Floriculture

SE Newman, Colorado State University, Fort Collins, CO, USA

Abbreviations

AIFD	The American Institute of Floral Designers
ASOCOLFLORES	the Colombian Association of Flower Exporters
FLO	Fairtrade Labeling Organizations International
FLP	Flower Label Program
IPM	integrated pest management
MPS	Milieu Project Sierteelt
NASA	United States National Aeronautics and Space Administration
NFT	nutrient film technique
SCS	Scientific Certification Systems

The Floriculture Industry

Floriculture refers to the cultivation or farming of flowering and ornamental plants for gardening and floristry, including floral design. Floriculture crops are typically herbaceous differentiating them from nursery crops, which are typically woody. Floriculture crops include flowering plants, bedding and garden plants, foliage or house plants, fresh cut flowers, and cultivated greens (Figure 1(a)–(d)). Bedding and garden plants are typically grown in cell packs and marketed in flats or trays, pots, hanging baskets, or large mixed containers for the landscape. Bedding and garden plants may be either annual or perennial and are often vegetable or herb transplants.

Floriculture crops are typically grown in a controlled environment or greenhouse (i.e. glasshouse) however, many cut flowers may also be grown out-of-doors in many climates. Geraniums, grown from seed and cuttings, petunias, impatiens, and pansies represent the top three bedding plant species grown in the United States (Figure 2). Poinsettias, hardy and florist chrysanthemums, orchids, and spring flowering bulbs represent the top four flowering potted plants grown in the United States (Figure 3). Lilies, tulips, and gerbera daisies represent the top three cut flower species grown in the United States (Figure 4).

Flowering potted plants are largely sold in pots for indoor or patio use. Foliage plants are sold in pots and hanging baskets for indoor and patio use as well. Larger plants are grown for office, hotel, and restaurant interiorscapes.

Cut flowers are traditionally sold as arrangements, in bunches or bouquets. Cut foliage or greens are usually included. Cut flower production includes the farming flowers and foliage in greenhouses or field production. Postharvest handling also includes chemical treatments, storage, and preservation and packaging technologies.

In the United States, bedding plants have the highest wholesale value with large pots or containers at the greatest value, yet flats and trays capture the greatest volume (Figure 5). Flowering pot plants follows bedding plants in value, with foliage, and cut flowers capturing the least value for United States wholesale floriculture production.

A growth area for floriculture includes large containers and hanging baskets with multiple bedding plant species artistically planted. These containers are typically marketed fully established and in bloom providing instant color for patio plantings.

Global Scale of Floriculture

The consumption of floriculture products is typically limited to societies that enjoy discretionary income. 'Discretionary income' is the amount of an individual's or family's income available for spending after essentials, such as food, clothing, and shelter, have been accounted for. Countries where their citizens enjoy discretionary income are typically capitalistic societies with a high standard of living. Citizens from European countries spend more per capita than any other country, with Japan and the United States following (Figure 6). Of the European countries, the greatest per capita consumption remains in the Western countries, including Switzerland, Norway, the Netherlands, Denmark, and Germany.

Cut flower consumption in the United States historically lags behind Western Europe and Japan primarily due to the lack of a tradition of maintaining fresh flowers in the home. For many years, cut flower sales in the United States have been linked to holidays, celebrations, and funerals. Organizations such as the Society of American Florists have conducted several market programs designed to boost cut flower sales past the traditional birthday, Valentine's and Mother's Day, wedding, and sympathy sales.

Economic Impact of Floriculture

On a global scale, the market value of floriculture is more than €60.8 billion. The wholesale production of

Figure 1 (a) Poinsettia cultivar trial at Colorado State University (Fort Collins, Colorado). (b) Commercial production of poinsettias (Denver, Colorado). (c) Bench top production of Kalanchoe with New Guinea impatiens baskets hanging overhead in the foreground and ivy geranium hanging baskets to the rear (Aurora, Oregon). (d) Snapdragons grown for cut flowers (Denver, Colorado).

floriculture products in the United States is a major component of agriculture with a farm gate value of over €5 billion (Figure 7). The Netherlands and Japan are close behind. However, it is important to note that the majority of production in the United States is bedding and garden plants, where cut flower production is greater in other countries.

Cut flower production primarily occurs in developing countries (Figure 8). The countries leading in production are in Asia, primarily China and India; in Europe, primarily Italy, the Netherlands, the United Kingdom, Spain, Germany, and France; and in Central and South America, primarily Mexico, Brazil, and Colombia. African countries, primarily Kenya, Zimbabwe, and South Africa, are increasing in production shipping primarily to the Netherlands and the United Kingdom.

The production and export of floriculture crops from developing countries provides trade and currency. Cut flower exports from Colombia are second only to coffee. Cut flower production for export provides jobs, increases international trade, and, through regional trade associations, provides education, health and child care services, and social development. Investments in floriculture in developing countries can serve to decrease many social ills including poverty, terrorism, and illegal drug trafficking.

Floriculture Production

The production or farming of floriculture crops is an intensive form of agriculture. Floriculture requires many inputs including labor, energy, water, fertilizers, and pesticides. The degree of technology and automation employed to grow floriculture crops is dependent on the region of the world and availability of resources.

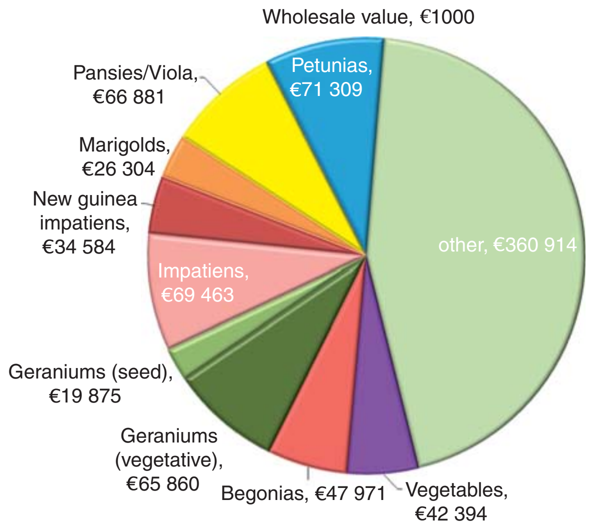

Figure 2 The wholesale value of bedding plant crops sold in the United States during 2007. (Agricultural Statistics Board (2008). Floriculture crops, 2007 summary. United States Department of Agriculture National Agricultural Statistics Service-Sp Cr 6-1 (08).)

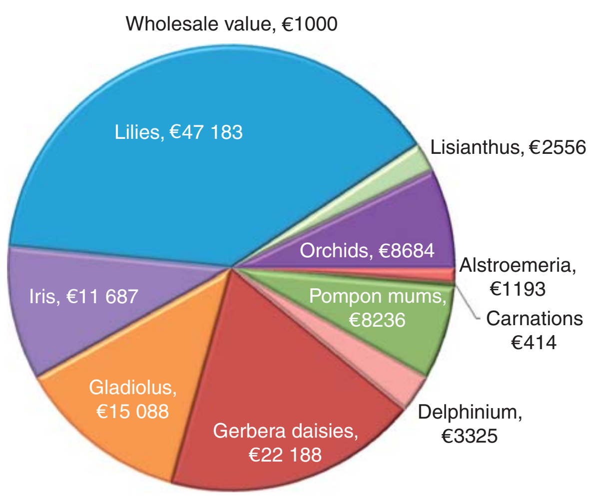

Figure 3 The wholesale value of cut flower crops sold in the United States during 2007. (Agricultural Statistics Board (2008). Floriculture crops, 2007 summary. United States Department of Agriculture National Agricultural Statistics Service-Sp Cr 6-1 (08).)

Labor

At the beginning of the twentieth century, the majority of the production of floriculture crops was located near urban centers. This was primarily due to the proximity to the market. However, the availability of manure, which was available from other farmers in proximity to cities, was also a factor. As the outskirts of urban communities grew, along with taxes, floriculture operations moved to less expensive land.

The geographic region where floriculture crops are now grown is not as important as it once was. Air transport of fresh cut flowers is a standard practice, thus allowing floriculture crops to be grown in regions that capitalize on the appropriate environment and ready access to labor.

Depending on the information source and region, labor tends to be approximately 25% of the cost of producing floriculture crops (Figure 9). The floriculture industry relies on inexpensive labor in most parts of the world. One of the critical factors in starting and maintaining a floriculture enterprise is the availability of year-round labor. In fact, it is critical to the success of a floriculture operation to have access to year-round labor from an agricultural base. Floriculture labor, as is much of agricultural labor, is often seasonal, hard, dirty, and perhaps dangerous where pesticides are involved. In many regions of the world, floriculture labor relies on a migrant labor force. This has been primarily due to the concept that indigenous workers do not want employment that is so insecure and exploitative. As local economies flourish, the local labor force in agricultural areas often shifts to service jobs that are less demanding. This movement leaves a void in the labor force, which is then filled by a migrant labor force.

Labor and energy expenses over the past 40 years have forced a considerable volume of floriculture crop production to locations in developing nations. In many developing countries of the world, a floriculture operation can employ more workers than the operations in developed countries. Along with reduced energy costs, these operations can grow floriculture crops at a fraction of the cost compared to operations in developed countries. For instance, Colombia now ships more than 74% of all cut flowers consumed in the United States.

In many parts of the world the pressures of migrant labor has become a major political issue. The United States Department of Labor has suggested that approximately 1.3 million citizens migrate between states working in agriculture. The future for many of these people is grim as they are typically poorly educated and often have limited access to health care. This is complicated by hard labor and exposure to chemicals.

Fair trade practices, an organized social movement capitalizing on a market-based approach to alleviate global poverty and promote sustainability, are becoming more widespread in agriculture. The concept advocates the payment of a fair price as well as social and environmental standards for the local labor force. Fair trade practices focus on exports from developing countries to developed countries. The primary agricultural exports involved include coffee, cocoa, sugar, tea, bananas, honey, cotton, wine, fresh fruit, and flowers.

Many developing countries through trade associations have taken a proactive stance toward protecting their

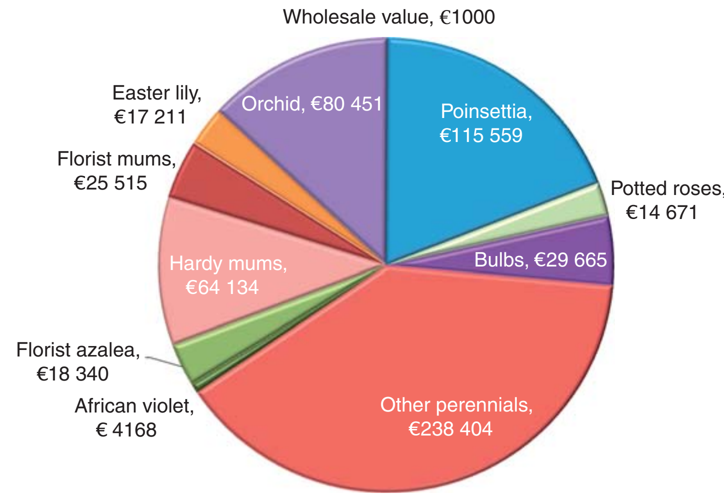

Figure 4 The wholesale value of flowering pot crops sold in the United States during 2007. (Agricultural Statistics Board (2008). Floriculture crops, 2007 summary. United States Department of Agriculture National Agricultural Statistics Service-Sp Cr 6-1 (08).)

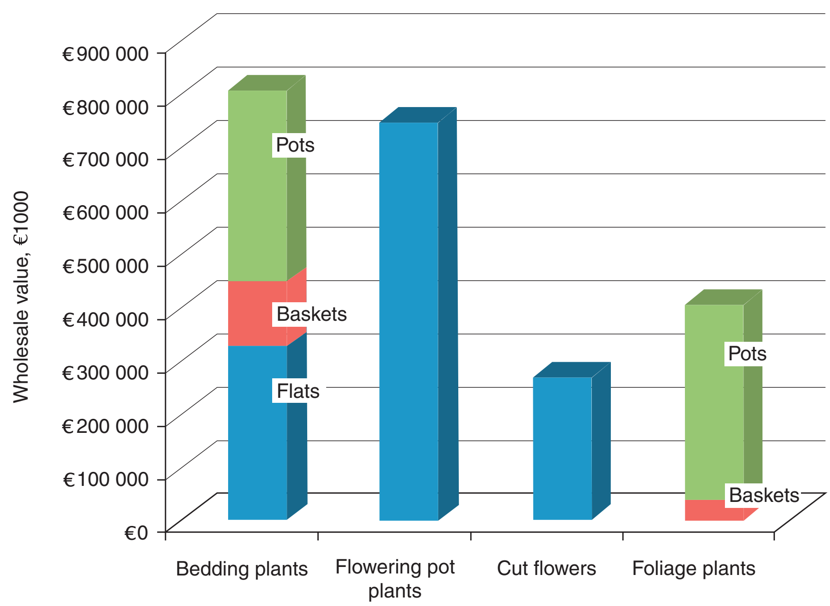

Figure 5 Summary of the wholesale value of floriculture crops sold in the United States during 2007. (Agricultural Statistics Board (2008). Floriculture crops, 2007 summary. United States Department of Agriculture National Agricultural Statistics Service-Sp Cr 6-1 (08).)

indigenous labor forces to guarantee fair trade practices. For instance, the Colombian Association of Flower Exporters (ASOCOLFLORES), which represents approximately 75% of the fresh cut flower imports into the United States, has adopted social development programs entitled. Cultivating Peace in the Family, The School of Floriculture, Flowers are Home, Child Care Centers, School Reinforcement, and Continued Education. These programs are designed to promote positive citizenship and sustainability of the industry.

Cultivating Peace in the Family is a professionally structured effort designed to teach floriculture workers and families to solve conflicts through nonviolent methods. It has demonstrated that the private sector can contribute to peaceful efforts in Colombia.

The School of Floriculture was established with partial funding from the USAID. Its purpose is to enable people displaced by violence to find work by providing training in cultivating, harvesting, grading, and packing of flowers. It consists of a 9-month theoretical course and 3-month hands-on work practice at the farms, after which participants can be employed permanently.

Flowers are Home assists farm workers to obtain housing loans or home improvement subsidies from government

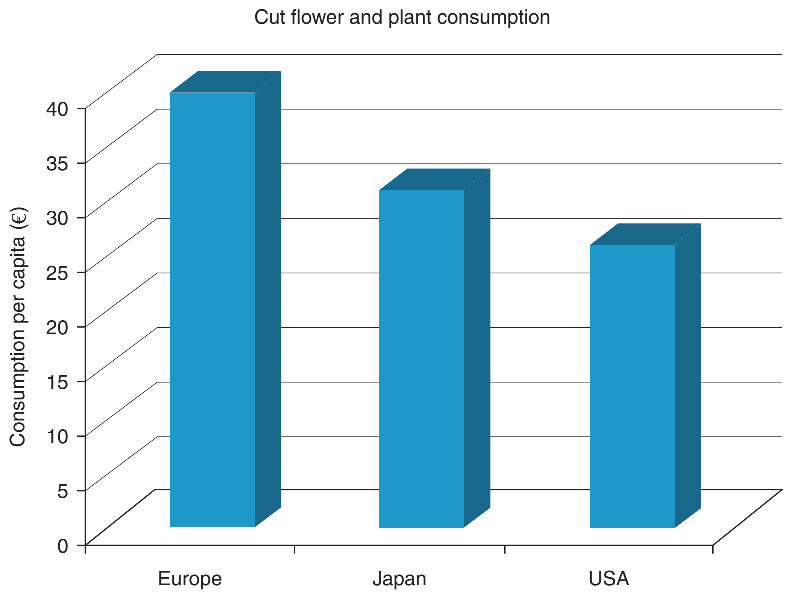

Figure 6 Top three countries that consume floriculture crops (AIPH (2004) Statistical yearbook. International Association of Horticultural Producers).

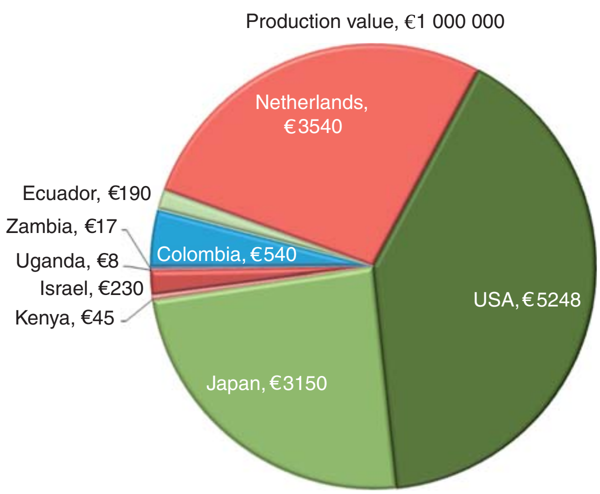

Figure 7 International value of floriculture crops (AIPH (2004). Statistical yearbook. International Association of Horticultural Producers).

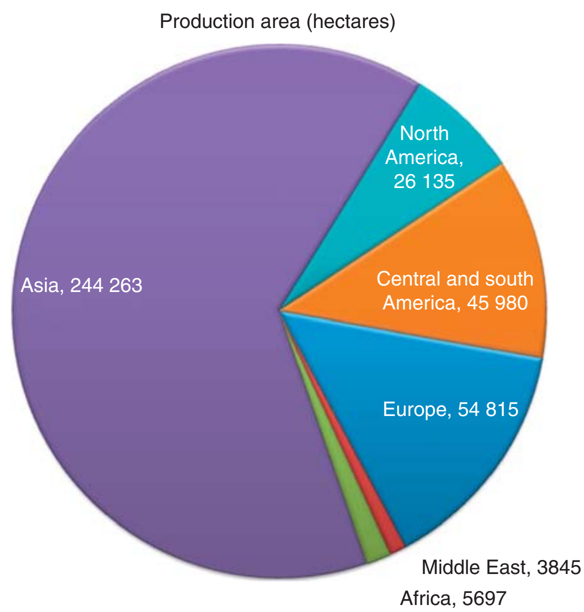

Figure 8 International floriculture production areas (AIPH (2004). Statistical yearbook. International Association of Horticultural Producers).

sources. Approximately 20 000 houses were projected to be built by 2009.

Child care centers are provided by many greenhouse enterprises. Approximately 20 000 children are being served while their parents work. Health and education services are also provided.

School reinforcement through ASCOLFLORES has provided more than 35 000 children benefit from oral health campaigns, and 13 500 children aged from 4 to12 receive school kits to complement their education.

Fairtrade Labeling Organizations International (FLO) is an organization that unites 20 international labeling initiatives to promote fair trading practices in 21 countries. These include producer countries in Latin America, Africa, and Asia. The FLO works to empower farmers and farm workers to lift themselves out of poverty by developing the business skills necessary to compete in the global marketplace. The practices include fair prices, fair labor conditions, direct trade, democratic and transparent organizations, community development, and environmental sustainability.

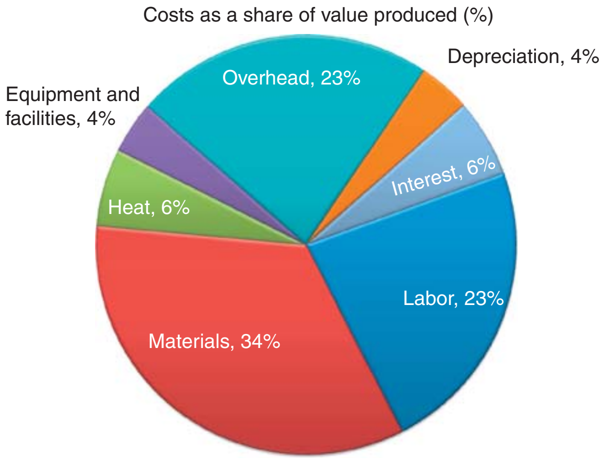

Figure 9 Costs of producing floriculture crops as a percentage of sales value in the United States (Uva, Wen-fei and Richards, S (2003). New York greenhouse business summary and financial analysis, EB 2003–12. Department of Applied Economics and Management, College of Agriculture and Life Sciences, Cornell University, Ithaca, New York, USA).

Automation

In many developed regions of the world, labor costs are high and migrant labor is not readily available. Therefore, to make floriculture production sustainable, mechanization and automation systems are in common practice. The development of automation systems is a result of increasing size of production facilities, specialization of crop production and the need for individualized plant treatment, increasing labor costs, increasing problems with the availability of skilled labor, health problems, product quality, and growing competition on the national and international market.

Greenhouse automation for growing floriculture crops is characterized as replacing humans or human activity in relatively simple tasks with a purely mechanical system. Robotic systems deal with more than one task, are reprogrammable, and are flexible with respect to the objects they have to handle. These systems are adaptable to the working environment using sensors and coded as 'intelligence.' Robotic systems serve to reduce labor costs, help to optimize greenhouse space, allow for more efficient centralized processing of the crop, improve working conditions, provide increased monitoring, grading, tracking, and tracing during the production process, and optimize product quality and worker safety. Some examples of robotic systems in use by the floriculture industry include seeding or sowing machines, rose cutting production for propagation, the sticking of unrooted cuttings, grafting, tissue culture robotics, transplanting machines, automated irrigation systems, mobile growing systems and internal transport, pesticide spraying, wiring plants to support wires, flower harvesting, and flower grading.

Energy

The energy balance for a typical greenhouse on an annual basis usage is approximately 75% for heating, 15% for electricity, and 10% for vehicles. Depending on the information source, the expense of energy to run a greenhouse in northern climates can be estimated at approximately 7–8% of the total sales revenue of an operation. Over the past 10 years, the price of natural gas has escalated considerably. At current US market values, it can be estimated that heating a greenhouse may cost as much as €13 m^{-2}, which ultimately increases the costs of production and reduces profitability.

Natural gas is the most common fuel source for heating greenhouses. Natural gas is extracted from wells. It is typically the most convenient being delivered through traditional utility services. No on-site storage is required and it is clean-burning, reducing maintenance on heating equipment.

Propane is a second choice to natural gas. It differs from natural gas, which is methane, and is sold in a liquefied form under pressure or liquid petroleum gas (LPG). Propane is typically used as a heat source in rural areas of the United States where natural gas is not available. It is delivered by truck and stored on site. Since propane is manufactured from crude oil rather than extracted from a well, its price fluctuates with the price of oil and its cost is approximately 1.5 times more than that of natural gas. Delivery and storage expenses may also increase this cost as well.

Fuel oils are similar to propane in that they must be delivered and stored on site. Many greenhouse operations have their boilers fitted to burn both natural gas and no. 2 fuel oil. When fitted as such, the manager has the option to heat with natural gas or oil depending on the market price. In addition, the greenhouse operation can purchase natural gas at a reduced rate with the option for interruption. Interruptible natural gas can occur when natural gas is in short supply. This may occur at times when a heavy heating load is predicted. The natural gas provider typically gives the greenhouse operation a lead time to switch to an alternative fuel for a period of time. This allows the provider more fuel reserves to service customers during heavy heating demands.

Fuel oils are also a common energy source for heating greenhouses. Depending on the market, fuel oils, including kerosene, no. 2, no. 4, and no. 6, are comparable in costs to natural gas. Fuel oils, like propane, must be delivered and stored at the greenhouse site. Boilers fitted to burn fuel oil require slightly more maintenance than those fitted to burn natural gas.

With the increase in prices for fossil fuels, alternative fuels are becoming more attractive for floriculture growers. Some alternative fuels for heating greenhouses include coal, wood and wood products, waste oil,

Table 1 Approximate heating value of common fuels (with conversions)

Natural Gas	1030 Btu ft^{-3}	100 000 Btu therm^{-1}	38.4 MJ m^{-3}
Propane	2500 Btu ft^{-3}	92 500 Btu therm^{-1}	93.1 MJ m^{-3}
Methane	1000 Btu ft^{-3}		37.3 MJ m^{-3}
Landfill gas	500 Btu ft^{-3}		18.6 MJ m^{-3}
Butane	3200 Btu ft^{-3}		119
Methanol		57 000 Btu gal^{-1}	15887 MJ m^{-3}
Ethanol		76 000 Btu gal^{-1}	21182 MJ m^{-3}
Fuel oil			
Kerosene	135 000 Btu gal^{-1}		37.6 MJ l^{-}1
No. 2	138 500 Btu gal^{-1}		38.6 MJ l^{-1}
No. 4	145 000 Btu gal^{-1}		40.4 MJ l^{-1}
No. 6	153 000 Btu gal^{-1}		42.6 MJ l^{-1}
Waste oil	125 000 Btu gal^{-1}		34.8 MJ l^{-1}
Biodiesel (waste vegetable oil)	120 000 Btu gal^{-1}		33.4 MJ l^{-1}
Wood			
Softwood	2–3000 lb cord^{-1}(250–375 kg m^{3})	10–15 000 000 Btu cord^{-1}	2900–4400 MJ MT^{-1}
Hardwood	4–5000 lb cord^{-1}(500–625 kg m^{-3})	18–24 000 000 Btu cord^{-1}	5240–7000 MJ MT^{-1}
Sawdust – green	10–13 lb ft^{-3}(160–208 kg m^{-3})	8–10 000 000 Btu ton^{-1}	9300–11 600 MJ MT^{-1}
Sawdust – kiln dry	8–10 lb ft^{-3} (128–160 kg m^{-3})	14–18 000 000 Btu ton^{-1}	16 300–21 000 MJ MT^{-1}
Chips – 45% moisture	10–30 lb ft^{-3}(160–480 kg m^{-3})	7 600 000 Btu ton^{-1}	8840 MJ MT^{-1}
Hogged	10–30 lb ft^{-3}(160–480 kg m^{-3})	16–20 000 000 Btu ton^{-1}	18 600–23 260 MJ MT^{-1}
Bark	10–20 lb ft^{-3} (160–320 kg m^{-3})	9–10 500 000 Btu ton^{-1}	10 500–12 200 MJ MT^{-1}
Wood pellets – 10% moisture	40–50 lb ft^{-3}(640–800 kg m^{-3})	16 000 000 Btu ton^{-1}	18 600 MJ MT^{-1}
Hard coal (anthracite)	13 000 Btu lb^{-1}	26 000 000 Btu ton^{-1}	30 200 MJ MT^{-1}
Soft coal (bituminous)	12 000 Btu lb^{-1}	24 000 000 Btu ton^{-1}	28 000 MJ MT^{-1}
Rubber – pelletized	16 000 Btu lb^{-1}	32 34 000 000 Btu ton^{-1}	37 200–40 000 MJ MT^{-1}
Plastic	18–20 000 Btu lb^{-1}		
Corn – shelled	7800–8500 Btu lb^{-1}	15 17 000 000 Btu ton^{-1}	17 450–20 000 MJ MT^{-1}
Corn – cobs	8000–8300 Btu lb^{-1}	16–17 000 000 Btu ton^{-1}	18 600–19 775 MJ MT^{-1}
Electricity	3412 Btu kW h^{-1}		1 MJ

Source: Bartok, Jr, John W. (2004). Approximate heating value of common fuels. http://www.hrt.msu.edu/Energy/pdf/Heating%20Value%20of%20Common%20Fuels.pdf (accessed 02 September 2008).

biodiesel, and electricity. For a more complete list see Table 1.

Coal continues to be used in certain parts of the United States where it is readily available and the existing infrastructure for delivery and storage is in place. There is some renewed interest in returning to coal as a fuel source for greenhouses with technology upgrades that reduce greenhouse gas emissions and provide automated stoker/feeder equipment.

Wood fuel has been used by many greenhouse growers for quite some time, but fossil fuel prices are reviving this interest even more than ever. Wood has several environmental advantages over fossil fuels including the fact that it is a renewable resource. As a renewable resource, it is a more sustainable and dependable supply. In addition, wood fired heating systems are considered to be carbon neutral in that the amount of carbon dioxide (CO_2) emitted during the burning is usually less than 90% of that given off by the burning of fossil fuels. Wood fuel has only minimal amounts of sulfur and heavy metals. Modern stack scrubber technologies make particulate emissions very controllable.

The primary economic advantage of using wood biomass as an energy source is that wood is significantly less expensive than fossil fuels. However, a greenhouse operation should evaluate the locally available supply of wood. The costs of transportation may reduce the benefit of using wood as fuel. Typically, hauling wood for fuel from more than 80 km is not economical. Yet, with automation and a ready supply, wood is a viable alternative to fossil fuel for greenhouse heat.

Alternative heating sources include geothermal, geothermal heat pumps, and solar energy. In regions where geothermal wells are available, greenhouses are an ideal candidate for using this resource. The water from these wells is typically at temperatures greater than 180°F, which typically is adequate for heating a greenhouse. Geothermal heat pumps or ground source heat pumps use water through closed-loop tubes to exchange heat with the ground. These systems are becoming more common for residential and commercial buildings. However, their use in greenhouses has not been widely explored.

All greenhouses by function are designed to be solar collectors. Solar greenhouses are designed to not just provide solar energy for photosynthesis, but also collect solar energy during sunny days and store that heat for use at night or during cloudy periods. Passive solar greenhouses are efficient for season extension and are used by small growers. Greenhouses that use active solar systems require supplemental energy to move solar heated air or water from collection panels to storage or collection areas and then to other regions of the greenhouse. At this point, solar electric or photovoltaic systems are not considered to be cost-effective for heating greenhouses. Yet, as this technology improves and the price of fossil fuels increases, photovoltaic heating systems may become cost-effective and attractive.

Water

Greenhouses require water for irrigation, cooling, pesticide application, root-zone media preparation, and cleanup. A typical greenhouse will use between 12 and $16\,l\,m^{-2}$ water per day. Therefore, a one-hectare greenhouse has the potential to use between 120 000 and 160 000 liters per day. The majority of this water is used for irrigation and its rate of use is dependent on the level of solar radiation, greenhouse shading, air movement in the greenhouse, types of plants grown, irrigation system design, and the degree of leaching employed.

Irrigation system design has the greatest impact on the volume of water used in a greenhouse. Irrigation water delivered by overhead sprinkler systems to spaced container-grown crops with heavy foliage is only approximately 20% effective. Boom irrigation systems provide uniform overhead irrigation when the bench is fully covered with flats or trays. All irrigation water applied with a drip system placed in each container reaches the root-zone medium. Ebb-and-flood systems, flood floors, and hydroponics provide the most uniform irrigation and conserve water by recycling and reusing the excess.

The quality of the water is just as important as the quantity of water available. Most greenhouses use either municipal or well water. Water that is low in soluble salts, especially sodium, is considered to be the best quality. Surface water sources from ponds, lakes, and irrigation canals may be contaminated with soil particles, plant debris, and algae, which must be filtered out. Poor-quality water can be treated using acid injection to remove carbonates, exchange resins or reverse osmosis to remove salts, filtration to remove debris, and disinfection to remove disease organisms.

Water discharge from greenhouses in the United States is typically not regulated, yet in many parts of Europe, water discharge regulation is becoming more common. Where discharge permits are required, the greenhouse operation is typically required to retain all irrigation runoff, retain all or part of storm runoff, dispose of irrigation runoff, prevent any pesticides from being discharged, maintain nitrate-nitrogen and ammonium-nitrogen discharge to less than 2 ppm, maintain the pH of the discharge water between 6 and 9, and maintain an acceptable level of suspended solids.

In states where water discharge is not regulated, best management practices are expected. Best management practices in a greenhouse usually include runoff minimization, efficient irrigation system design, reduction in overwatering, integrated pest management using less pesticide application, fertility optimization, reduction in storm runoff by diversion and storage for irrigation, and proper disposal of greenhouse runoff through treating and recycling runoff and reverse osmosis.

Fertilizers

Commercial floriculture production uses root-zone media that usually contain little or no fertilizer. Most crops are grown in small volumes of soil, such as 15 cm deep benches, pots, and market packs. The limited amount of medium used does not retain water and nutrients well. Therefore, fertilizers are applied to crops on a regular schedule using injectors integrated with the irrigation system. When fertilizers are injected with each irrigation, less material is used than when plants are fertilized every 2 weeks or monthly.

Complete fertilizers are necessary for successful production of floriculture crops. Root-zone media that are common for floriculture crops often provide little or no nutrient value. To provide adequate nutrition, root-zone media are supplemented with products that provide more than the conventional macro elements, nitrogen, phosphorus, and potassium. Some of these products blended into media include dolomitic limestone, which provides calcium and magnesium as well as pH modification, super phosphate, and micronutrient mixes.

Commercially prepared fertilizer blends designed for floriculture crops are available from many manufacturers. They are typically designed for specific crop types or production conditions. These products typically provide a blend of products that provide adequate levels of primary macro elements, including nitrogen, phosphorus, and potassium; secondary macro elements, including calcium, sulfur, and magnesium, as well as all microelements. Most floriculture crops grow best with a ratio of 2:1:2 from nitrogen (N), phosphate (P_2O_5), and potash (K_2O). In addition, most floriculture crops grow best where the nitrogen provided is 60% or more in the nitrate-N form. Because floriculture crops are grown with a small volume of root-zone medium with a relatively low cation exchange capacity, ammonium uptake stimulates the release of a hydrogen ion from the root, which in turn drives the pH of the medium down.

Many floriculture crop growers use single-element fertilizer materials to customize their fertility program to the needs of the crop and greenhouse conditions. Customized fertilizer blends that target plant needs are more efficient and prevent waste.

Sub-irrigation systems such as ebb-and-flood, flood floors, and capillary mats provide uniform irrigation and conserve water by recycling and reusing excess water (**Figure 10**). These systems are also effective in conserving fertilizer waste. Floriculture crop growers that use subirrigation systems use fertility levels at one-half of that used by conventional irrigation/fertility systems, and since the fertilizers are recycled, little or none is wasted, thus preventing potential pollution from runoff.

Cut flower crops are typically grown in greenhouses in permanent structures including ground beds, raised beds, and benches. Hydroponic systems are also in common use for cut flower production. Hydroponic culture refers to plant growth without soil and is a method of growing plants using a complete nutrient solution replacing the root-zone media. A variety of systems are in use, including solution culture, nutrient film technique (NFT), and slab culture.

Solution culture uses no solid root-zone medium, but provides a nutrient solution designed to provide all necessary elements for plant growth. Plants are supported by netting and staking, ensuring straight stems. NFT uses a narrow trough where a solution is circulated bathing the roots with nutrients (**Figure 11(a)** and **(b)**). Its primary advantage over solution culture is reduced volume of solution as well as increased oxygenation of the roots. Hydroponic slab culture uses media such as rock wool, glass wool, and coconut coir fiber to support plant root systems. Nutrient solutions are then provided to the plants on a regular basis.

Pest Management

Many pesticides traditional to the floriculture industry have been eliminated from the market due to loss of registration or due to regulatory pressures to reduce the environmental impact from organophosphate and carbamate insecticides. One such product that has recently not received a re-registration for floriculture in the United States is chlorpyrifos. The loss of this effective insecticide has left a marked void in the pesticide arsenal for a floriculture grower and there are many other products that will not be re-registered in the future.

Consumers of floriculture products maintain high standards of quality. Pest and disease damage on ornamental products is not tolerated by consumers, which often requires a sizeable investment in pesticide applications. To maintain profitability, floriculture growers are relying on softer, more environmentally friendly pesticides, integrated pest management (IPM), and beneficial organisms to manage pests and diseases.

Integrated pest management or IPM in a greenhouse includes pest prevention, sanitation and exclusion, management of the greenhouse environment, monitoring of the greenhouse crop, mechanical control, environmental control, cultural control, biological control, and chemical control. With increased environmental pressures, IPM practices are becoming widespread in the floriculture industry. A brief description of common IPM practices used by greenhouse growers follows.

Figure 10 Ebb and flood floor greenhouse production of geraniums grown in large containers (Larkspur, Colorado).

(a)

(b)

Figure 11 (a) Gerbera daisy cut flower production in nutrient film technique (NFT) troughs (Encinitas, California). (b) The root system of Gerbera daisy cut flower production in nutrient film technique (NFT) troughs (Encinitas, California).

Pest prevention in the greenhouse includes advanced planning of the crop to be grown and IPM programs, the practice of good sanitation and pest exclusion methods, the proper management of the greenhouse environment and other cultural practices, and the monitoring or scouting, which refers to regular, systematic inspection of crops and growing areas.

Sanitation involves clean practices in the greenhouse. Clean practices include eliminating weed infestations inside and outside the greenhouse. Reducing pest entry through exclusion is a good management strategy. Checking and quarantining plants that are being brought into the greenhouse for pest infestations is important. It is best to isolate and quarantine any new plants to determine if an insect or disease is being transmitted.

Exclusion methods include screening vents, doorways, and other openings, inspecting newly introduced plants or plant shipments, using pest-free stock, controlling weeds, removing crop debris, promptly removing infested plants or plant parts, and maintaining the growing area as pest-free as possible. Keeping the greenhouse pest free before planting is the most effective and least expensive pest control strategy one can employ.

Management of the greenhouse environment includes preventing plant stress. Plants under stress are predisposed to pest infestations. Drastic temperature fluctuations as well as excessive wet and dry cycling will predispose the plants to damage. The use of proper environmental controls, heating, cooling and lighting, and proper cultural practices, fertility, and irrigation, will favor high-quality crop production and discourage potential pest and disease problems.

Monitoring the greenhouse crops is a strategy to detect any pest or disease outbreaks early and at a time when they are easy to manage. Once a pest infestation becomes widespread, the crop may be severely damaged and the management options become limited. Many refer to monitoring as scouting. Scouting is the regular, systematic inspection of crops and growing areas.

Mechanical pest control in a greenhouse implies the use of labor and equipment to reduce pest populations directly. Mechanical control may be as simple as removing infested plants. Other typical mechanical control activities include hand-pulling and mulch application. Installation of screens and sticky barriers are other examples of mechanical control.

Modification of the greenhouse environment by manipulation of temperature, light, and humidity is an effective means to control pests and prevent damage. Heating greenhouse media through solarization, steam pasteurization, or proper composting controls most soilborne pests. Altering humidity and temperature by increasing ventilation, by increasing heat, or through modification of irrigation practices, for example, switching from sprinkler to drip, can reduce many foliar pathogens.

Cultural control measures to prevent pest outbreaks include choosing crop species or cultivars that are less susceptible to infestations than others, rotation of crops from susceptible to not susceptible, altering planting times, and adjusting the duration and frequency of irrigation intervals. Also, cultural control includes fertility. Too much fertility or incorrect fertilizer choice may result in succulent growth that favors high populations of insect pests, such as aphids.

Beneficial organisms can be used in a greenhouse to reduce pest populations. Biological control methods to be effective must be integrated with other methods, such as exclusion and sanitation. Pesticides are rarely used unless they are compatible with the pest's natural enemies. A low-level pest population must be present for a successful biological control program. Living organisms that can be used to reduce pest populations include predators, parasites, and pathogens.

Chemical control implies the use of a pesticide. The United States Environmental Protection Agency defines a pesticide as any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest. Pesticides are often misunderstood to refer only to insecticides, but the term pesticide also applies to herbicides, fungicides, and various other substances used to control pests. Some pesticides are considered to be organic. Organic pesticides are those that come from natural sources. These natural sources can be plants, fungi, bacteria, or similar by-products. Examples include pyrethrum, spinosad, and minerals, such as boric acid, cryolite, and diatomaceous earth.

Sustainable Practices

Sustainable practices, to date, have not been a major factor in the US floriculture industry. Sustainable agriculture integrates environmental stewardship and farm profitability to provide for prosperous farming communities. These practices are easily adapted to the floriculture industry and this integration is advancing today. VeriFlora is a certification program established to provide sustainable performance standards for growers and handlers of floriculture crops. The VeriFlora program establishes criteria in the following areas.

Environmental sustainability of production practices includes controlling pests and diseases with the least environmental impact, building soil fertility and health to support the ecosystem, preventing erosion, capturing and storing carbon from the atmosphere, and phasing in organic practices over time. Environmental sustainability includes resource conservation and energy efficiency, conservation of natural resources through efficient water use and quality control practices, energy-saving initiatives, greenhouse gas reduction efforts, and product packaging minimization.

Sustainable practices also include ecosystem protection and the protection of wildlife and habitat in and around floriculture farms and integrated waste management. This is to ensure safe storage and proper handling and disposal of farm chemicals and the encouragement to compost or recycling of agricultural and nonagricultural wastes.

Social and economic sustainability through fair labor practices that ensure a safe, equitable, and healthy work environment guarantees the right to organize, and provides access to key services as needed. Included are programs that support local communities through preferential purchasing, hiring, infrastructure improvements, and collaborative problem solving.

Product integrity, product safety, and product quality through quality assurance and product tracking procedures ensures that sustainably grown products are properly handled from the time they leave the farm until they reach the consumer, for maximum freshness and longevity.

Scientific Certification Systems (SCS), an independent third-party verification company that provides sustainable agriculture, fisheries, and forestry standards, is the organization that provides VeriFlora certification.

Other international programs that seek to ensure sustainable practices certification as well as fair trade practices include the Milieu Project Sierteelt (MPS) from Holland, the Flower Label Program (FLP) based in Germany, and Florverde created by ASOCOLFLORES in Colombia.

Floriculture Consumption

Floristry

According to the Society of American Florists, there are 22 753 retail florists, 21 783 supermarkets, and 16 432 plant nurseries and garden centers that sell flowers and plants in the United States. This places the retail floriculture industry at a value of €12.8 billion in 2007. Yet, as stated earlier, cut flower consumption in the United States historically lags behind Western Europe and Japan. In the United States, €26 is spent per capita compared to €40 in Europe.

Cut flower sales in the United States are linked to holidays, celebrations, and funerals. Christmas and Chanukah, Mother's Day, and Valentine's Day are the top three calendar sales occasions for purchasing flowers and plants in the United States (Figure 12). Of those, 79% are for women and 63% are purchases for personal use; however, 67% of fresh flower purchases are for gifts. Cut flower purchases in Europe tend to be more consistently for personal use on a daily basis, year round.

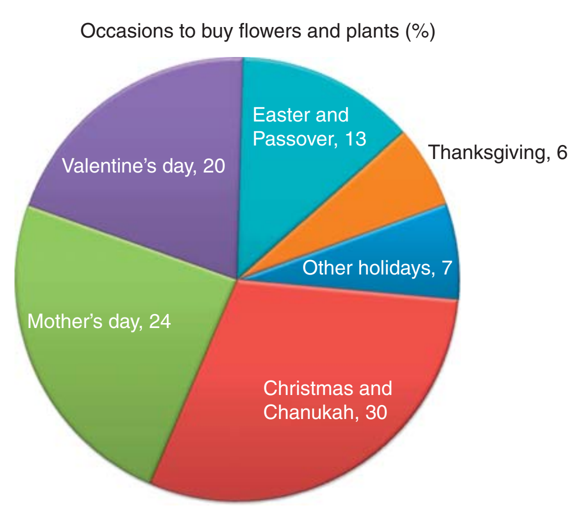

Figure 12 Consumer purchases of flowers and plants for US holidays at all outlets (Society of American Florists and IPSOS-Insight Floral Trends Consumer *Tracking* Study, 2005).

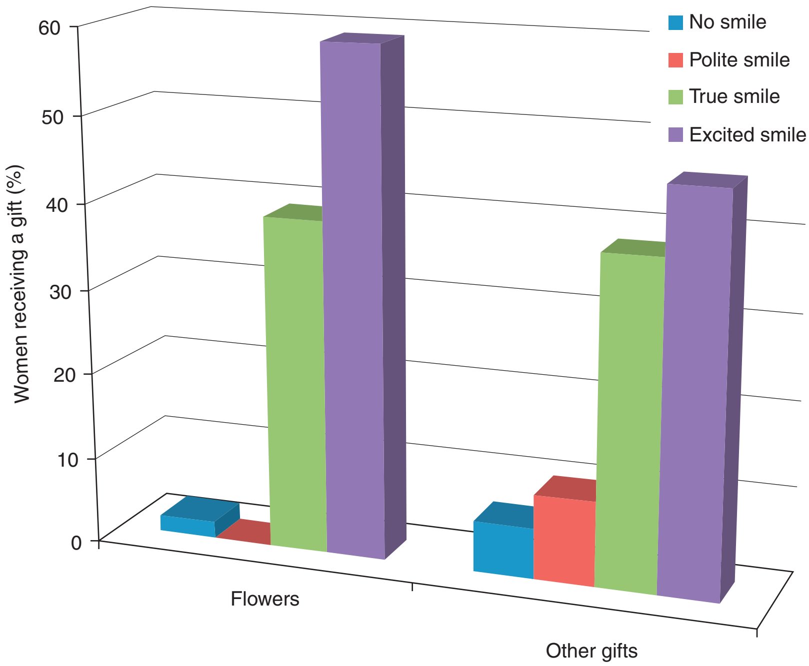

Figure 13 Personal responses by women when receiving the gift of flowers or another gift in the United States (Society of American Florists and Rutgers University, 2000).

Floral design is a satisfying career. Floral designers include men and women with various aspirations and talents. They will work in or own retail florists or may work independently as freelance designers. The American Institute of Floral Designers (AIFD) is committed to establishing and maintaining higher standards in professional floral design. Working with its membership, AIFD maintains excellence in the industry through educational and design programs.

Impact of Flowers

Floriculture crops are credited to be a special gift to one another. In fact, research conducted by Rutgers University and the Society of American Florists indicated that the gift of flowers tends to stimulate a truly excited smile compared to other gifts (Figure 13). In addition, fresh flowers have been demonstrated to improve conditions in the workplace. Research has been shown to stimulate innovative thinking. Research conducted by Texas A&M University with the Society of American Florists indicated that men generate 30% more ideas when working in environments with flowers and plants and their fluency increases 15% (Figure 14). An abstract sculpture on the desk increases fluency as well whereas no embellishments in the workplace reduce fluency.

Work conducted by the United States National Aeronautics and Space Administration (NASA) for Skylab during the late 1980s and early 1990s demonstrated that interior plants in the home or office have the capacity to purify the air of many interior toxins including formaldehyde, benzene, and trichloroethylene. Introducing plants into the interior environment serves to reduce a condition known as the sick building syndrome. The sick building syndrome is found in buildings where toxins emitted from synthetic materials become concentrated inside sealed buildings, making people sick. Interior plants have the capacity to alleviate this problem.

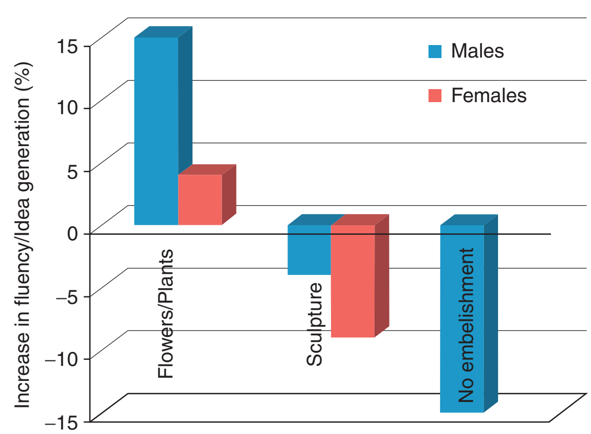

Figure 14 Increases in work-related fluency/idea generation when flowers and plants are included in the work environment in the United States (Society of American Florists and Texas A&M University, 2003).

See also: Colombia: Environmental Health Issues, Fertilizers, Irrigation Strategies for Sustainable

Environmental and Influence on Human Health, Pesticides: Human Health Effects, Sick Building Syndrome.

Further Reading

Boodley JW and Newman SE (2009) *The Commercial Greenhouse*, 3rd edn. Clifton Park, NY: Delmar, Cengage Learning.
Dole JM and Wilkins HF (2005) *Floriculture: Principles and Species*, 2nd edn. Upper Saddle River, NJ: Pearson Education, Inc.
Hanan JJ (1998) *Greenhouses: Advanced Technology for Protected Horticulture*. Boca Raton, FL: CRC Press.
Jerardo A (2004) Floriculture and Nursery Crops Outlook (flo-003). United States Department of Agriculture – Economic Research Service, Washington, District of Columbia, USA.
Nelson PV (2003) *Greenhouse Operation and Management*, 6th edn. Upper Saddle River, NJ: Pearson Education, Inc.
Wijnands J (2005). Sustainable international networks in the flower industry: Bridging empirical findings and theoretical approaches. Scripta Horticulturae, Number 2. The Hague: International Society for Horticultural Science.
Wolverton WC (1985) Foliage plants for removing air pollutants from energy-efficient buildings. United States National Aeronautics and Space Administration, National Space Technology Laboratories. Indoor Air Quality Committee, Washington, District of Columbia, USA.

Relevant Websites

http://www.asocolflores.org/
Association of Colombian Flower Exporters.
http://ellisonchair.tamu.edu/
Ellison Chair in International Horticulture.
http://www.aiph.org
International Association of Horticultural Producers.
http://www.bulb.com/
International Flower Bulb Centre.
http://www.safnow.org/
Society of American Florists.