that grows up to 0.5 metres tall.

Ethno-botanical Use: Many claims made about the therapeutic effect of onions [68]. Believed to be anti-inflammatory [69], anti-cholesterol, anti-cancer [70], and anti-oxidant [71]. Used extensively in homeopathy. Onion juice good for bee and wasp stings, fungal skin conditions and scrapes [72].

Economic and Potential Uses: Food production

Part of the Plant Containing Oil: Whole plant, approximately 0.05% yield.

Method of Extraction: Steam distillation of the crushed fresh onions. Onion constituents partly water soluble, so special recovery techniques required.

Agronomy –

Propagation: by seed

Cultivation: Prefers well drained light sandy and loamy soils. Bulb growth is responsive to day long sunlight

Harvesting: Whole plant for bulb under the ground.

Known Production: Egypt

Chemical Constituents: Major constituents alkyl and allyl sulfides. Other constituents include methyl propyl disulfide, methyl propyl trisulfide and dipropyl trisulfide [73].

Olfactory Description: A persistent and pungent odour.

Any Standards or Threats: N/A

Assessment of Potential: Cosmetics and pharmaceuticals. As a nemacide in agriculture [74].

Plant Common Name: Oregano

Botanical Name: *Origanum vulgare* (many other species include *O. heracleoticum, O. coridothymus, O. mastichina*)

Location and Climate Range: Native to Europe, particularly the Mediterranean region and South-Central Asia.

Natural Habitat: Long established garden plant

Description: A perennial herb that grows up to 80 cm in height. It has opposite leaves 1-4 com long, with purple flowers 3-4 mm long, held in erect spikes.

Ethno-botanical Use: Used as a stimulant, antiseptic, anti-spasmodic, expectorant, stomach ache, treatment of colds, influenza and fevers.

Economic and Potential Uses: Used in Mexican and Italian cooking as a fresh or dried material. Used in fine perfumery sparingly.

Part of the Plant Containing Oil: Whole plant around 0.05-1.0% oil

Method of Extraction: Steam distillation

Agronomy –

Propagation: Seed, cuttings or plant division.

Cultivation: Very easily cultivated in the field. Prefers very well drained soil.

Harvesting: Usually harvested when flowering occurs. Multiple harvests are usually practiced during the summer season.

Known Production: Europe and New Zealand

Chemical Constituents: *Methyl* carvacrol 21.6%, *para*-cymene 11.3%, myrcene 9.3%, *gamma*-teroinen 4.1%, carvacrol 8.0%, thymol 7.1%, germacrene 3.9%, (E)-β-farnesene, β-caryophyllene 3.5%, *alpha*-humulene 2.8%, sabinene 2.7%, linalool 2.6%, β-phellandrene 2.4% [75].

Olfactory Description: Odour of oregano, resembling “pizza”

Any Standards or Threats: N/A

Assessment of Potential: Oregano is and anti-oxidant and also has anti-microbial activity, which has some potential in the preservative area [76].

Plant Common Name: Pandan (also known as the screwpine)

Botanical Name: *Pandanus amaryllifolius/odorus*

Location and Climate Range: Grown throughout tropical Asia, Sri Lanka, Vietnam, Thailand, Malaysia and Indonesia, in full sun or part shade.

Natural Habitat: Normally low lying wet areas.

Description: *Pandanus amaryllifolius/odorus* grows between 1 and 2 metres tall. Its main trunk/stem is supported by aerial roots. The leaves are long and smooth with a lush green appearance, usually 40-60 cm long. The centre of the leaves are depressed in a "V" shape from the trunk/stem and gradually flatten out.

Ethno-botanical Use: Pandan leaves have been used in baths for women after childbirth, as a hairwash, as an infusion with oil to treat rheumatism, diabetes, as a purgative, in the treatment of leprosy and as a diuretic. Pandan leaves are also used to flavour rice, agar agar (jelly) and in drinks. Pandan leaves are also used to make potpourri *(bunga rampai)*, fragrant cars and keep away snakes from the house compound.

Economic and Potential Uses: As a potential flavour and fragrance material. In aromatherapy.

Part of the Plant Containing Oil: Leaves

Method of Extraction: Solvent or CO_2 extraction

Agronomy –

Propagation: Through the planting of suckers from the base of the plant or plantlets with aerial roots developed. The suckers and plantlets should be planted in moist soil.

Cultivation: Pandan is a water demanding crop and thrives in a humid environment.

Harvesting: Leaves and stems can be cut. Remaining plantlets will re-grow.

Known Production: No known commercial production. As a household compound plant, leaves are harvested as needed for cooking and medicinal purposes.

Chemical Constituents: The extract obtained through solvent extraction contains Octadecane 2.66%, Tetradecane 6.33%, Eicosane 3.8%, Heneicosane 11.2%, Octadecane 2.6%, Hexadecane 6.8%, Octacosane 7.46%, Undecane 3.5%, 3-methyl-5-propyl-hexadecane 4.0%, Tetradecane 4.0%, Hexadecanoic acid (palmitic) 23.104% and 1,4-cyclononadine 24.0% [77].

Olfactory Description: A smooth pleasant greenish honey-ambergris, musky, odour.

Any Standards or Threats: No standards, stability issues need investigation. Not on GRAS list.

Assessment of Potential: There is some potential in flavours, but the product can be reconstituted easily with the use of aroma chemicals. Pandan could be used as an infusion in aromatherapy.

Figure 12.10. *Pandanus amaryllifolius/odorus*

Plant Common Name: Pandanus

Botanical Name: *Pandanus odoratissimus*

Location and Climate Range: Found along the coastlines of tropical Asia, India, Australia and the Pacific Islands.

Natural Habitat: Near coastlines in sandy soils.

Description: This species can grow up to 20 metres tall and has long slender leaves growing out of the main stems. Its leaves are dark green with sharp edges and the stems have aerial roots growing from them, forming a buttress base. Male trees bear white fragrant flowers, while the female trees bear "pineapple" like fruits.

Ethno-botanical Use: Leaves used for weaving and thatching.

Economic and Potential Uses: Fragrance and aromatherapy

Part of the Plant Containing Oil: Flowers, also ripe fruits have an essential oil

Method of Extraction: Steam distillation

Agronomy –

Propagation: Rarely cultivated but from plantlets with some aerial root formation.

Cultivation: N/A

Harvesting: Would have to be wild harvested.

Known Production: Southern India

Chemical Constituents: Phenethyl methyl ether (pandanol) 38%, terpinen-4-ol 19%, alpha-terpineol 8%, and phenyl ethyl alcohol 7% [78].

Olfactory Description: Flowers are a delicate, but powerful, fruity, rosy warm floral type odour

Any Standards or Threats: Not known.

Assessment of Potential: Some oil in trade as kewra oil from India. May have some interest as a fine fragrance oil, although any production volumes would be very limited due to the difficulty of wild collection and develop cultivars. Kewra water, the distillate is sold as fragrant water for Indian cooking.

Figure 12.11. *Pandanus odoratissimus along The Coastline in Sabah, Malaysia.*

Plant Common Name: Perilla *(Shiso)*

Botanical Name: *Perilla frutescens*

Location and Climate Range: Mountainous areas of China, India, Japan, Vietnam and Korea, in temperate climates. Also in Russia, United States and South Africa.

Natural Habitat: Cool temperate climates but has adapted to warmer climates.

Description: An annual green leafed herb. The leaves are round and corrugated. Resembles the appearance of basil.

Ethno-botanical Use: For lung infections, influenza, seafood poisoning, incorrect energy balance [79].

Economic and Potential Uses: Used in flavours and in traces for fine perfumery, has some anti-inflammatory properties, and oxime of perillaldehyde, perillartin is used as an artificial sweetener [80].

Part of the Plant Containing Oil: Flowers and leaves around 0.2%

Method of Extraction: Steam distillation

Agronomy –

Propagation: By seed direct into the field.

Cultivation: Sown into open well drained fields.

Harvesting: Harvest when flower head shows, sun dry before distillation [81].

Known Production: China, Korea, Japan and Vietnam.

Chemical Constituents: Perillaldehyde 50-60%, limonene, caryophllene, farnesene. (Other chemotypes: perilla ketone, toxic to some animals, a citral chemotype rich in rosefuran, perillene chemotype and a number of other chemotypes).

Olfactory Description: A powerful oily odour, reminiscent of cumin

Any Standards or Threats: Perillaldehyde is irritant to the skin.

Assessment of Potential: A potential flavour oil and for aromatherapy use. Some interest reported for the rosefuran chemotype as a flavouring material [82]. Seeds also contain a fixed oil similar to tung or linseed oil, used in paints, varnish, ink and waterproof coatings.

Plant Common Name: American pepper, Peruvian peppertree

Botanical Name: *Schinus molle*

Location and Climate Range:

Natural Habitat: Native to the Peruvian Andean deserts.

Description: An evergreen tree that grows up to 15 metres high. It has a rough grey like bark which appears twisted. The upper branches of the tree droop with compound shaped leaves that are between 8-25 cm long and 4-10 cm wide. Males and female white flowers appear on separate trees in panicles at the end of drooping branches. It has a bright pink fruit approximately 5-7 mm in diameter in clusters, with woody seeds inside. The fruit starts green and turns to red.

Ethno-botanical Use: Used as an anti-depressant, diuretic, toothache remedy, rheumatism and menstrual disorders.

Economic and Potential Uses: Blended with commercial pepper for certain markets in the Western hemisphere. Used as a flavour in beverages. Used to treat wounds because of anti-bacterial properties [83].

Part of the Plant Containing Oil: fruit contains around 5% oil and leaves around 2% oil.

Method of Extraction: Distillation and CO_2 extraction

Agronomy –

Propagation: Through seed and suckers. Seeds require soaking before germination.

Cultivation: A quick growing and drought tolerant tree.

Harvesting: Fruits and leaves (all parts of the tree have an essential oil)

Known Production: Peru

Chemical Constituents: *alpha*-phellandrene 26.5%, limonene 21.0%, elemol 10.8%, *alpha*-eudesmol 6.1%, also *alpha*-pinene, *beta*-pinene, *beta*-phellandrene, camphene, *para*-cymene [84].

Olfactory Description: Spicy notes

Any Standards or Threats: On GRAS list, Use of limonene in cosmetics subject to EC Directive 76/768/EEC.

Assessment of Potential: As a flavour in confectionary and fragrance oil, cosmetic, aromatherapy and pharmaceutical use. As an agricultural anti-fungal [85].

Plant Common Name: Tea Tree (Australian)

Botanical Name: *Melaleuca alternifolia*

Location and Climate Range: The tree was thought to be a sub-tropical dweller, but was introduced into the tropics of Northern Queensland in the late 1980s, where it was found to grow much faster and generate much higher yields than the sub-tropical climate regions.

Natural Habitat: It grows wildly in swampy areas along the Northern and Southern coastal areas of New South Wales, Australia. The tree was introduced by the author into

Malaysia during 1991 [86], and it was introduced into other parts of South-East Asia later during the 1990s.

Description: *Melaleuca alternifolia* can grow to a height of 5 m in the wild. The green leaves are arranged in rosettes, with small linear leaf blades, approximately 3-4 mm long and 0.4-2.5 mm wide. The bark is stringy and papery.

Ethno-botanical Use: Used medicinally by the indigenous people of Australia for treatment of wounds.

Economic and Potential Uses: Tea tree oil is used primarily in cosmetics, aromatherapy and as a medicinal oil for burns, tinea, acne, sunburn, and other topical ailments.

Part of the Plant Containing Oil: Leaves up to 1.3% oil.

Method of Extraction: Steam distillation

Agronomy –

Propagation: Primarily through seed

Cultivation: Easy to maintain crop once established in the field. Can withstand long periods of drought, floods and even fire.

Harvesting: Usually harvested whole and mulched for ease of distillation. The tree re-grows with with added coppicing after the first harvest, creating more biomass and thus higher yields.

Known Production: China, Australia, Cambodia, Malaysia

Chemical Constituents: Tea tree oil contains a number of constituents including terpinen-4-ol, 1,8-cineole, caryophyllene, *para*-cymene, myrcene, *alpha*-cadinine, *alpha*-copaene, cymenene, *beta*-elmene, hexanol, humulene, limonene, linalool, nerol, *apha*-pinene, *alpha*-phellandrene, sabinene, *alpha*-terpinene, *gamma*-terpinene, *alpha*-terpineol, terpinolene, *alpha*-terpinolene, *alpha*-thujene, and veriflorene.

Olfactory Description: A potent cineole/terpineol odour, reminiscent of a medicinal odour,

Any Standards or Threats: Under investigation by the SCCP (EU) as a skin irritant.

Assessment of Potential: The collapse of many Australian tea tree producers in the late 1990s and early 2000-2002, made many users very weary about committing tea tree oil in their formulations, so much demand was eliminated. Production is now re-establishing itself in China, where production there is now more than in Australia. New markets in agro-fungicides are also developing which will increase demand once more for the oil, but not at the same price levels as was seen during the 1980s, although at the time of writing the price is high once more.

Figure 12.12. Tea Tree *(Melaleuca alternifolia)* Planted in 1993 Left for Seeding Purposes at the Author's Property in Perlis, Malaysia.

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