Australian Government

Australian Centre for International Agricultural Research

Final report

project

Domestication and commercialisation of *Canarium indicum* in Papua New Guinea

project number	FST/2004/055
date published	July 2012
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final report number	FR2012-21
ISBN	978 1 921962 91 2
published by	ACIAR GPO Box 1571 Canberra ACT 2601 Australia

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1 Executive summary

Over the last decade, the problems of long-term decline and acute pest problems affecting PNG's traditional lowland agricultural export crops (cocoa, coconut) have highlighted the urgency of identifying options for diversification. *Canarium indicum* (galip), a nut-producing tree species native to the lowlands of Papua New Guinea, the Solomon Islands, and Vanuatu, has long been considered to be one such option. This is due largely to the nut's distinctive properties, particularly its soft texture, which distinguishes it from all the major internationally traded nuts. In addition, galip-nut is nutritious, well known locally, and non-perishable after basic processing.

An ACIAR-financed feasibility study (FST/2002/010) confirmed the potential of galip-nut (strong demand domestically and, potentially, overseas; high potential for cultivar development), but also found that supply-side issues of quantity and quality were limiting factors for its development. The present project was designed to respond to these opportunities and constraints through an integrated domestication and commercialization approach, addressing problems of inherent quality and uniformity (domestication) and efficiency of supply (commercialization and marketing). Within these two broad themes, the project has worked within three major research and development areas : genetic resource exploration, characterization and conservation; development and application of vegetative propagation techniques; market research. These were aimed at the following research objectives: (i) Prospect, characterise, select and multiply individual trees in PNG that have superior commercial traits for cultivar development and field tests; (ii) Improve market prospects for these products in PNG, Solomon Islands and Vanuatu (iii) Deliver selected cultivars and training to the participating communities; (iv) Disseminate information to stimulate adoption.

The project's work in these areas has yielded important results: (a) observations made on thousands of samples collected from trees in five different provinces have established that variation in commercial traits such as kernel:nut mass ratio is concentrated at the tree-within-location level rather than between locations-within-province or between provinces; (b) the genetic base of the species has been made more secure through the establishment of gene banks containing hundreds of accessions from different origins; (c) efficient methods of vegetative propagation by cuttings have been developed—a major advance given that, hitherto, the species has been considered difficult to propagate; (d) project staff have developed effective techniques for marcotting on mature trees; (e) the potential of the domestic market and options to exploit it have been identified.

The project, with other *Canarium* R+D work financed by ACIAR and the European Union, has helped lay the base for a major new export industry centred on East New Britain (ENB) province, with significant impacts. Farmers would expect annual net cash income of around PGK 1000 per hectare (around AU$ 450 at current exchange rates) from galip plantations, a large amount for low-income producers. Scaled-up over a projected ENB planted resource of 25,000ha, this translates to a multi-milion dollar industry benefiting farmers, processors and their employees. The expansion of galip-nut cultivation should also to lead to increased local consumption, with beneficial effects on health, nutrition, and vulnerability to climatic extremes. In addition, the project has had important short-term impacts. The improved vegetative propagation techniques have already been used in multiplication of germplasm for galip planting programs, and project staff and villagers have gained new skills in these and other components of tree domestication.

We make two key recommendations. Both are fundamental to successful future development of the industry and to the maximization of the impacts of the project, and both build on the results decribed above. Neither appears to have been taken into account in current initiatives. First, studies are urgently needed of the genetics of the seed sources now being used to establish the planted resource in ENB; current efforts are based largely on one seed source of largely unknown genetic characteristics. This constitutes a risk to

the industry. Second, further work on vegetative propagation is needed, as the difficulty of propagating mature material remains a key obstacle to cultivar development. Most of the necessary research investment could be made over a 3-5 year period, but the recommendations need to be implemented in the short- to medium-term, as the lead-time to impact of some of the associated activities is of the order of 10-15 years.

2 Background

2.1 Introduction

The broad context of the project lies in the PNG government priorities of food security and export-driven growth, coupled with the need to diversify smallholder livelihoods and concerns over the socioeconomic consequences of ongoing decline of PNG's two main lowland export crops (coconut, cocoa). The development of a *C. indicum* (galip) industry was identified as one response to these concerns. This proposal was further explored in an ACIAR-financed feasibility study (FST/2002/010), which confirmed the potential of *C. indicum*. The constraints and opportunities identified in the feasibility study informed the specific objectives of the project. All these considerations are described in more detail below.

2.2 General context

The PNG Government (Medium Term Development Strategy 2005-10) and NARI/ACIAR/ACNARS (2002 Provincial Consultations) identified food and nutritional security and export-driven economic growth of rural industries as high priority for research and development. At the same time, a Horticulture Industry Sector Study (McGregor 2003[1]) (commissioned by the PNG Department of Agriculture and Livestock as part of the Government's Export-Driven Economic Recovery and Development Strategy and funded by the Secretariat of the Pacific Community (SPC)) concluded that tree nuts offer probably the best export market prospects of any horticultural product from PNG, and that the biggest constraint to expanding formal market sales is the lack of consistency in supply, in terms of quality and volume. These concerns and findings were reflected in the ACIAR 2005-2006 Annual Operational Plan, which included two relevant forestry priorities: domestication and improvement of multiple-use, fast-growing indigenous tree species for smallholders and plantation development, and development of lesser-known non-timber forest products for communities (including fruits, nuts, fodder, oils and resins).

These diversifying strategies reflect problems as well as opportunities; by the time of the feasibility study, the need for diversification was already becoming urgent, as the widespread coconut/copra industry had been in decline for a number of years. Since 2006, copra prices have risen[2]. However, the overall situation has worsened due to the incursion in 2006 of the cocoa pod borer (*Conopomorpha cramerella*: Gracillariidae) which has had a major effect on the industry in East New Britain (Figure 1). As cocoa is generally grown under coconut shade, decline of the copra industry, and consequent senescence and lack of replanting of coconut trees, also affects the cocoa industry.

2.3 Feasibility study

C. indicum (galip) is one of several Papua New Guinean tree species that produce nutritious nuts. Galip-nut has long been considered to be a product of particularly high potential. In large measure, this potential is seen to be a product of the nut's distinctive properties, particularly its soft texture, which distinguishes it from all the major internationally traded nuts. In recognition of this potential, from 2003-2006 James Cook University (JCU) and the PNG National Agricultural Research Institute (NARI)

[1] *cited in the FST 2004/055 Project Document*

[2] *To a 30-year high in 2011; since fallen back but still well above the 30-year mean (http://www.indexmundi.com/)*

Figure 1. Impact of the cocoa pod borer in East New Britain province, PNG. Left to right: PNG Growers' Association Alert, 2006; national newspaper article, 2007; abandoned cocoa plantation, 2010; farmer sowing peanut in cleared cocoa plantation area, 2010. Photos: Jonathan Cornelius.

co-implemented an ACIAR-financed feasibility study on domestication and commercialization (ACIAR Project FST/2002/010). The immediate background to the current project is in the findings of this feasibility study. These can be categorized as either opportunities (potential) or constraints, and are summarized below.

2.3.1 The potential

High current and potential demand

All (i.e. 100%) of rural people surveyed in the feasibility study used galip-nut as a food, and 80% of respondents reported that they would like to eat more. The annual value of the domestic market was estimated at AUD 100 million (based on consumption of 4000 MT yr^{-1}, i.e. 2 million people each eating 2kg yr^{-1}). In general, the project found great enthusiasm among producers, traders and tourist outlets around the region. The results of preliminary niche markets surveys in Australia (restaurants, nut processors, food manufacturers) were positive: all respondents said they would consider *Canarium* kernels as a potential nut ingredient in new products (Bunt and Leakey 2008).

An already established product

An expanded market could build on current traditional use, current supply base (semi-wild trees around villages, wild trees), existing markets, and recognized livelihood benefits. Galip is not a new crop to farmers, and its wider cultivation would have benefits independent of the success of potential export markets.

High phenotypic variation

There is high between- and within-population phenotypic (and, by implication, genetic) variation in key morphological and nutritional traits (Leakey et al. 2008), indicating high potential for genetic improvement.

Compatibility with cocoa

Galip is a valuable and high quality timber (indeed, it is in threat because of this: over 50% of the superior *Canarium* trees identified by NARI in 1990 had been logged for timber by 2003), and it can be grown as a shade-tree in cocoa plantations.

2.3.2 Constraints

Supply: quantity

Consumers of different types reported difficulty in securing galip-nut in the quantities required or desired. Eighty percent of rural consumers surveyed in East New Britain would have liked to consume more galip than they were able to, and a high proportion of respondents (41%) across all locations—particularly in urban locations such as Port Moresby— reported that they had difficulty in buying kernels, even during the main production season. Similar problems were also reported in Solomon Islands and Vanuatu (Bunt and Leakey 2008).

Supply: quality

In East New Britain, over half of survey respondents said they have encountered quality problems with the kernels they bought, e.g. rotten, stale, or over-dried kernels (Nevenimo et al. 2008). The inherent variability mentioned above also poses problems for a potential export industry.

Both aspects of the supply-side problems reflect the nature of the resource, i.e. essentially wild and undomesticated, leading to variable kernel quality and lack of product uniformity, variable and unpredictable supply due to the small size of the resource and its irregular production cycle (seasonality), ad hoc harvesting and processing, and informal marketing. The Horticulture Sector study previously mentioned also cited the biggest constraint to expanding formal market sales to be the lack of consistency in supply, in terms of quality and volume.

2.4 Project approach: key issues and justification

The project was designed to respond to the key issue of supply-side problems through an integrated domestication and commercialization approach, that is by addressing problems of inherent quality and uniformity (domestication) and efficiency of supply (commercialization).

The project has worked within three major research and development areas within the broad themes of domestication and commercialization. These were:

- genetic resource exploration, characterization and conservation;
- development and application of vegetative propagation techniques;
- market research.

Three three areas are complementary: vegetative propagation is the quickest and most effective means of developing superior germplasm, but can only fulfil its potential if information on patterns of genetic variation—particularly, at which geograchic scale variation is concentrated—is available. Similarly, market information should, amongst other functions, inform decisions on selection criteria.

2.5 Related projects

FST 2004/055 forms part of a suite of related projects. Specifically:

- The EU-financed PNG Nut Development Project, coordinated by NARI (2006-2009), included distribution of 42,000 galip seedlings to both village farmers and larger plantation enterprises.

- The ACIAR-funded project “Processing of *Canarium indicum* nuts: adapting and refining techniques to benefit farmers in the South Pacific” (FST 2006/048), aimed at the development of post-harvest handling and processing techniques that optimise quality, while being appropriate for small-scale agriculture.

3 Objectives

The project aim was to overcome the supply-side constraints hindering the development of the galip-nut industry in Papua New Guinea, thereby contributing to improvement of food security and enhancement of economic growth.

This aim was to be achieved through fulfilment of four specific objectives (Figure 2).

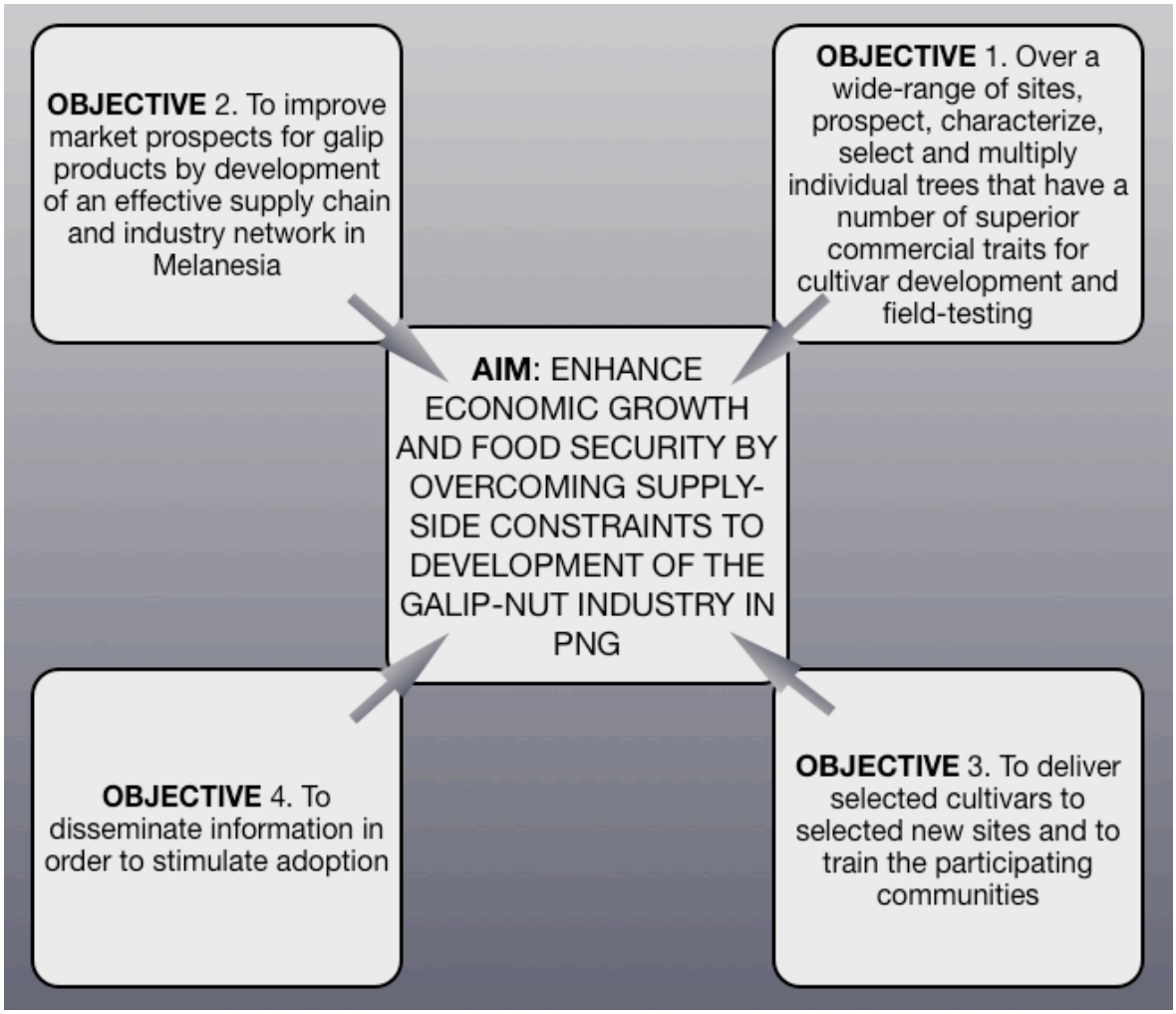

Figure 2. Aim and objectives of Project FST 2004/055

Essentially, the approach was a dual one of development of germplasm and propagation techniques (Objectives 1 and 3), coupled with improvement of market prospects (Objective 2), both complemented by supporting capacity-building activities (Objectives 3 and 4).

4 Methodology

The project has worked within three major research and development areas within the broad themes of domestication and commercialization. These were:

- genetic resource exploration, characterization and conservation;
- development and application of vegetative propagation techniques;
- market research.

The concentration on and emphasis of work within these areas reflects both initial plans and adaptive modifications during project implementation. These aimed at maximizing the potential of the methodology, the activities, and project resources (particularly project personnel) to contribute to meeting the specific objectives and aim, whilst responding to the evolving needs of the overall galip-nut industry development effort. Specific modifications to our approach are described below in the description of methodology (4.1.4, 4.1.5, 4.3).

4.1 Genetic resource exploration, characterization and conservation

The approach to this research component is summarized in Figure 3.The different steps illustrated are described in more detail below (4.1.1-4.1.4).

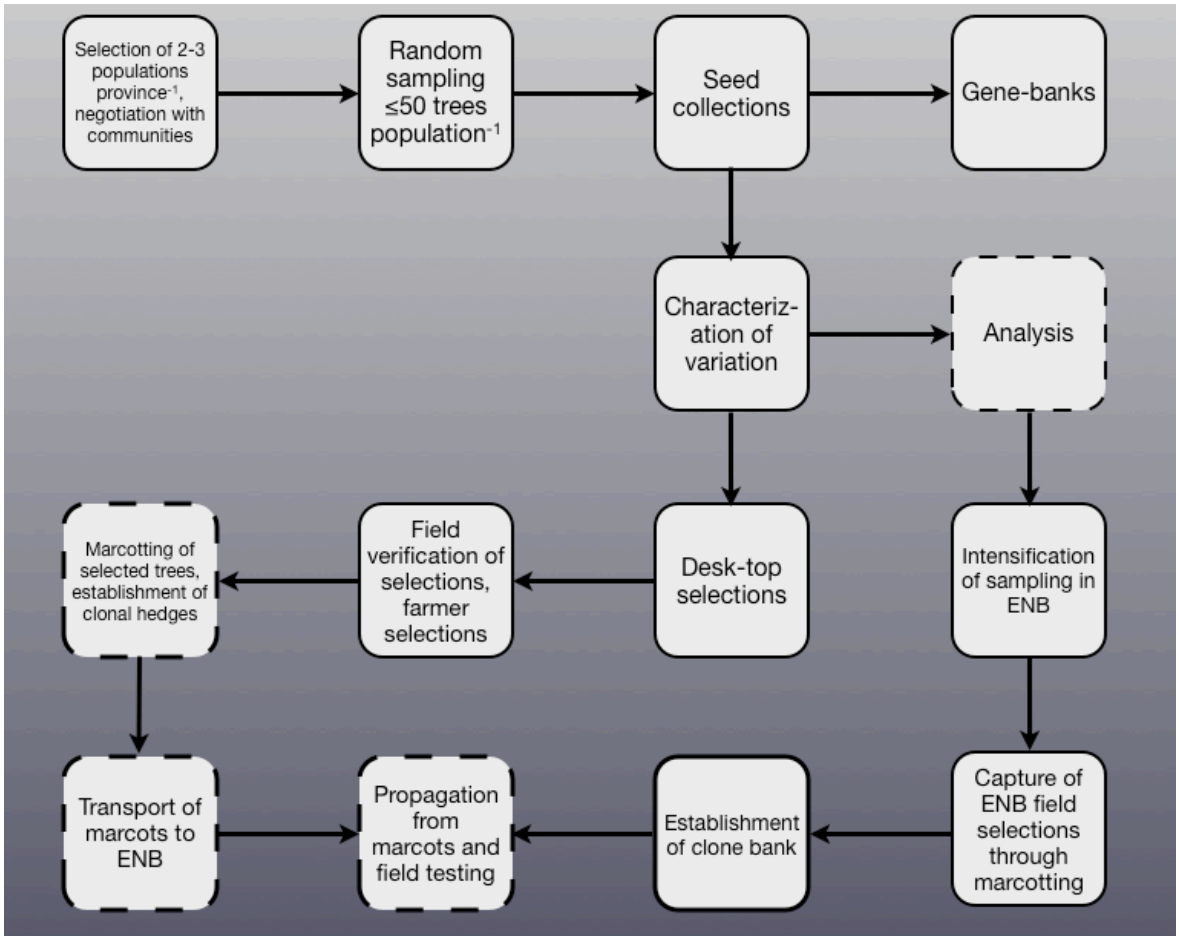

Figure 3. Project FST 2004/055: approach to exploration, characterization, and conservation of genetic resources (dotted lines indicate incomplete work areas)

The different steps illustrated are described in more detail below (4.1.1-4.1.4). In some cases, intermediate products or results are also described, principally because in some cases intermediate results have led to modifications in approach.

4.1.1 Selection of populations, sampling, and seed collection of populations

C. indicum occurs in both insular and mainland parts of lowland PNG. Due to the discrete nature and geographic separation of different parts of the range, we expected to find appreciable genetic differentiation between different populations. As efficient selection relies on sampling and selecting from the range of variation present, it was therefore decided to sample populations from five different provinces (Figure 4). This strategy also reflected the village-level orientation of the planned domestication work.

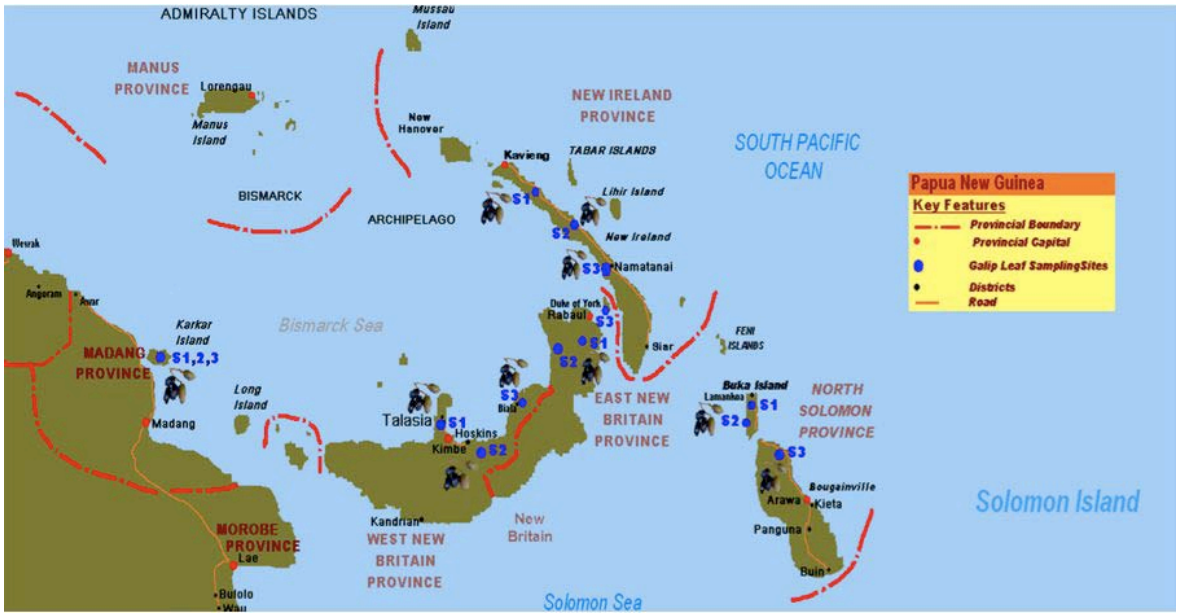

Figure 4. Initially selected sampling locations for Project FST 2004/055

Locations were selected based on presence of galip-nut populations, agreement of community members, and logistical considerations (including accessibility, size of trees, and availability of local support personnel). Individual sampled populations are described and shown in Appendix 1 (Table A1.1, Figures A1.1 to A1.5).

The objective of the sampling was to derive unbiased estimates of phenotypic variation within and between populations. Strictly speaking, this would require a formal random sampling procedure, e.g. involving random transects. However, this was not possible due to the many logistical and time constraints on project operations (in many cases, sample sites could only be reached from provincial or district capitals after long sea or land journeys, leaving limited time for the actual sampling and seed collection). For this reason, we employed a “walk and sample” procedure, i.e. walking through villages and asking farmers to show us their galip-trees, but without restricting our sampling to those they considered their best trees (Figure 5).

In all cases, sampling was carried out in or around villages rather than in undisturbed forest. The origin and history of galip-trees in these locations is mixed. Farmers collect and transplant wildings from their “best” trees, and also bring seed from other, sometimes fairly distant locations. Even large trees are not necessarily remnants of natural forest, and many populations have been affected by logging (see Table A1).

Figure 5. NARI project staff members Mr. Tio Nevenimo and Ms. Katherine Yagau with a sampled C. indicum *tree*

The initial plan of sampling three populations per province was largely achieved (except for West New Britain Province). Selection of 50 trees per population proved to be more problematic, but overall a satisfactory set of samples was obtained (Table 1). Each individual tree was measured (girth and maximum canopy width), and total fruit crop was estimated. Nut samples were shipped to Kerevat for gene bank establishment (4.1.2) and characterization measurements (4.1.3).

4.1.2 Establishment of ex-situ gene-banks

In most populations, many mature galip-trees had been felled in logging or agricultural operations and remnant trees of merchantable size can be considered to be endangered. This is not a new phenomenon: over 50% of superior *Canarium* trees identified by NARI in 1990 had been logged by 2003[3].

Because of this threat to *Canarium* genetic resources, project staff established a series of gene conservation plantations on the NARI Experiment Station at Kerevat using seed that was surplus to requirements for the characterization measurements (see 6.1.3).

[3] *Leakey et al. 2004. FST 2004/055 Project Proposal.*

Table 1. Summary of sampling by province and village

Province and village	Number of trees	Mean number fruits tree^{-1}
AUTONOMOUS REGION OF BOUGAINVILLE		
Sialau	45	15.2
Tohatsi	46	18.2
Nova	43	9.0
EAST NEW BRITAIN		
Kabaira	43	15.9
Nanuk	42	19.0
Kikitaba	25	14.8
MADANG		
Kaur #2	50	22.2
Liksal	20	22.6
Matugar	31	19.7
NEW IRELAND		
Maliom	15	11.5
Karias	16	16.4
Siar	9	17.0
WEST NEW BRITAIN		
Arrelgilpau	12	9.0
Kandoka	12	7.3
TOTAL / GRAND MEAN	29.2	16.4

4.1.3 Characterization of variation

Measurement variables are detailed in Table 2. The complete data set, including both tree and nut measurements, has >60,000 individual observations. A postgraduate student is currently working on the complete analysis, which will both characterize phenotypic variation between and within populations and elucidate the relationships between traits.

Preliminary analyses (means and standard deviation by province and village) have been carried out on the variables KIT, KNR, NIS, NL and NW (see Table 2 for meaning of variable abbreviations).

Table 2. Measurement variables used in characterization analysis

Variable	Abbreviation	Units / precision	Comments
Mass of nut-in-shell	NIS	to 0.01g	= i.e.exocarp, endocarp, kernel-in-testa
Nut length	NL	to 0.01mm	Respectively long and short axes of nut, measured with digital caliper
Nut width	NW	to 0.01mm	
Mass of fresh kernel-in-testa	KIT	to 0.01g	
Mass of fresh kernel, testa removed	KF	to 0.01g	
Ratio of KF:NIS	KNR	%	
Mass of dry kernel, testa removed	KD	to 0.01g	

4.1.4 Selection and marcotting of field selections

Preliminary (desk-top) selections were made by ranking trees according to kernel:nut ratio; NARI staff fixed a ratio of 0.17 as the cut-off point for selection. These selections were later re-inspected in the field by project staff; trees that were considered impossible to work with (principally, that were too tall to marcot) were discarded. Finally, farmers were invited to make additional selections following their own criteria, subject to also meeting the 0.17 criterion.

Project staff set marcots or carried out preparatory pollarding or pruning in most of the sample locations, but the formidable logistical difficulties of this work soon became apparent and, because of both this and specific technical reasons based partly on preliminary results from the characterization data (see below) domestication activities in villages outside East New Britain were discontinued. The following specific factors led to this decision:

Delay to project activities due to cocoa pod borer emergency

The cocoa pod borer arrived in East New Britain in 2006, and for much of the first year of Project FST 2004/055 project staff were heavily engaged in combatting the resulting emergency (due to the internal problems affecting the Coconut and Cocoa Institute (CCI) at this time, NARI was charged with control of the pest). This delayed the first prospection visits and, consequently, the whole selection and propagation cycle.

Distribution of variation

Preliminary analysis of the characterization data revealed that variation in nut characteristics at the inter-population and inter-provenance level, although not trivial, is of

much lower magnitude than within-population variation. Given the high cost and difficulty of village-based activities (see below), it became evident that project resources were better spent on exploiting within-population variation at more accessible locations, i.e. in East New Britain (see 4.1.6).

Technical difficulty of marcotting

Success in marcotting requires pruning in the crown, i.e. to permit marcotting on resprouts. This means that that the period from tree selection to coppicing-ready marcot is at least 9 months (three months for post-prune regrowth to be ready for marcotting, three months for the marcots to root, at least three months for weaning and establishment of the severed marcot.

Logistical difficulty of marcotting and other work

Finally, work of this type in most of the provincial sites was affected by logistical difficulties that compounded the problems mentioned: with the exception of Madang, local collaborators did not work effectively between visits by project staff; previously lopped trees were not always ready for marcotting when project staff visited (and there was no way of getting prior information from the isolated villages); heavy rain sometimes prevented work from proceeding during visits (trees become slippery and could not be climbed safely); severed marcots and rootstocks for approach grafting died due to lack of water or lack of watering.

4.1.5 Mass propagation and testing

The difficulties mentioned above would have impeded the production and distribution of selected cultivars during the project life. However, even had these difficulties not arisen, a number of other conditions would need to have been satisfied. First, more detailed work on the phenotypic characteristics of the selections would need to have been carried out. Probably, this would require looking at characteristics other than kernel size, e.g. oil content and quality, as even the largest-sized nuts in our collections are no larger than average-sized nuts from Nissan Island[4]. Second, any selections would need to be genetically tested on different sites before they could be distributed with confidence. Genetic testing could easily take 10-15 years (for production of plants, establishment of tests, time until fruit production, and evaluation of fruit quality and yield over several years).

4.1.6 Intensification of sampling in East New Britain and capture of field selections through marcotting

As explained above (4.1.4), from 2009, project field activities in germplasm prospection were re-oriented towards intensification of sampling in East New Britain. Further selections were made in the three participating communities, an additional community (Tinganagalip; see Figure A2) and the plantation at Vimy (Figure A2). Additional selections in the villages and at Tinganagalip were made with farmers. These reflected farmers' criteria such as nut size, shell hardness, and high yield.

Selected trees were marcotted and successful propagules established in a new clone bank site at NARI-Kerevat (LAES[5]).

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[4] *NARI has been sourcing galip-trees from Nissan Island for distribution under a European Union development project since 2008. The population appears to be a highly selected landrace.*

[5] *Lowland Agricultural Experiment Station*

4.2 Development and application of vegetative propagation techniques

A series of vegetative propagation experiments was initiated, beginning shortly after project inception in 2006, under the direction of vegetative propagation specialist and project consultant Dr. Richard Pauku. Dr. Pauku, who is based in Honiara, visited Kerevat to install and monitor experiments in 2006, 2007, and 2008. All experiments were carried out either at NARI-Kerevat or in the young plantations located on the Vimy Estate.

The vegetative propagation research reflects the proposed approach to domestication, i.e. (a) "capture" of superior adult tree phenotypes by marcotting, grafting, or cuttings (b) mass propagation of outplanted marcots through hedging (c) subsequent propagation by cuttings (for both field testing and operational planting).

Specific experiments and their associated hypotheses are listed in Table 3.

The experiments can be classified in the following broad categories:

- Factors affecting success in the rooting of succulent, leafy juvenile cuttings (experiments 1,2,19,21);
- Factors affecting success of marcotting of mature trees (experiments 3, 4, 8/15);
- Factors affecting stock-plant growth and stock-plant effects on rooting success of leafy juvenile cuttings (experiments 5,6,21);
- The effect of stem girdling on production of shoots and aerial roots in young trees (experiment 7).

Table 3. Vegetative propagation experiments established under the Project

Experiment	Date established	Null hypotheses
1	September 2006	Different rooting hormone doses (indole-3-butyric acid, IBA), varying rooting media, and source (node on ortet) of cuttings have no effect on rooting of single-node leafy stem cuttings from seedlings of *C. indicum*
2	September 2006	Different lamina areas and stem lengths have no effect on rooting of single-node leafy stem cuttings from seedlings of *C. indicum*
3	December 2006	Different concentrations of auxin (IBA), tree height, and marcot-ball media have no effect on rooting of marcots on shoots from mature pollarded stem of *C. indicum*
4	September 2006	Different concentrations of auxin (IBA), tree height, and marcot-ball media have no effect on rooting of marcots on shoots from mature pollarded stem of *C. indicum*
5	September 2006	Different doses of fertilizer, irradiance and stem diameter have no effect on growth of stumps (cutting sources) derived from *C. indicum* seedlings
6	December 2006	Different combinations of fertilizer and irradiance do not affect growth of seedling stockplants of *C. indicum*
7	December 2006	Stem girdling does not induce rooting or sprouting in mature trees of *C. indicum*
8, 15	December 2006	Different concentration of IBA, branch height and media have no effect on rooting of marcots on mature *C*. *indicum* trees over 2 seasons
19	April 2008	Different substrates and cutting leaf-area have no effect on rooting of three-node cuttings from four-month old seedlings of *C. indicum*
21	April 2008	Different stock-plant irradiance treatments have no effect on rooting of three-node cuttings from four-month old seedlings of *C. indicum*

4.3 Commercialization Component

Objective 2 of Project FST 2004/055 (To improve market prospects for these [galip-nut] products by development of an effective supply chain and industry network in Melanesia) envisaged three activities:

1. Facilitate national marketing by linking farmers, block holders and plantation owners through the establishment of nucleus estates;

2. Facilitate a regional industry network with PNG, Solomon Islands and Vanuatu (Melanesia);

3. Evaluate national and regional market opportunities for *Canarium*.

Mr. Colin Bunt (Macro Agribusiness Consultants Pty Ltd) was contracted to facilitate these activities, initially through consultations and diagnostic visits to stakeholders in PNG, Vanuatu, and Solomon Islands, to be followed up by a regional workshop to formulate supply chain strategies and marketing protocols. The workshop was scheduled for mid-2007.

Mr. Bunt visited Vanuatu and Solomon Islands in early 2007 (27th January to 4th February) in order to expore interest in the regional network. Prior to this, he also had consultations with Sunshine Coast University staff (Dr. Helen Wallace and Dr. Jenny Carter), who were beginning the ACIAR Project 'Processing of *C. indicum* nuts: adapting and refining techniques to benefit farmers in the South Pacific'. It was felt that due to the complementary nature of the topics to be covered and the number of people and institutions involved in both projects, the JCU workshop should be scheduled to coincide with the USQ project initiation workshop.

In the event, it proved difficult to organize a joint workshop until November 2009, when project staff (Jonathan Cornelius, Richard Pauku, NARI personnel) participated in the Canarium Industry Development Workshop held at NARI-Kerevat and coordinated by USQ. A wide range of stakeholders discussed the prospects for the industry in PNG and a number of key initiatives and priorities were agreed upon. These had a number of implications for the relevance and future development of FST 2004/055 marketing activities. These are outlined below with respect to the three activities mentioned above.

1. Facilitate national marketing by linking farmers, block holders and plantation owners through the establishment of nucleus estates

Although the establishment of nucleus estates was obviously not achievable as a direct project result, wider activities in the Gazelle Peninsula were already moving in this direction. The EU-financed PNG Nut Development Project, coordinated by NARI (2006-2009), included distribution of 42,000 galip seedlings to both village farmers and larger plantation enterprises. NGIP Agmark, PNG's largest cocoa processor, expressed firm interest and intention to purchase nut production from these plantings, while they and other, cocoa and spice exporters in ENBP have buying networks throughout the lowlands and expertise in the commodity export business[6], i.e. a supply chain linking growers with processors was already in place, at least in principle. NARI and Agmark also announced the formation of an industry steering group.

2. Facilitate a regional industry network with PNG, Solomon Islands and Vanuatu (Melanesia)

There was general agreement over the importance of eventually establishing a regional industry network, but also a general consensus that such a group would only be feasible and effective if a long-term funding mechanism could be identified and implemented. Dr.

[6] *Personal communication, John Moxon, NARi, 2009.*

John Moxon (then head of NARI-LAES) suggested that such an organization could eventually be financed by industry resources, once the planted resource base starts to become commercially viable. However, there was little support for the establishment of such a network in the short-term. Not only would it be unlikely to be sustainable beyond the short-term of project life, but also it was not seen as a priority for ensuring regular supply (i.e. through taking advantage of regional variations in harvesting times). This was because the long shelf-life (up to two years) of the processed product (i.e. roasted and salted kernels) permits steady supply, in spite of seasonality of production.

3. Evaluate national and regional market opportunities for Canarium

Although current development and research, including FST 2004/055, aimed at developing a major export commodity resource, there was consensus over the importance of researching and developing the PNG domestic market (also an aim of FST 2004/055). It was suggested that marketing research, and particularly future efforts by FST 2004/055, should focus on identifying potential domestic markets and market requirements for commercially produced, processed/value added products.

It was recognized that there was little or no information available on the potential for expansion of the domestic industry, beyond qualitative findings of a supply deficit in traditional markets (see 2.3.2). Domestic market development could (a) serve as a transition or scaling-up phase towards eventual export production, with producers becoming accustomed to improved harvesting and post-harvest practices; (b) provide a safety-net against export market fluctuations, as in the macadamia industry; (c) facilitate and prepare the ground for the export market, i.e. through tourist exposure, “suitcase” export, etc. (d) provide critical (early) cash-flows for industry participants (growers, processors and marketers).

Based on these three considerations, a proposal for a re-orientation of the marketing work was prepared by Mr. Bunt and Jonathan Cornelius, submitted to ACIAR, and subsequently approved by Dr. Russell Haines. Objectives, research areas, and methodology are listed in Table 4.

The research was completed as proposed and results are presented in 6.3.2

Table 4. Summary of approved proposal for modfication to marketing and commercialization work of the project

***Objective**:*	Investigate the domestic market for commercial Galip nut products in PNG as the starting point for a new commercial PNG agricultural industry with export potential.
Time-frame:	Completion by 25th May 2010
Specific areas to be researched	• The immediately available production base, based on an estimate of Galip trees in forest by province and planted resource as per the crop budgets and projections developed by NARI. This will include allowances for marketable yields based on probable market quality requirements (liaise with SCU Processing Project). • Overview of current nut imports into PNG, for example, volumes by product, price range, origin, major importers and distributors. • Overview of the current commercial market for nuts within PNG (for example; retail, food service companies, food manufacturing). • Nut purchasing and consumption trends in PNG and potential for future growth. • Packaging overview, for example, the types of packaging in use in the nut industry, trends in primary and secondary packaging. • Labeling requirements. • Potential for "suitcase export" via domestic market outlets. • Possible galip product differentiation and value adding options suitable for the PNG market. • Preliminary marketing strategy for domestic marketing of commercial galip products over the next 5 years (actions, timeframes and key success factors). • Likely resource requirements to implement a domestic marketing strategy, including potential supply chain constraints/issues.
Methodology:	• Initial contacts with potential informants (i.e. of both information and further sources of information) by phone and email. Here, maximum advantage would be taken of contacts made with Agmark and others in the Canarium Industry Developmnet workshop • Site visit to PNG (10 days) for in-depth consultations with contacts identified in initial contacts and to locate informants not contactable by phone or email. • Collation and analysis, follow-up phone and email contacts, and preparation of final report

5 Achievements against activities and outputs/milestones

Achievement of outputs and milestones (as listed in Tables 3.2 and 5.2 of the project document) are described below.

5.1 Objective 1: To Over a wide range of sites, prospect, characterise, select and multiply individual trees that have a number of superior commercial traits for cultivar development and field tests

5.1.1 Outputs and milestones

1.1 Outputs: Tested propagation protocols recorded and optimal procedures disseminated to provincial teams. Milestones: 1. 50% rooting by month 6, 80% by month 12; 2.Research publication

The project developed effective techniques for mass-propagation of juvenile material of *C. indicum*, suitable both for rural situations without piper water or electricity and for application by larger-scale, agro-industrial operations. Marcotting and approach-grafting techniques were developed and refined by the project and by project end were being used routinely for capture of adult field selections. An article summarizing these results has been prepared (Appendix 2).

1.2 Outputs: Single tree collections of fruits from 50 trees/village from three sites in each of the five provinces for empirical evaluation of phenotypic variation.

The project made single-tree collections from 410 trees in 14 villages in Madang, New Ireland, West New Britain, East New Britain and Bougainville. The output was completed sufficiently to allow characterization of phenotypic variation between and within provinces (see 6.1.2).

1.3 Outputs: Data on the intraspecific variation of nuts and kernels from 550 trees. Milestones: 1. all trees characterized by month 6; 2. Identification of elite trees for vegetative propagation at NARI and in villages. 3. Research publication

The output was completed sufficiently to allow characterization of phenotypic variation between and within provinces. In total, 6718 nuts were measured (nut length, nut width, masses of kernel-in-shell, fresh kernel-in-testa, dried kernel-in-testa, fresh testa, dried testa, ratio of masses of fresh and dry kernel to nut, fruit colour), plus the following tree characteristics: estimated tree age, estimated total yield of nuts, dbh, crown width, estimated height. Preliminary selections were made by NARI, based primarily on several nut characteristics: ratio of nut:kernel dry weight, ratio of nut:kernel fresh weight, fresh and dry kernel weight.

An Australian National University postgraduate student is working on a full data analysis. Kernel mass data are summarized in Section 6.1.2.

1.4 Output: Farmer-identified elite trees for vegetative propagation locally Milestone: Farmer selected trees identified (month 6)

These outputs and milestones were largely achieved. In follow-up visits (i.e. subsequent to initial seed collection) Bougainville (February-March 2008), Madang (February-March and April) 2008, New Ireland (March 2008), West New Britain (April/may 2008) and East New Britain, preliminary selections were screened and additional farmer-selected trees were added: (a total of 210 confirmed selected trees, average of 21 village^{-1}).

1.5 Output: A set of elite clones selected on basis of characterization and farmer selection at NARI and in the village nurseries. Milestone: Selected trees being propagated (month 12)

Work was continued towards meeting this output until 2008-009. Large numbers of marcots were set on selected trees, but there was high mortality both pre- and post-severance due to difficulties of ensuring timely harvesting of marcots and adequate nursery practice by provincial partners. In 2009, tree selection and marcotting outside ENB were discontinued (see section 4.1.4).

1.6 Output: Trained farmers starting village-level domestication (at least 2-3 per village). Milestone: 1. 15 Pilot village nurseries established and villagers trained in propagation; 2. Nursery and propagation skills upgraded

Awareness-raising events were held in the villages (Madang: six meetings; WNB: three meetings; New Ireland: three meetings; Bougainville: two meetings + 1 local radio broadcast). Marcotting techniques were demonstrated to villagers or CCI staff (with galip and other species e.g. *Inocarpus*, *Barringtonia*, *Psidium* in Madang) in most of the villages visited, and farmers showed great interest in applying the technique to various species of interest. Attempts were made in 2008-2009 and previously to set up village nurseries, initially with the aim of supplying seedlings for subsequent approach grafting. These attempts were unsuccessful due to lack of support from local collaborators.

1.7 Output: A collection of selected clones/site established in the village communities and replicated at NARI, Kerevat. Milestone: Selected germplasm established in NARI and village nurseries

The establishment of clonal collections in the villages was not feasible due to reasons mentioned above (Section 4.1.4). However, a large collection of germplasm was established at NARI-LAES in Kerevat (Section 6.1.3).

1.8 Output: Replicated field tests of promising selections, at all provincial sites Milestone: Field trials established in NARI and provincial sites

Establishment of replicated field trials was not possible during the life of the project, due to the issues described in Section 4.1.4.

1.9 Output: Clonal hedges of selected phenotypes managed for regular vegetative propagation to provide partially improved material to meet immediate demand by users; Milestone: Stockplants established in NARI and provincial sites

Vegetative propagation of selected phenotypes implies propagation of mature material, particularly in cases such as *C. indicum*, in which part of the fruit is the product of interest. The project has propagated selected mature-tree genotypes using marcotting, but as of project end marcot-derived clones were not sufficiently well-established and robust to be coppiced (needed to produce material suitable for striking cuttings).

1.10 Output: List of potential pest and diseases of Canarium. Milestone: Information for dissemination to stakeholders

No significant pest and diseases of *Canarium* were noted during project implementation.

1.11 Output: First commercial plantings with selected cultivars by smallholders and larger estate holders. Milestone: First improved production plantings established by month 46

The establishment of a commercial resource based was targeted by the EU-funded Galip-nut development project implemented by NARI from 2006. By 2009 around 90,000 galip seedlings had been established in East New Britain, on both clan-based landholdings and larger farms. This material has been sourced from Nissan Island and other atolls. FST

2004/055 has contributed to this effort, as Nissan Island material has been multiplied vegetatively by NARI using non-mist propagators introduced by the project.

5.2 Objective 2: Improve market prospects for these products by development of an effective supply chain and industry network in Melanesia

5.2.1 Outputs and milestones

2.1/2.2 Outputs: Establishment of a local Interest Group (Nucleus estates) to promote local level trade and technical support. Milestones: Functional national Supply Chain in PNG, promoting cooperation between smallholder producers and nucleus estates within PNG; with linkages to the industries in Solomon Islands and Vanuatu, to take advantage of the year-round complementary timing of harvesting seasons across the region Month 2 (2.1); Establishment of a regional industry network for indigenous nuts with annual workshops. Agreed strategies and protocols for supply chain Milestones: Functional Melanesian Supply Chain sharing market intelligence, processing and promotional initiatives; coordinated supply and distribution activities in domestic and regional export markets (2.2)

A projected workshop was not held during the first year due to problems with the cocoa pod borer and personnel instability. Subsequently, the decision was made to hold a joint workshop with the new ACIAR Galip-nut processing and packaging project (USC/NARI). This was scheduled by USC for May 2008 but this date proved impossible for NARI due to conflict with another event. The workshop was finally held in November 2009 and led to a re-orientation of activities away from Outputs 2.1 and 2.2 and towards Output 2.3 (see also Section 4.3).

2.3 Output: Results from niche market surveys evaluated for use by members of the industry network. Milestones: functional national and Melanesian Supply Chain, with a regional newsletter by month 30

As indicated elsewhere (see 4.3), as a result of the *Canarium* Industry Development Workshop organized by USC and NARI and at LAES-Kerevat from 9th-11th November 2009, marketing activities were re-orientated towards preliminary study of the domestic market. The domestic market survey was carried out by 2004/055 project collaborator Colin Bunt (Macro Consulting) in May 2010. The results are described in Section 6.3.2.

5.3 Objective 3: Delivery of selected cultivars to new sites and training the participating communities

5.3.1 Outputs and milestones

3.1 Output: Selected cultivars established in provincial sites. Milestone: Germplasm planted in community nurseries, month 31

3.2 Output: Trained communities growing selected cultivars for the first time. Milestone: Trained farmers, month 31

As development of cultivars was not possible during the life of the project, neither of these outputs has been generated by project activities.

5.4 Objective 4: Dissemination of information to stimulate adoption

4.1 Outputs: 1. Producers and industry partners across the country and wider region who are well informed about the results of the projects domestication and commercialization activities; 2.Consumers knowledgeable about indigenous nut products. Milestone: Informed public, producers and consumers (continuous, according to flow of outputs)

NARI staff have been assiduous in informing local organizations and people about the project's activities (see Output 1.6). It should also be noted that the project was part of a wider NARI initiative on *C. indicum* aimed at developing a productive resource base and that this effort as a whole has included a strong "awareness" component to which project staff have contributed. NARI held dozens of awareness meetings with smallholder farmer groups throughout the Gazelle peninsula, including weekly meetings in each ward, and also carried out field days and produced radio and newspaper releases[7] (see, for example, Appendix 3).

4.2 Output: trained communities growing selected cultivars for the first time

As development of cultivars was not possible during the life of the project, communities have not been trained in cultivation techniques for them. However, communities in East New Britain have been reached by the activities described in 4.1.

[7] *Personal communication, John Moxon, NARI, 2009.*

6 Key results and discussion

6.1 Genetic resource exploration, characterization and conservation

6.1.1 Genetic resource exploration

Genetic resource exploration was carried out by the project as a necessary stage in accomplishing seed collection and marcotting in villages. Therefore, a systematic evaluation of the state of the galip resource in and around communities was not attempted. However, it is worth documenting here that in most of the communities visited, project staff reported that most populations had been subjected to logging and that in many cases all trees were relatively young (see Appendix Table A1). These reports tally with earlier reports that most superior trees identified by NARI in 1990 had been logged by 2003.

The impact of such unplanned harvesting on genetic resources can be over estimated. Logging for timber is very unlikely to have led to selection against favourble nut characteristics and, even if it had, the conditions for such negative phenotype selection to lead to genetic change are quite stringent (see, for example, Cornelius *et al*. 2005 for the case of "dysgenic selection" in mahogany). However, there is no justification for complacency: logging has clearly occurred, and although the galip resource has regenerated and the species remains common in and around villages, this tells us little about effective population sizes; it could be that in some cases entire local populations might have regenerated from just a few remnant trees, implying a potential for loss of genetic variation through founder effects.

6.1.2 Genetic resource characterization

The analysis of the characterization data (see Section 4.1.3) revealed that variation between provinces and between villages-within-provinces is small in comparison to variation between trees-within-villages) (Table 5, Table 6). For example, in the case of kernel mass (KIT), the coefficient of variation percentage (CV%) of province means was 3.6%, whereas the CV% between-trees was almost an order of magnitude higher (26.0%). Similarly, whereas the CV% of village means for nut length was 2.9%, between-tree CV% was 11.4%.

The magnitude of within-population variation suggests clear potential for within-population selection (Table 7); depending on trait, the best families are between 24-36% superior to the provincial means (Table 8). It should be noted, however, that not all of this within-population variation is likely to be of genetic origin. In particular, there may be strong environmental influences on simple measures of fruit or nut size (e.g. due to maternal nutrition factors). However, we would expect environmental effects to be less important in the case of the ratio of kernel mass and nut mass (on the assumption that environmental influences would have a similar effect on all fruit components). This is of some importance as NARI identified this trait as the most important for selection.

Table 5. Phenotypic means and standard deviation by sampled province, fruit characteristics of C. indicum (NL: nut length; NW: nut width; NIS: nut-in-shell mass; KIT: kernel-in-testa mass; KNR: ratio of KIT to NIS.

	NL (mm)		NW (mm)		NIS (g)		KIT (g)		KNR	
Province	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
ARB	42.55	5.32	23.00	3.10	8.71	2.18	2.01	0.59	0.23	0.06
ENB	43.53	4.85	22.31	1.88	9.22	1.98	2.06	0.56	0.22	0.04
Madang	44.46	4.70	22.17	2.69	10.32	2.14	2.19	0.44	0.21	0.03
New Ireland	44.31	4.45	21.71	2.03	9.02	1.78	2.09	0.51	0.23	0.05
WNB	44.85	4.45	21.21	1.94			Data unavailable			
OVERALL GRAND MEAN, CV%	43.57	11.4%	22.38	11.6%	9.31	23.2%	2.08	26.0%	0.23	17.4%
CV% OF PROVINCE MEANS	2.1%		3.0%		7.5%		3.6%		4.2%	

Table 6. Phenotypic means and standard deviations by sampled province and village, fruit characteristics of C. indicum (NL: nut length; NW: nut width; NIS: nut-in-shell mass; KIT: kernel-in-testa mass; KNR: ratio of KIT to NIS

		NL (mm)		NW (mm)		NIS (g)		KIT (g)		KNR	
Province	**Village**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**
ARB	Sialau	40.41	6.03	21.95	3.16	8.86	1.48	1.90	0.39	0.22	0.03
ARB	Tohatsi	43.99	4.61	23.38	2.82	9.77	2.15	2.20	0.36	0.23	0.05
ARB	Nova	43.27	4.56	23.68	3.12	7.37	2.17	1.92	0.87	0.26	0.08
ENB	Kabaira	42.41	5.49	22.27	1.77	9.06	2.13	2.08	0.63	0.23	0.04
ENB	Nanuk	44.18	3.95	23.22	1.50	9.92	1.56	2.17	0.48	0.22	0.04
ENB	Kikitaba	44.35	4.85	20.84	1.75	8.35	2.00	1.86	0.53	0.22	0.03
Madang	Kaur #2	45.24	4.31	22.60	2.77	10.61	1.80	2.32	0.38	0.22	0.03
Madang	Liksal	44.65	4.62	21.97	2.80	10.75	3.21	2.22	0.57	0.21	0.02
Madang	Matugar	43.34	5.15	21.75	2.51	9.57	1.61	1.97	0.36	0.21	0.03
NI	Maliom	44.74	3.18	21.37	2.00	8.32	1.68	1.91	0.56	0.23	0.05
NI	Karias	44.06	5.47	21.40	2.01	9.34	1.67	2.09	0.45	0.23	0.04
NI	Siar	44.02	4.69	22.83	1.90	9.61	1.94	2.37	0.40	0.25	0.04
WNB	Arrelgilpau	44.93	4.08	21.29	2.33			Data unavailable			
WNB	Kandoka	44.77	4.97	21.14	1.57			Data unavailable			
OVERALL GRAND MEAN, CV%		43.57	11.4%	22.38	11.6%	9.31	23.2%	2.08	26.0%	0.23	17.4%
CV% OF VILLAGE MEANS		2.9%		4.0%		10.4%		8.2%		4.4%	

Table 7. Means by province and % superiority over mean of best family; fruit characteristics of C. indicum (NL: nut length; NW: nut width; NIS: nut-in-shell mass; KIT fresh kernel-in-testa mass; KNR: ratio of KIT to NIS

	NL (mm)		NW (mm)		NIS (g)		KIT (g)		KNR	
	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
A.R. Bougainville	42.55	33.68%	23.00	44.39%	8.71	94.83%	2.01	100.50 %	0.23	95.65%
East New Britain	43.53	27.36%	22.31	19.90%	9.22	55.86%	2.06	79.61%	0.22	36.36%
Madang	44.46	32.88%	22.17	19.35%	10.32	88.57%	2.19	60.27%	0.21	57.14%
New Ireland	44.31	18.57%	21.71	19.62%	9.02	51.66%	2.09	40.19%	0.23	52.17%
West New Britain	44.85	31.04%	21.21	26.83%			Data unavailable.			
OVERALL GRAND MEAN, CV%	43.57	29.8%	22.38	24.49%	9.31	38.45%	2.08	36.06%	0.23	26.09%
CV% PROVINCE MEANS	2.1%		3.0%		7.5%		3.6%		4.2%	

6.1.3 Genetic resource conservation

The germplasm collection derived from seed collected in the prospection visits (see 5.1.2) was planted principally as five-tree non-replicated line plots (Figure 5). The collection includes 224 open-pollinated families from 8 locations in Bougainville, Madang, and West New Britain (Table 8).

Figure 5. C. indicum *genetic resource conservation plot at NARI Lowland Agricultural Experiment Station, Kerevat, East New Britain, with project scientist Katherine Yagau (photo: Jonathan Cornelius, 2010)*

In late 2009, a new area was cleared at NARI Kerevat to establish a clone bank with marcots collected at the five East New Britain sites. As of mid-2011, 233 ENB clones had been established in this site, with a total of 368 plants (i.e. 1.65 ramets clone^{-1}) (Table 9).

These plantations serve three important purposes.

First, given the continuing loss of mature galip trees both to logging and farming, they fulfil a valuable *ex situ* gene conservation function, sampling not only the 233 ENB clones and the 224 families, but also the pollen parents of the latter.

Second, the germplasm collection constitutes a resource for genetic improvement that will become increasingly important as the galip industry develops.

Third, the ENB marcots can be used to continue the vegetative propagation research carried out under the project. In particular, once well established, marcots can be coppiced in order to provide cuttings material for further research into methods for vegetative propagation of mature material.

Table 8. Genetic resource plantations (seedling material) established at NARI-Kerevat

Province / village	LAES[1] Location	Number of families	Mean number of plants family^{-1}
AUTONOMOUS REGION OF BOUGAINVILLE			
Sialau	Block 109	9	5.1
Tohatsi		6	4.9
Nova		3	4.7
Sialau	Block 108	14[2]	3.0
Tohatsi		14[2]	2.75
Nova		3	2.5
MADANG			
Kaur 2	Along River Navuvu	50	7.8
Liksal		19	4.6
Matugar		97[3]	1
WEST NEW BRITAIN			
Arrelgilpau	Block 109	6	5
Kandoka		3	5

[1]Lowland Agricultural Experiment Station; [2]Includes one family also present in Block 109; [3]Includes extra families not included in characterization

Table 9. Number and location of ortets of C. indicum *represented in the clone bank of East New Britain material in LAES-Kerevat, as of June 2011*

	Location of ortets (sites in ENB)					
	Vimy	Kabaira	Nanuk	Kikitabu	Tinganagalip	Totals
Number of trees cloned (ortets)	35	130	20	20	18	223
Number of ramets established at LAES-Kerevat	78	130	76	63	21	368

6.2 Development and application of vegetative propagation techniques

6.2.1 Results of experimental studies

The results of the series of vegetative propagation experiments (see 4.2) are described below and in Table 10.

Rooting of cuttings

Our research has demonstrated the efficacy of non-mist propagators for propagation of *C. indicum*, hitherto considered a "difficult-to-root" species (Gunn et al. 2004). Rooting percentages of >90% can readily be achieved using succulent, three-node cuttings from shade-grown seedlings struck in either soil or coir, and following application of 0.8% IBA to cuttings (Figure 6).

Figure 6. Polypropagator in reconditioned propagation area (left); successfully rooted cuttings (right). Both NARI-LAES, Kerevat. Photos: Richard Pauku.

Rooting percentages were notably lower in the earliest experiments (i.e. experiments 1 and 2). In part, this is attributable to particular treatment combinations that gave significantly inferior results and therefore affected overall rooting percentages, i.e. non-application of IBA, use of cuttings not from node 2 (experiment 1), leaf area < 80cm^2, use of cuttings of <3 nodes length (experiment 2; but note that single-node cuttings from node 2 performed as well in Experiment 1 as three-node cuttings in Experiment 2), use of sawdust as a rooting medium. However, even at optimum combinations of these variables (i.e. ostensibly in the same conditions as Experiments 19 and 21) maximum rooting was ⩾40%. As the stockplants used for Experiments 1 and 2 were six-month old, semi-lignified seedlings grown at close spacing, this suggests that the use of healthy and vigorous stockplants is crucial to success in propagation. The results of Experiments 1 and 2 also suggest that use of correct treatments may become more important when techniques are adapted to more challenging material, e.g. from coppiced marcots.

Table 10. Summary of results of vegetative propagation experiments established under the Project

Experiment	Hypotheses	Findings
1	Different rooting hormone doses (indole-3-butyric acid, IBA), varying rooting media, and source (node on ortet) of cuttings have no effect on rooting of single-node leafy stem cuttings from seedlings of *C. indicum*	Effect of hormones Auxin (IBA) affected the rooting ability of cuttings raised under different media. In all media, percentage rooting was greater in cuttings with IBA treatment than those without. Percentage mortality varied but not significant between different IBA concentrations. Effect of rooting media Percentage rooting of cuttings for each media varied over time. However, cuttings raised in soil were more successful than those raised in coir, sand or sawdust. Cuttings raised in soil had lowest percentage mortality compared with those raised in coir, sand or sawdust. Effect of node position Across all media, node 2 cuttings had lowest percentage mortality. Rooting of cuttings was also influenced by different node position; node 2 cuttings had greater rooting success in all media compared with nodes 1, 3 or 4. Percentage of rooting was higher with cuttings struck in soils than those struck in coir, sand or sawdust in all node positions. Number of roots per rooted cutting was not significant between nodes.
2	Different lamina areas and stem lengths have no effect on rooting of single-node leafy stem cuttings from seedlings of *C. indicum*	Effect of lamina area Leaf area affected rooting ability of cuttings. Significant differences on percentage rooting were found between three leaf area treatments; overall, percentage rooting increased with increasing leaf area in both media. Comparatively, cuttings with leaf areas 20cm2, 40cm2 and 80cm2 have all recorded percentage rooting of 3.7%, 6.7% and 9.7% respectively by week 13 in coir/gravel mix media. By contrast, lower rooting percentage was found in sawdust/gravel mix media (20cm2 = 0.9%, 40cm2 = 5.6% and 80cm2 = 7.9%). Trimming of the leaves did not affect significantly numbers of roots. There were significant differences in percentage mortality between cuttings with leaf area of 20cm2 and 80cm2 but not between 20cm2 and 40cm2 or 40cm2 and 80cm2 in coir/gravel mix media. By contrast, significant differences in percentage mortality were found between cuttings with leaf area of 20cm2 and 40cm2, and 20cm2 and 80cm2 but not between 40cm2 and 80cm2 in sawdust/gravel mix media. Effect of stem length Percentage rooting differed significantly between longer (3-nodes) and shorter cuttings (1-node) in coir/gravel mix media, but not in sawdust/gravel mix media. When combining leaf area and stem length treatments, rooting was greatest in longer (3-nodes) cuttings with large leaf area.

Table 10. Summary of results of vegetative propagation experiments established under the Project (continuation)

Experiment	Hypotheses	Findings
3	Different concentrations of auxin (IBA), tree height, and marcot-ball media have no effect on rooting of marcots on shoots from mature pollarded stem of *C. indicum.*	Only 14% of the marcots rooted within 3 months of marcoting; most did so late in week 11 and 13. A high percentage (76%) of rooted marcots produced more than one root (actual number of roots was not counted as to avoid disturbing the marcots). Effect of IBA There was no significant difference in percentage rooting between marcots treated with IBA and those without. Effect of tree height The percentage rooting of marcots from different sections of the tree does not differ significantly from each other. Effect of ortet There was significant difference in percentage rooting of marcots between trees. Tree 27 recorded highest success rate of 83.3%, with no mortality. Effect of media The two media tested for rooting the marcots were found not to have differed from each other. Percentage mortality between different treatment combinations was also found not to be significantly different from each other.
4	Effects of IBA, marcot-ball media, clone, and matrcot position on rooting of marcots set on mature clonal stockplants of *C. indicum*	Overall percentage rooting of the marcots was 29.2%, with most marcots rooted within 7 weeks from establishment. Effect of IBA There was a significant difference in percentage rooting between marcots treated with IBA and those without; most IBA treated marcots rooted. Effect of media Significant differences in percentage rooting were found between media, with marcots rooted in coir being more successful than those rooted in soil. Effect of clone Percentage rooting was not significantly different between clones. Effect of position of marcot on stem No significant effect

Table 10. Summary of results of vegetative propagation experiments established under the Project (continuation)

Experiment	Hypotheses	Findings
5	Different doses of fertilizer, irradiance and stem diameter have no effect on growth of stumps (cutting sources) derived from *C. indicum* seedlings	Effect of Irradiance Production of shoots was significantly different between different irradiance treatments; stumps exposed to full sun produced more sprouts or shoots than either light or dense shade Effect of fertilizer There was a significant difference in shoot production between seedlings treated with different rates of NPK fertiliser; high levels (100g) of NPK fertiliser produced more shoots than lower levels. (Fig 20). Stem diameter The stump size had significant effects; large stumps (>21mm) produced more shoots than small diameter (0-10mm) stumps. There were no statistically significant differences in shoot production between medium stumps (11-20mm) and large stumps.
6	Different combinations of fertilizer and irradiance do not affect growth of seedling stockplants of *C. indicum*	Effect of fertilizer Fertilizer dose significantly affected internode length and diameter; high levels of NPK reduced length and diameter of internodes. Effect of irradiance The full sun irradiance treatment was associated with higher internode lengths and diameter. However, seedlings receiving 50g NPK fertiliser and planted under dense shade produced long internodes. Shortest and smallest diameter internodes were found in seedlings receiving 100g NPK and in dense shade.
7	Stem girdling does not induce rooting or sprouting in mature trees of *C. indicum*	Girdling and rooting: Girdling induced aerial rooting. Overall, about 58% of the girdles had roots; auxin (IBA) treated girdles were more successful (66.7%) compared to 50% rooting on girdles with no auxin treatment. Full girdling around the stem was more successful (100%) than half girdling (16.7%). There were no well developed roots formed around girdles on small trees. However, well developed roots were found around girdles on medium and large trees. About 75% of girdles on medium trees (5-6cm diameter) had rooted compared to 50% rooting each on those girdles on small and large trees. Sprouting: Sprouting occurred in about 25% of the girdles; 17% of the sprouts were found below the girdle compared to 8% above the girdle. About 42% of the girdles healed after callusing, of which 50% were girdles with no auxin (IBA) applied on them. Percentage mortality of girdled trees was about 17%.

Table 10. Summary of results of vegetative propagation experiments established under the Project (continuation)

Experiment	Hypotheses	Findings
8, 15	Different concentration of IBA, branch height and media have no effect on rooting of marcots on mature *C. indicum* trees over 2 seasons	Overall, there was at least one successful marcot on eight of the 14 trees. In general, percentage rooting and percentage mortality were similar between different treatment levels. However, stem position significantly affected percentage mortality; mortality rates in the upper crown were approximately one-third of those in middle and upper crown. The random effect of tree (block) was also significant for both rooting and mortality. There were no other significant main effects or interactions.
19	Different substrates and cutting leaf-area have no effect on rooting of three-node cuttings from four-month old seedlings of *C. indicum*	After 3 months, survival percentage was 95.6%, rooting percentage of surviving cuttings was 94.4%, inclusive rooting percentage was 90.45, percentage shoot incidence of surviving cuttings was 58.0% and mean length of longest root was 18.0mm. Rooting substrate significantly affected transformed survival percentage (F=5.7, p=0.22). Untransformed survival percentages were similar for soil (98.3, s.e. 1.70), coir (96.7, s.e. 1.93), and soil/sawdust (98.3, s.e. 1.70) and higher than for soil/coir/sawdust mix (90.1%, s.e. 1.74). There were no other significant treatment or interaction effects. However, rooting percentages paralleled those for survival: those for coir, soil, and coir/soil/sawdust were ≥95%, and greater than for soil and sawdust (86.2%, s.e. 6.4).
21	Different stock-plant irradiance treatments have no effect on rooting of three-node cuttings from four-month old seedlings of *C. indicum*	Overall survival percentage was 94.4%, rooting percentage was 94.2%, inclusive rooting percentage was 90.3% and 49.2% of surviving cuttings had produced new shoots within three months. Mean length of the longest root was 2.0cm. Survival percentage and length of the longest shoot were the same in the two treatments. Treatment means for the other variables were closely similar, with no significant differences (%shoots: 50%, s.e. 11.4 (sun), 48.3%, s.e. 15.0 (shade); %rooting: 91.7% s.e. 5.7 (sun), 96.7%, s.e. 3.3 (shade); %inclusive rooting: 86.1% s.e. 6.7(sun), 94.4% s.e. 5.5 (shade).

Our research was aimed at developing working protocols, and was not designed to elucidate physiological explanations for the observed responses. However, basic research into physiology of rooting may be of critical importance in adapting these protocols for use with more challenging material, e.g. reproductively mature shoots of coppiced marcots.

Marcotting

Rooting percentage of marcots was both higher and less variable (i.e. between trees) in nursery-grown, mature material than in marcots set on mature trees in the field. In addition, treatment effects were stronger in nursery grown material (higher success rates after IBA application and in coir rather than soil). It appears that, in the field, treatment effects may be masked by the high variation between individual trees. The causes of this between-tree variation are unknown and will require further research to elucidate.

In spite of low per-marcot success rates, the research reported here has confirmed the utility of marcotting as a technique for "capturing" selected genotypes in the field. Approach-grafting has also been applied as a supplementary technique. In spite of low success rate per marcot, success rate on a per-tree basis in East New Britain using marcotting or approach grafting (or both) has been close to 100%, facilitating the establishment in a field clone bank of 368 ramets of 223 East New Britain clones. We consider that the capture of genotypes of phenotypically superior individuals, rather than their mass-propagation, is the main application of marcotting in *C*. *indicum*. The approach may also be useful to villagers for cloning of individual trees (indeed, in many villages in which NARI has carried out marcotting, community members have learned the technique and applied it to *C*. *indicum* and other fruit species, both native and exotic). Current effectiveness of marcotting is already adequate for this purpose, and we suggest that future research should concentrate on techniques for mass propagation of material from such clones and on techniques for induction of flowering.

6.3 Commercialization Component

6.3.1 Visits to Vanuatu and Solomon Islands at project inception

Vanuatu

The visit to Vanuatu confirmed that, as in PNG, supply constraints were inhibiting industry growth. One principal outlet (The Kava Store, run by Mr. Charles Long Wah) was unable to meet domestic demand.

Village-level processing was seed as one option for overcoming supply constraints the drying of nuts at source with small, relatively portable food dehydrators. This approach was said to increase returns to the grower, to streamline quality control, and permit more effective supply chain management. However, cash flow was reported as a major issue for village growers, as harvesting, cracking, drying and transport costs have to be met in advance of selling the product.

Processing in Port Vila involved freezing nuts within 24 hours of cracking, peeling the testa (while still frozen), refreezing, coating in sugar and then drying down of the product prior to packaging. At the time of the visit (January 2007), the Kava Store was retailing nuts in foil packs for retail sale. Supermarket operators reported that the new presentation had been well received by consumers at prices of 780vt (AUS $9.13) per 300g.

The potential to supply nuts from the Solomon Islands to meet production shortfalls to Vanuatu was discussed. It was considered that this might constitute an effective way of stimulating industry development in both the Solomons and Vanuatu.

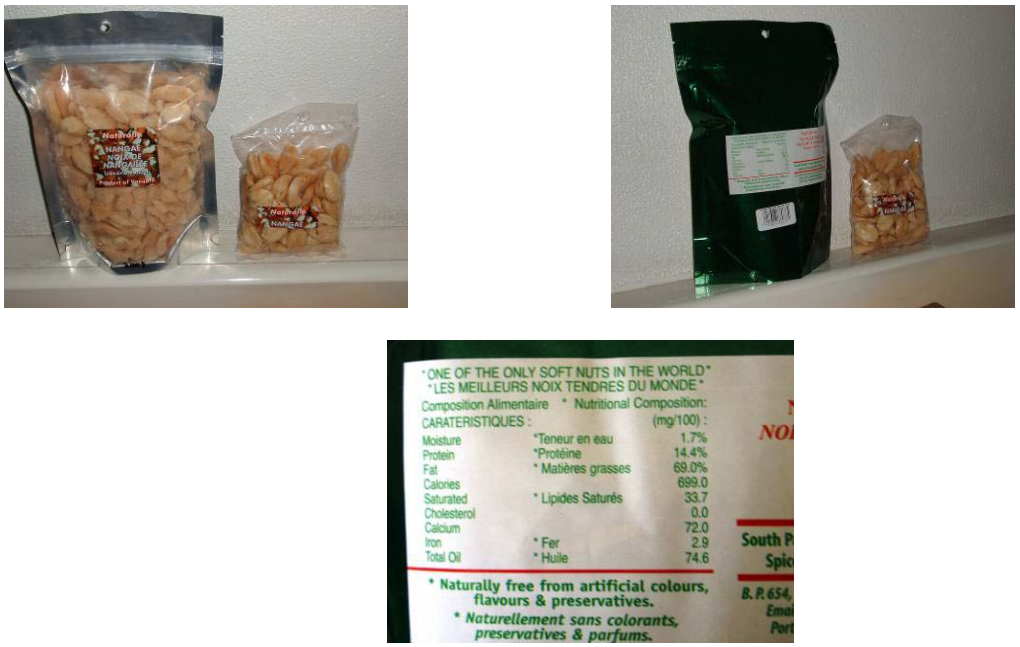

Figure 7. Galip packaging in Vanuatu. Above: front and rear views of new 300g retail foil packs (left) placed next to an example of the 100g plastic pack used previously (top); below: details of the nutritional composition from the product label (foil pack). Photos: Colin Bunt.

6.3.2 Domestic marketing study, 2009

The domestic market study is of lasting interest for stakeholders in the galip industry; in order to ensure its continued and wide availability, it is included here as Appendix 4.

The key findings of the study were as follows:

1. There is little or no published data on current importation, sales, pricing and consumption of packaged nuts.
2. However, all packaged nuts other than Chinese peanuts are sold in very small quantities and at luxury prices.
3. PNG consumer markets tend to be driven by price rather than value. Consequently, the price of Chinese packaged peanuts (PNK 3.00 for a 100g packet) would effectively dictate the price for packaged galip, although this does not imply that the packets would have to contain 100g (e.g. 50g packets retailed at or below PNK 3.00 could be competitive).
4. All retailers consulted considered that packaged galip had high market potential because it is an almost universally known product.
5. Simple, partially transparent packaging highlighting PNG origin, and containing a familiar form of galip (e.g. dried and roasted) product was considered optimum for normal domestic markets (e.g. supermarkets, trading stores). Alternative preparations and packaging could be tested in selected expatriate- or tourist–dense locations (airport lounges, hotels, etc.).
6. Point-of-sale promotions and tastings are likely to be critical to effective product launch.
7. The food service and manufacturing sector was more cautious in their response towards galip, due to stringent HACCP (Hazard Analysis Critical Control Points) requirements for new ingredients. They require product samples of acceptable standard in order to be able to evaluate possible interest.

8. Tentative projections of consumer demand suggest that the domestic market would be capable of absorbing 25-100% of domestic plantation production from 2014-2016, i.e. when the planned export market is likely to still be under development. That is, the domestic market has the potential to fulfil an important "fall-back" function in case of slower than anticipated development of the export market. However, in the absence of an export market and with the projected quantities of nuts available from 2015 there is a danger that smallholders will not receive the financial returns they might be expecting.

Based on these findings, Mr. Bunt made a number of key recommendations for the development of the domestic market. These are summarized in Figure 8 (below).

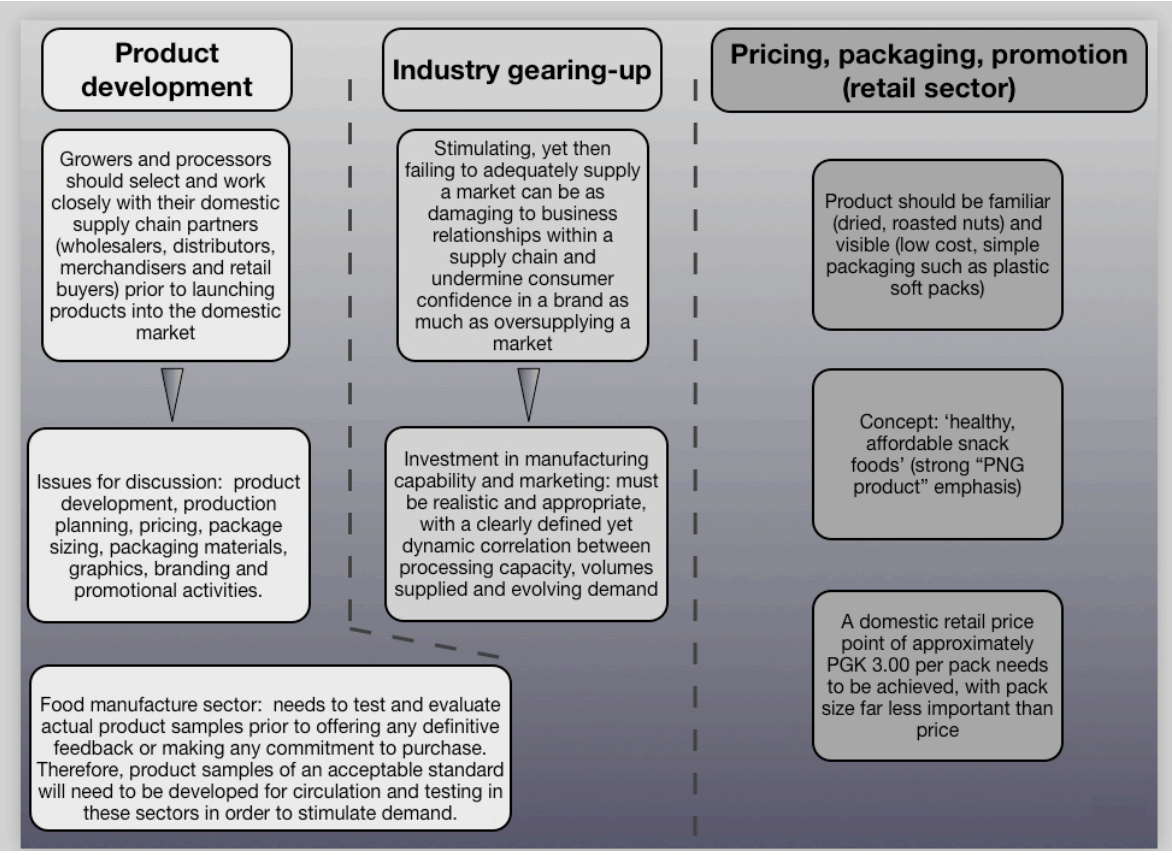

Figure 8. Recommendations for development of the PNG domestic market for galip-nut

7 Impacts

The project was part of a wider initiative, including components funded by the European Union as well as ACIAR, aimed at development of a new, export-orientated galip-nut industry. To a large extent, its impacts are therefore dependent on the successful development of this industry. This is reflected in our description of project impacts, particularly those projected to have an effect from 2015.

7.1 Scientific impacts – now and in 5 years

The relationships between project outputs and scientific impacts are illustrated in Figure 9.

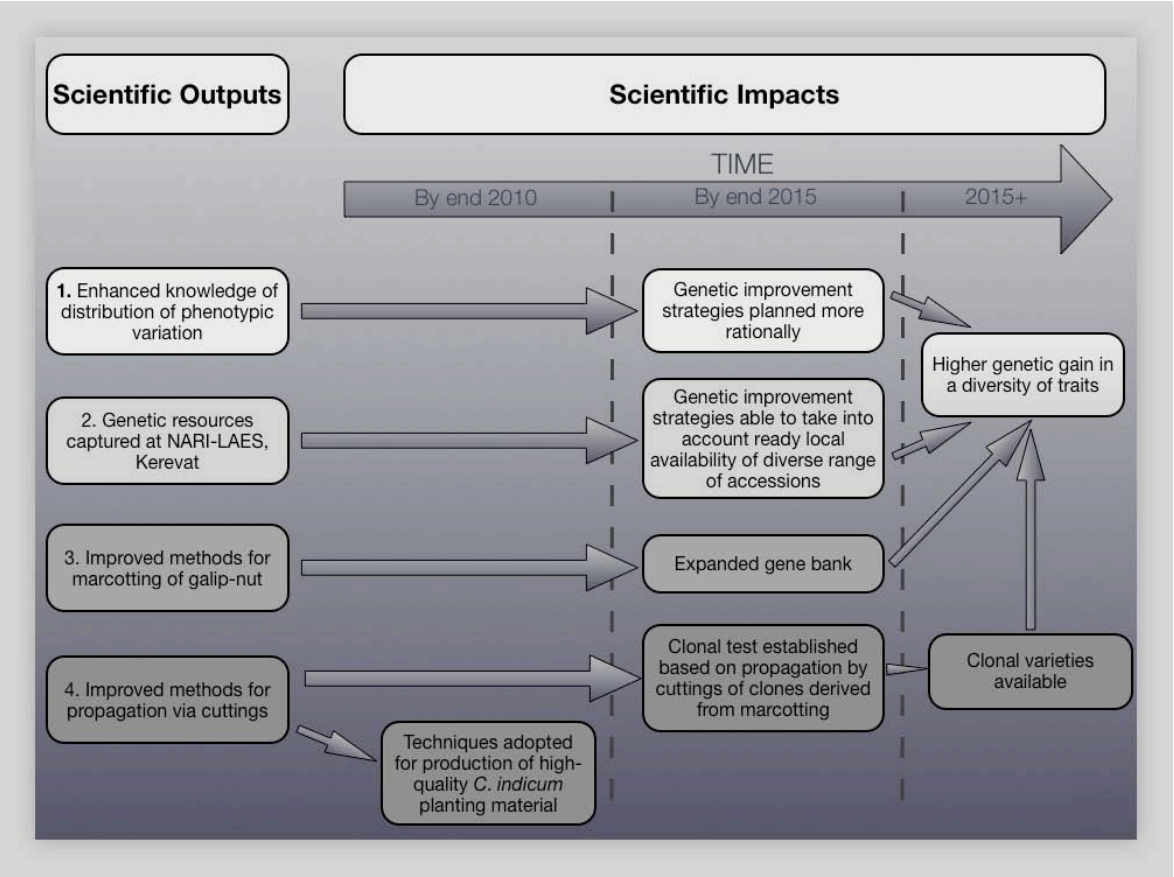

Figure 9. Current and projected scientific impacts of Project FST 2004/055

7.1.1 Scientific impacts during project life-time

As outlined previously, the project has had notable success in developing efficient methods for propagation of *C. indicum* by cuttings. Although the species has been considered to be difficult to propagate, the simple and inexpensive methods developed by the project give rooting percentages of >90%. This project output has been adopted during project life by NARI staff working on the EU Galip projects: the scientific impact in this case is the use of this new approach for bulking-up of the high-quality material from Nissan Island.

The understanding of the importance of within site variation and the guidelines for vegetative propagation are also important scientific impacts.

7.1.2 Scientific impacts from 2015

Many perennial crops have been subjected to an essentially unplanned domestication process[8], a history that is partly responsible for the pest problems that afflict many crops (e.g. cocoa pod borer). The scientific impacts that we project from 2015 reflect an assumption that galip-nut domestication will not follow the unsustainable route of massive propagation of a few clonal varieties, but rather that it will be based on intensive selection and development of a variety of cultivars, clonal or otherwise, supported by the maintenance and strategic use of a broad genetic resources collection. The genetic resources assembled by the project (Tables 8, 9) would constitute that collection, and would be used as follows:

- for development of new varieties, either directly (clonally) or after further breeding work (perhaps combining flavour or textural traits with desirable morphological (e.g. kernel size) or processing (e.g. soft shell) characteristics;
- as a possible source of resistance genes, in the event of appearance of critical pest or disease problems;
- as a ready source of material for propagation and other experiments.

7.2 Capacity impacts – now and in 5 years

The project has increased knowledge and skills both of project researchers and project collaborators in communities. All the capacity impacts described below have the potential to lead to additional scientific and community impacts subsequent to project end, as outlined in sections 7.1 and 7.3.

7.2.1 Community level

The project's work in germplasm prospection, germplasm collection, staff's work in explaining project activities, and propagation has exposed villagers to new ideas and skills.

Knowledge of the potential of galip—beyond local sales and home consumption—has been raised, and in many case project staff have reported enthusiastic reception of the idea of cultivating galip as an export crop. Such awareness, both in East New Britain and beyond, plays an important role in preparing the ground for the emerging industry.

Many villagers have observed and helped project staff carry out marcotting of galip-trees and, with help from project staff, have learned the technique. Remarkably, very few villagers knew how to marcot or were aware of the technique, in spite of its ease or application to many genera (e.g. *Citrus*). Some villagers have already applied the technique to other species, both in East New Britain (Figure 9) and in Madang, where following demonstration of marcotting techniques villagers began to use them in propagating both exotic and native fruit and nut species (chestnut, guava, mon fruit and migin).

7.2.2 Project staff

NARI Project staff members have acquired important new skills and knowledge as a result of their participation in the project. All staff members have been agronomists with conventional agronomic training and, in the case of the junior staff, had not previously been exposed to the key elements of participatory domestication, i.e. the concept of planned domestication of a wild or semi-wild species and the application of participatory

[8] *See, for example, various instances described in Smith et al. (1992). Tropical Forests and their Crops.*

Figure 9. Citrus marcot in Tinganagalip, East New Britain. The marcot was set by a local farmer who learnt the technique from observing FST 2004/055 Project staff.

methods to genetic improvement. Specific skills and knowledge acquired included the following:

- experience gained in planning and carrying out field-work with significant logistical difficulties;
- awareness raised of techniques involved in domestication, e.g. selection, description, and marking of mother-trees, handling and control of identity of individual seedlots;
- vegetative propagation skills, in some cases honed to expert level in propagation of cuttings and marcotting, including construction of polypropagators.

Project consultant Dr. Richard Pauku made an important contribution to local capacity building, particularly in construction, maintenance, and use of polypropagators, and has contributed some useful best practice guidelines (included here as Appendix 5). NARI scientist Mr. Tio Nevenimo was also directly responsible for new propagation skills gained by junior staff (Ms. Katherine Yagau, Mr. William Sibaris, Mr. Simon Minnah), particularly in approach-grafting and marcotting.

7.3 Community impacts – now and in 5 years

7.3.1 Economic impacts

The economic impacts of the wider galip-nut R+D program are expected to be felt from around 2015, when production from the thousands of trees distributed since 2006 is expected to come on stream. By 2022, the full projected estate of 25,000 ha (1 million trees at 40 trees ha^{-1}) is expected to be complete, with maximum production reached 15 years later (2037).

Economic impacts have been estimated by Fisher (2011); key summary indicators are summarized below (Table 11). Farmers would expect annual net cash income of around PGK1000 ha^{-1} (around AU$ 450 at current exchange rates). This is about half the per capita GDP and represents a significant amount for low-income producers. Scaled-up to a provincial (ENB) level, it translates to a multi-milion dollar industry (Table 11).

Table 11. Summary of economic impacts of the galip-nut R+D programme in Papua New Guinea (after Fisher 2011: Table 8, Table 10, Table 11)

Annual Cash income[1]	Annual costs	Economic return to farmers		Economic return to processors, ENB
		per ha[2]	East New Britain	
PGK 2400 ha^{-1}	PGK 1470 ha^{-1}	PGK 10,931 ha^{-1}	PGK 19.1 million yr^{-1}, 2015-2022[3]	PGK 1.4million yr^{-1} (2015), rising to 31.2 million yr^{-1} (2032)[4]

[1]At mature production levels of 60kg nut-in-shell $tree^{-1}$ yr^{-1}, 40 trees ha^{-1};PGK 1 kg^{-1} (nut-in-shell); [2]Net present value per ha over an infinite time horizon, discount rate 5%; [3]Net present value corresponding to projected planting per year of 70,000 trees, 40 trees ha^{-1}, 5% discount rate. Total area of estate is completed in 2022; [4]Based on maximum production of 12.5kg processed kernels $tree^{-1}$ yr^{-1}, 25000 ha @ 40 trees ha^{-1}, profit to processors of PGK 2.5 kg^{-1} kernels

Fisher (2011) attributes around 31% of these benefits to the ACIAR research on galip-nut. The contribution of the present project is likely to increase with time as the genetic resources safeguarded start to be integrated into breeding programmes and as these make increasing use of vegetative propagation techniques.

7.3.2 Social impacts

Although the new industry is orientated principally towards external markets, stakeholders also acknowledge the importance of the domestic market (sections 4.3, 6.3.2, Appendix 4). The planned expansion of area under galip-nut is likely to lead to increased local consumption, whether via local markets or self-supply. As galip-nut is a healthy and nutritious food, this will have beneficial effects on local diets and will increase resilience to climatic extremes, e.g. drought: perennial crops tend to be more drought resistant than annual staples and galip, unlike cocoa and other principal export crops, is a traditional food crop.

7.3.3 Environmental impacts

As a result of the project's activities and outputs, local agrobiodiversity (galip genetic resources) have been secured. The expansion of planting of this native species also has

the potential to lead to positive impacts on other native species associated with it.

7.4 Communication and dissemination activities

NARI staff have been very active in informing local organizations and people about the project's activities. Awareness-raising events were held in the villages (Madang: six meetings; WNB: three meetings; New Ireland: three meetings; Bougainville: two meetings and one local radio broadcast.). The project also produced a newsletter (Appendix 6).

The wider galip R+D program included a strong "awareness" component to which project staff contributed. NARI held dozens of awareness meetings with smallholder farmer groups throughout East New Britain's Gazelle peninsula, including weekly meetings in each ward, and also carried out field days and produced radio and newspaper releases[9]. (see, for example, Appendix 3).

Project staff are currently working on two article manuscripts:

- Pauku et al: Vegetative propagation of *Canarium indicum* L. (Burseraceae) in Papua New Guinea (intended for Agroforestry Systems)
- Yagau et al.: Phenotypic variation and correlations in *Canarium indicum* L. (Burseraceae) in Papua New Guinea (intended for Euphytica).

[9] *Personal communication, John Moxon, NARI, 2009.*

8 Conclusions and recommendations

We concur with Fisher's (2011) comment that "beyond the life of the current ACIAR projects, it will take significant further R+D effort to reach the ultimate goal of a commercially viable galip-nut industry." ACIAR's current programs, in particular the recently approved PARDI/PRA project "Developing markets and products for the Pacific Island and PNG Canarium nut industry", recognize this need and promise signficant advances in commercialization. At the same time, current programs strongly emphasize market research, particularly for processed nuts. As these programs begin to impact on the industry, it seems likely that there will be increasing recognition of the need for research on pre-harvest issues, including genetics and breeding. However, such work can have relatively long lead-times to impact, without necessarily requiring major long-term investment. Here, we suggest two priority research areas of importance for the industry. **Both proposed work areas are relatively inexpensive, but are fundamental to developing a succesful and sustainable industry**.

8.1 *Canarium indicum* genetics and pre-improvement

Planting of galip in East New Britain under the EU-financed development project has been based largely on seed from one source: Nissan Island. Nissan Island is a coral atoll with a land area of around 30km^2, located approximately equidistant to East New Britain and Bougainville. Nissan Island seed is being used because it produces nuts with very much larger kernels than other sources.

There are three obvious explanations for the superiority of the Nissan Island material:

- First, intensive farmer selection on nut phenotype. The effectiveness of selection would be amplifed by relatively small population size and the virtual absence of gene flow from outside sources.
- Second, import of seed from a tree or trees with large kernel size and subsequent proliferation (including displacement of any pre-existing local varieties).
- Third, a mix of these two possibilities.

The Nissan Island material is sometimes referred to as "elite" material, and in effect is regarded as a kind of pre-existing genetically improved source. However, it differs from typical products of conventional genetic improvement in a number of ways:

- Its genetic diversity is unknown. Both mechanisms mentioned above would be likely to be associated with or lead to relatively low genetic diversity.
- It has not been field-tested.

Both issues are of concern. Low genetic diversity may be associated with susceptibility to pests and diseases, including pathogens that may be absent on the relatively isolated Nissan Island. Lack of field-testing means that little is known about the incidence of genotype-environment interaction and, in particular, whether its performance in the distinctive Nissan Island environment will be sustained in other, different environments such as those of the Gazelle peninsula of East New Britain.

The risk posed by these factors can be overstated. It seems likely that Nissan Island material will flower and fruit in East New Britain and will probably produce nuts at least as good as those of local sources (at least in kernel size). As far as diversity is concerned, even if the Nissan Island material is highly depaupate, this can be seen in a wider horticultural and agricultural (as opposed to forestry) context, in which in many cases production is based on a few varieties, some of which may be genetically uniform (e.g. Hass avocado, etc).

Nevertheless, it is obvious that germplasm sourcing in the case of the emerging galip-nut industry has been based on the essentially serendipitous availability of a local landrace with largely unknown genetic characteristics and that there are clear risks associated with this. We suggest that in order to place the genetic base of the emerging industry on a sounder footing, several activities are needed.

First, a **genetic diversity study** should be carried out using neutral genetic markers (either AFLPs or microsatellites). This study should include material from Nissan Island trees, plus simiilar sized samples from Madang, New Britain, New Ireland, Bougainville mainland and, if possible, Solomon Islands. The study would aim at (a) establishing whether the Nissan Island material is notably genetically depauperate and (b) would establish its genetic affinities and, possibly, its ultimate origin. Some of the material could be sourced directly from the NARI-LAES gene bank established by the project.

Second, an open-pollinated **progeny test of Nissan Island material** should be carried out. Even if neutral genetic diversity is high, genetic variance in traits subject to selection can still be low. This would indicate lack of potential for further improvement within the Nissan Island landrace. If variation is present, the test will allow estimation of key genetic parameters used in breeding and would also permit identification of any traits exhibiting non-quantitative inheritance.

Third, a **provenance test** of galip should be established, with a least one replication in East New Britain. The test should include material from similar sources to the diversity study. It would permit the quantification of between-population genetic variation in the full range of commercial and potentially commercial traits.

Fourth, resources need to be dedicated to **maintaining the germplasm collections** established at NARI-Kerevat, including permanent marking and mantenance. Given the difficulties of carrying out germplasm collections in other provinces, these collections have great importance as a genetic resource for the growing industry.

8.2 Further development of vegetative propagation techniques

Vegetative propagation is the quickest and most effective approach to genetic improvement. In many fruit and nut species, the availability of vegetatively propagated cultivars is a fundamental part of the production system and in many cases essential for profitability and for achievement of quality standards expected to be required for export purposes. Project FST 2004/055 has made important advances in vegetative propagation of *C. indicum*, but more work is necessary in order to realize the potential of the species. In particular, methods for mass propagation of reproductively mature material need to be developed. This will bring two key benefits.

First, vegetatively propagated material sourced from the crown of reproductively mature trees will produce fruit closer to the ground (Figure 10) and may develop a crown-like, rounded form, without passing through a period of juvenile habit. Galip is a large tree (up to 40 height), and fruit cannot be picked from older individuals without climbing, which is hazardous and expensive. Fruit can be collected from the ground, but in this case it is susceptible to degrade. As well as making harvesting easier, the availability of smaller, more manageable trees also facilitates intercropping with other crops.

Figure 10. Precociously fruiting galip plant, grafted by NARI researcher Mr. Tio Nevenimo

Second, methods for propagation of mature material are essential for cultivar development, because (a) superior phenotypes and genotypes are only detectable in mature trees and (b) due to outcrossing, recombination, and possible non-additive genetic effects, superior trees are not necessarily true-breeding.

We therefore recommend the continuation of research into vegetative propagation. This should address factors affecting success of propagation of mature materialm particularly via cuttings, as this approach offers higher potential for mass-propagation. The marcotted clone bank set up by the project should be used as a source of cuttings, as the use of scions from a variety of mother-trees will enable the identification of possible genetic influences on propagation success and their separation from environmental factors (including components of candidate propagation techniques such as media, hormones, etc.).

9 References

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10 Appendixes

10.1 Appendix 1: Sampled populations of *C. indicum*

Sampled populations are described below (Table A1) and shown in Figures A1 to A5 (below)

Table A1 Locations and characteristics of sampled populations of C. indicum

Province and populations	Location	Comments on individual populations	People involved, general comments
AUTONOMOUS REGION OF BOUGAINVILLE			
Sialau Village, Selau Suir LLG, North Bougainville District	North coast of Bougainville Island (Figure A1)	Mostly relatively large trees; little new planting is evident. Many trees have been felled for timber or agriculture. Mean dbh of sampled trees: 100.3cm (CV 73.5%).	Gabriel Andrai (NARI), Simon Minah (NARI), Gabriel Wayen (DPI), Wilfred Malin (DPI)
Tohatsi Village, Buka LLG, North Bougainville District	Northeast tip of Buka Island (Figure A1)	Large and tall trees. Mean dbh: 119.6cm (CV:50%)	
Reke/Nova Village, Buka LLG, North Bougainville District	Southern Buka Island (Figure A1)	The trees are said to have originated from Nissan Island. Most are young and were said to have large nut sizes. Mean dbh of selected trees: Nova: 60.9cm (CV 28.1%)	

Table A1. Locations and characteristics of sampled populations (continued)

Province and populations	Location	Comments on individual populations	People involved, general comments
EAST NEW BRITAIN			
Kabaira Village	Close to sea level above Kabaira Bay on eastern side of northern Gazelle peninsula (Figure A2)	Mean dbh of sampled trees: 56.7cm (CV 48.5%)	Mr. Tio Nevenimo, Mr. Gabriel Andrai, Ms. Kathy Yagau, Mr. William Sibaris, Mr Minnah Simon (all of NARI)
Kikitabu Village	Inland, northern gazelle peninsula (Figure A2)	Mean dbh of sampled trees: 61.5cm (CV 92.5%)	
Nanuk Village	Inland, central Gazelle peninsula (Figure A2)	Mean dbh of sampled trees: 100.3cm (CV 73.5%)	
Tinganagalip Village	Inland, northern gazelle peninsula (Figure A2)	This site added in 2009 following the decision to intensify activities in East New Britain (see Section 4.1.4). As trees were selected based on farmer criteria rather than randomly, selections in this location were not included in the characterization data base. Project staff report that, according to the Councillor and the village elders, most of the community's older trees were logged for timber (Tavilo Timber and other companies) or cleared for farming. As a result, most on-farm galip trees are very young and were said to have been planted since the 1994 Rabaul eruption.	

Table A1.1. Locations and characteristics of sampled populations (continued)

Province and populations	Location	Comments on individual populations	People involved, general comments
MADANG			Mr. Tio Nevenimo (NARI), Mr. Will Akus. MS. Serah Aloysius Joe, Mr. John J (CCI)
Kaur (Kour) village, Karkar Island	North coast of Karkar Island.164º00'E, 3º00'S (Figure A3)	Mr. Nevenimo reported that trees in Karkar Island are of two broad types: those used for oil, typically with small nuts, and those used for eating, typically with larger nuts. Most selected trees are >50 years old. Mean dbh of sampled trees: 95.4cm, C>V. 64.8%.	
Liksal village	Coastal location south of Karkar Island (Figure A3)	Project staff report local anecdote that many of the galip-trees in this area (Murunas) may have originated from Karkar Island. In general, trees in the zone are relatively small, with ages estimated at <40 years. Mean dbh of sampled trees: 61.9cm, C.V. 50.6%.	
Matugar village		Project staff report local anecdote that many of the galip-trees in this area (Raikos, Murunas) may have originated from Karkar Island. In general, trees in the zone are relatively small, with ages estimated at <40 years. Mean dbh of sampled trees: 78.3cm, C.V. 37.2%.	

Table A1.1. Locations and characteristics of sampled populations (continued)

Province and populations	Location	Comments on individual populations	People involved, general comments
WEST NEW BRITAIN			Mr. Tio Nevenimo (NARI) and local guides
Arralgilpua, Kandrian-Glosta (Glouceser) District	North coast of West New Britain, coastal location (Figure A4)	Project staff report that the area is said to have been logged in the 1980s, leading to the loss of most larger trees. However, there are many smaller trees which are said to be derived from wildlings collected from under selected trees and then transplanted to newly cleared gardens. Mean dbh of selected trees: 63.8cm, CV 23.8%	
Kandoka Village, Kaliai, Kandrian-Glosta (Glouceser) District	Western West New Britain, inland location (Figure A4)	Most trees are located close to the village in old coconut or food crop gardens, and were reported to be <50 years old and smaller than trees in secondary forest in the Glosta area.	

Table A1.1. Locations and characteristics of sampled populations (continued)

Province and populations	Location	Comments on individual populations	People involved, general comments
NEW IRELAND			Simon Minnah (NARI), Greg Oliva (Unitech STD), Peterson Wavingare (Unitech STD, Charles Aisi (OIC)
Maliom, Namatania District, Konoagil LLG	Southeast coast of New Ireland (Figure A5)	Mean dbh of selected trees: 50cm, CV 24.1%	All the trees selected were relatively young, due to intensive logging
Siar Village, Namatania District, Konoagil LLG	Southeast coast of New Ireland (Figure A5)	Mean dbh of selected trees: 61.8cm, CV 34.6%	
Karias Village, Namatania District, Konoagil LLG	Southeast coast of New Ireland (Figure A5)	Mean dbh of selected trees: 47.1cm, CV 22.7%	

[1]Mindre Village in Raikos District was initially selected, but later dropped due to inaccessibility

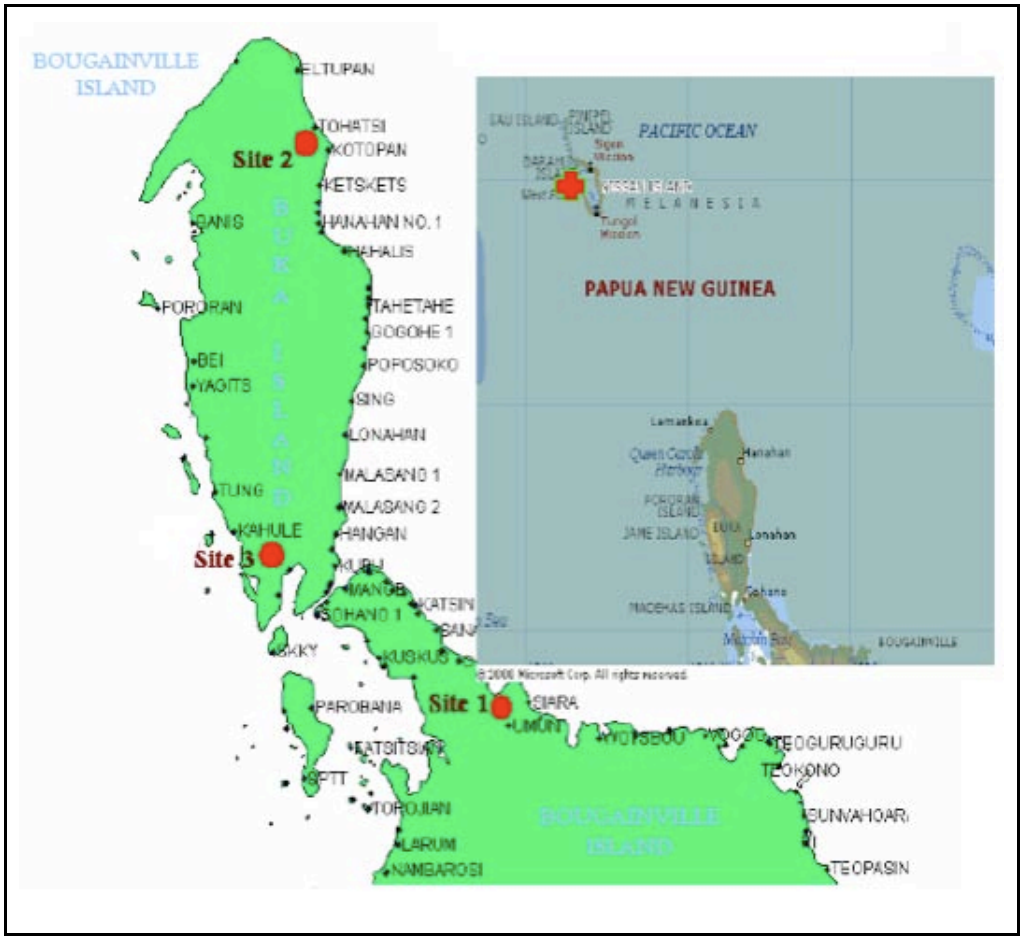

Figure A1 Sampled populations, Autonomous Region of Bougainville

Figure A2. Sampled populations, East New Britain Province

Figure A3. Sampled populations, Madang Province

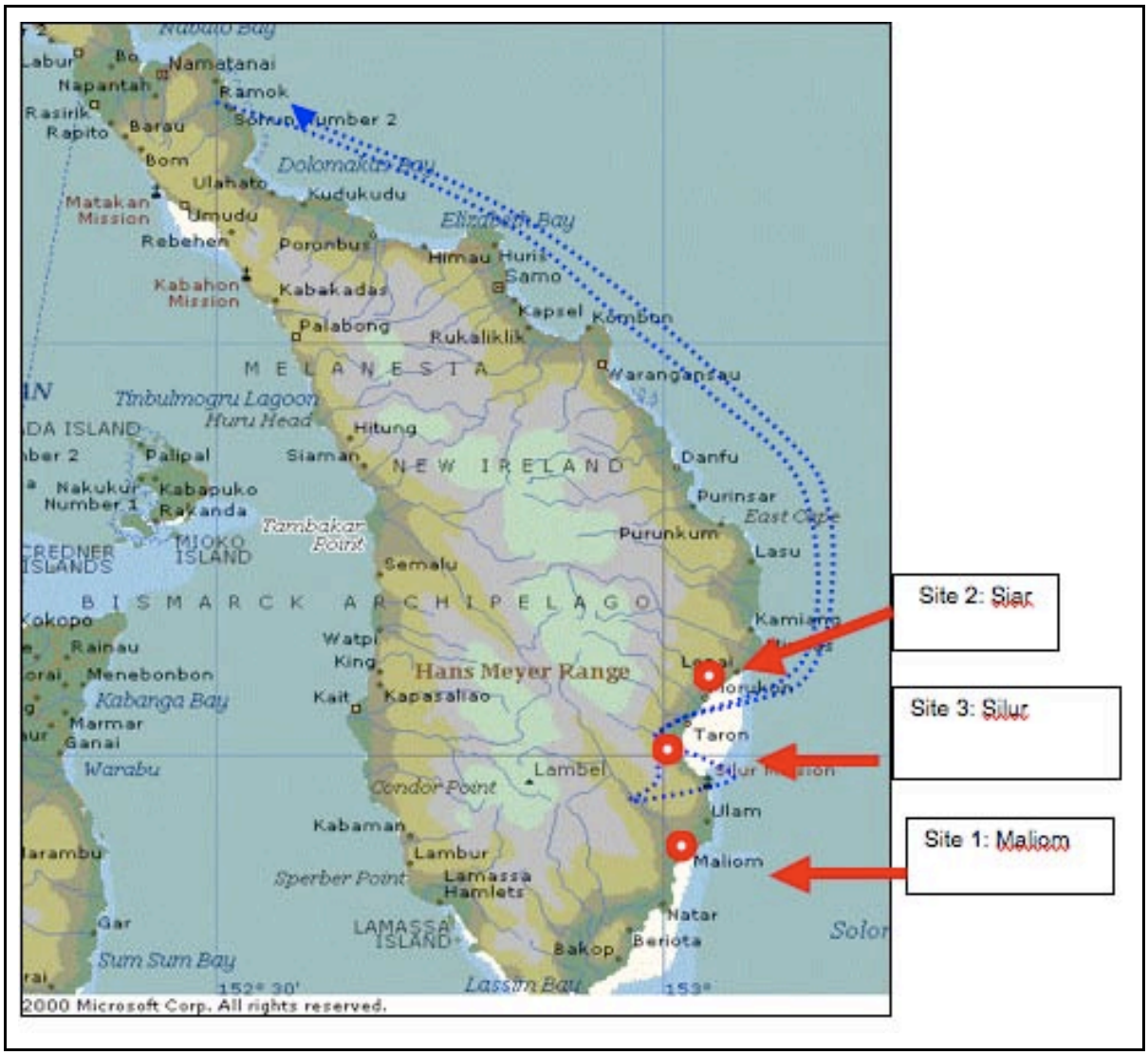

Figure A4. Sampled populations, New Ireland Province

Figure A5 Sampled populations, West New Britain

10.2 Appendix 2: Draft article on vegetative propagation

Vegetative propagation of *Canarium indicum* L. (Burseraceae) in Papua New Guinea

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Introduction

Galip-nut (*Canarium indicum* L.) is a traditionally important tree species, native to the lowland rainforests of Melanesia (Papua New Guinea, Solomon Islands and Vanuatu) and eastern Indonesia (Evans, 1996; Thomson and Evans, 2006; Nevenimo et al., 2007). Although, its timber is of commercial value and the species is frequently logged, edible nuts are its most important product. Kernels are commonly eaten both raw and roasted, are used as a source of cooking oil, and are sold to meet household expenses (Nevenimo et al. 2008). Due to their pleasant, mild taste and unusually soft texture, galip-nuts have long been considered to have export potential (Fleming 1996). There are ongoing efforts in East New Britain Province (ENBP) to create an export industry, partly motivated by the recent decline in the cocoa industry due to the recent incursion to ENBP of the cocoa pod-borer (*Conopomorpha cramerella*, Lepidoptera: Gracillariidae).

Although there is evidence of historical domestication of galip-nut, there is considerable phenotypic variation in kernel size, oil content, and other characteristics (Leakey et al. 2008). As in other partial domesticates, this variation represents both constraint (due to undesirable variation in product quality) and opportunity (i.e. the possibility of developing superior cultivars). As in other established and novel fruit species, vegetative propagation offers high potential to

respond to both constraint and opportunity, i.e. by development of superior cultivars. However, galip-nut has hitherto been considered to be difficult to propagate (Gunn et al. 2004). The present paper reports recent research conducted by the PNG National Agricultural Research Institute (NARI) and research partners that has been successful in developing techniques for propagation of juvenile and mature material.

We were particularly interested in facilitating selection and propagation by rural communities and organizations. Therefore, our research into propagation of cuttings was carried out in non-mist poly-propagators (NMPs) (Leakey et al. 1990a). These are simple, low-cost and robust systems that require neither piped water, constant irrigation nor electricity, and that are therefore suitable for adoption by such groups. Essentially, an NMP consists of a wooden frame with a close-fitting, hinged lid; both base and lid are made watertight by enclosure in clear polythene. The NMP is filled with successive layers of large stones (6-l0cm), small stones (3-6cm) and gravel, and topped with an appropriate rooting medium to a total depth of approximately 25 cm. The propagator is then filled with water to a depth of about 20cm.

NMPs have been used effectively for propagation of dozens of tropical tree species (Leakey et al. 1990a). However, not all species can be easily propagated, and development of working protocols often requires investigation of the effects of various critical factors. Our research examined the effect of several factors that frequently affect success in vegetative propagation, including application of auxins, cutting leaf-area, rooting substrate, cutting size and node position, and irradiance of stockplants.

Auxins, such as IBA, can enhance rooting by facilitating transport of carbohydrate down the stem base (Hartmann et al., 1997; Dick and Dewar 1992). However, the response to exogenous auxin varies between species (e.g. Lo 1985, Leakey 1990). Leaf area of cuttings can be important because of potential trade-offs between photosynthetic capacity (important because assimilates present in softwood stems may be insufficient to keep cuttings alive during the process of

rooting) and water loss through transpiration, which may lead to desiccation and death (Leakey 2004). These trade-offs imply that there may be an optimum leaf area that provides an optimum balance. The importance of rooting media is widely recognized (Hartmann et al., 1997), as it influences gas exchange and moisture availability, affecting key processes such as replacement of water lost through transpiration, stomatal closure, respiration and photosynthesis.

We also investigated techniques for marcotting (air-layering). In fruit and nut species, phenotypic superiority can only be identified in mature trees that are already producing fruit. Typically, the genotypes of such trees are "captured" by grafting. However, previous experience of NARI staff has indicated that galip-nut is difficult to graft. While marcotting is an apparently easy way of capturing the mature genotype, success can be dependent on factors similar to those mentioned above, as well as others specific to this technique (e.g. crown position).

Materials and methods

Juvenile material: propagation of leafy stem cuttings

A series of experiments was carried out between 2006 and 2008, aimed at identifying effective protocols for rooting of juvenile cuttings. All cuttings were harvested from diverse seedling material (one cutting seedling^{-1}) in the NARI nursery at Keravat, ENBP, and struck immediately in NMPs. For experiments 1 and 2, the best available sources of cuttings were six-month old, semi-lignified seedlings grown at close spacing. The material used for experiments 3 and 4 was younger, vigorous, and succulent. Specific objectives, treatments, experimental design, and response variables are summarized in Table 1.

NMPs are essentially closed systems and required only occasional topping up of water during experimental periods. Experiments were analyzed by analysis of variance on plot means. The count-based percentage variables (rooting and survival percentages) were transformed by arcsin

before analysis. In the results section, “significant” refers to probabilities of ≤ 0.05 under the null hypothesis.

Table 1. Experiments on propagation of leafy stem cuttings of *Canarium indicum* at the NARI Lowland Agricultural Experiment Station, Keravat, East New Britain, 2006-2008

Experiment number, date established, objectives, plant material	Treatments and levels	Experimental design	Response variables evaluated
#1, 22.9.06. Assessment of the effects of different concentrations of indole-3-butyric acid (IBA), rooting media, node position Materials: six months old potted seedlings of unknown provenance grown under 50% shade, single-node cuttings, 100% leaf area	Three IBA concentration (0, 0.3% and 0.8%) Four rooting media (coir, sand, soil and sawdust) Four node positions (1, 2, 3, 4 from apex)	3x4x4 factorial without replication, 20 cuttings treatment^{-1}	Number of roots per cutting, % rooting, % mortality
#2, 27.9.06. Assessment of the effects of lamina area, cutting length, rooting media Materials: six months old potted seedlings of from six mother-trees of local provenance (Vimy, East New Britain), grown under 50% shade, 0.3% IBA	Three lamina areas (1 leaflet, ≈20cm^2; 2 leaflets, ≈40cm^2; 3 leaflets, ≈80cm^2) Three stem lengths (1, 2, 3 nodes) Two rooting media (3:1 coir/gravel and 3:1 sawdust/gravel)	3x3x2 factorial without replication, 6 cuttings treatment^{-1}	Number of roots per cutting, % rooting, % mortality
#3, 14.4.08. Effect of substrate and cutting leaf-area Materials: three-node cuttings from four months old seedlings of Nissan Island (Autonomous Region of Bougainville) provenance, 0.3% IBA, 50% shade	Four substrate types: soil; coir; 1:1 soil and sawdust; 1:1:1 soil, sawdust and coir (1:1:1) Two leaf areas: 80%, 100%.	4x2 factorial, two replications per treatment combination.	Survival %, Rooting % of surviving cuttings, % of surviving cuttings with new shoots, mean length of longest root of surviving cuttings, all at three months. "Inclusive rooting" is rooting % where dead cuttings are classified as non-rooting
#4, 17.4.08. Effect of stockplant irradiance conditions Materials: three-node cuttings from four months old seedlings of Nissan Island (Autonomous Region of Bougainville) provenance, 0.3% IBA	Two irradiance treatments (full sun, 50% shade)	Randomized complete block, six cuttings treatment^{-1}, six replications per treatment.	

Mature material: marcotting

Experiments 5 and 6, aimed at developing marcotting protocols for *C. indicum*, were carried out respectively on clonal stock held in the NARI nursery at Keravat and on mature plantation trees.

For experiment 5, four ramets of each of four ortets were selected. The ortets had themselves been propagated three years previously by marcotting of mature trees from Vunatung Plantation near Kokopo, ENBP. The stem of each ortet was girdled (1cm wide strip) at three different positions along the stem. One of two IBA treatments (0%, 0.8%) was applied to the girdled stem, and a rooting ball composed of one of two rooting media treatments (coir, soil), wrapped with clear plastic, was attached to the stem. Two-weekly observations were made from weeks five to 13, with an additional final observation at week 22. The following response variables were measured: time to root formation, number of roots per marcot (final observation only), incidence of roots (= % rooting), and mortality (% mortality).

Experiment 6 looked at the effect of branch position (lower, middle, upper crown), substrate type (coir; coir, soil, sawdust mix), and IBA concentration (0%, 0.8%) on marcotting success. On 6th and 7th December 2006, 12 branches that had regrown after pruning 12 months previously (four in each of the lower, middle, and upper crown) were selected on each of 10 trees at Vunatung Plantation near Kokopo, ENBP. At each crown level, the four combinations of the two levels of the other treatments were applied, i.e. one combination to each of the four branches. Marcot balls were approximately xml in volume and were covered with transparent plastic in order to allow disturbance-free inspection. In May 2007, marcots were reset on 6 of the original trees and on four additional trees.

Monthly observations were made each month from January to April and July to November 2007. The two observation periods correspond respectively to non-fruiting and fruiting seasons. The following response variables were measured: time to root formation, number of

roots per marcot (final observation only), present and absence of root (= % rooting), and mortality (% mortality). The data were analyzed by analysis of variance (three-way factorial with trees treated as blocks).

Results

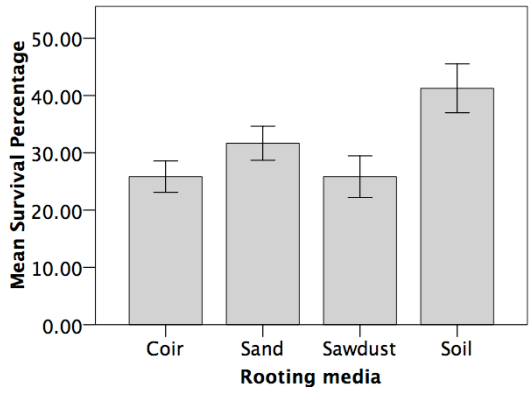
Juvenile Stem Cuttings

Experiment 1: Auxin, rooting media, and node position

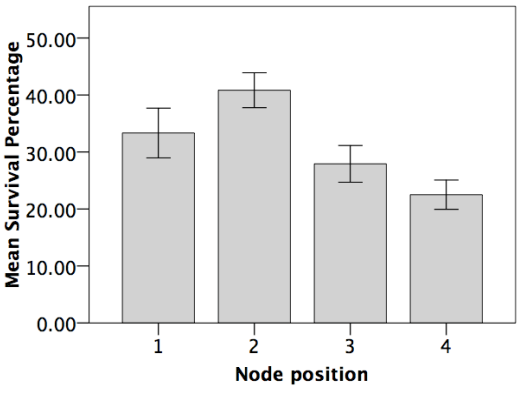
After three months, survival percentage was 31.2%, rooting percentage was 18.9%, and there was a mean of 1.1 roots per surviving cutting. There were significant effects of rooting media, auxin concentration, and node position on all three variables, except for auxin v. survival rate. There were no significant interactions.

Survival rate in soil was markedly higher than in the other substrates (40.5% v. ≤31.7%) (Figure 1a). Similarly, node 2 cuttings had survival of 40.8% v. ≤33.3% for other positions (Figure 1b). Overall, the highest mortality rates were attained for node 2 cuttings struck in soil with 0.3% IBA (60% survival).

IBA concentration had a positive effect on both rooting percentage and number of roots, which were highest at the highest concentration (Figures 1c, 1d). Cuttings struck in soil had the highest rooting percentages (28.3% v. 10.0-20% for other substrates) (Figure 1e) and numbers of roots (Figure 1f). Cuttings from Node 2 had higher rooting percentages (30.8% v. 15.4%-21.5%) (Figure 1g). Cuttings from node 1 produced a notably smaller number of roots (0.6 v. ≥1.2 for other positions) (Figure 1h). The rooting percentage of the best treatment combination (soil, 0.8% IBA, node 2) reached 50%.



(a)



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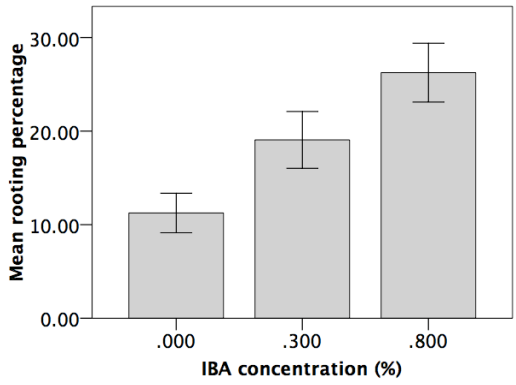

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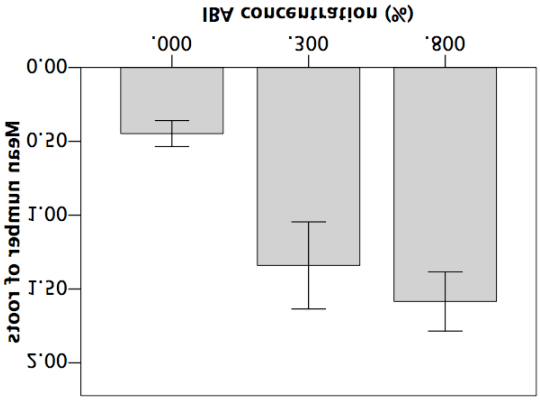

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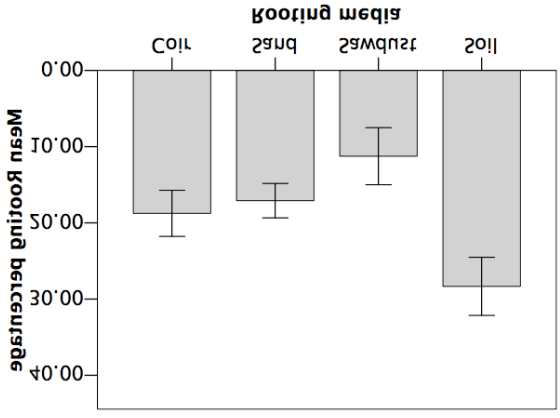
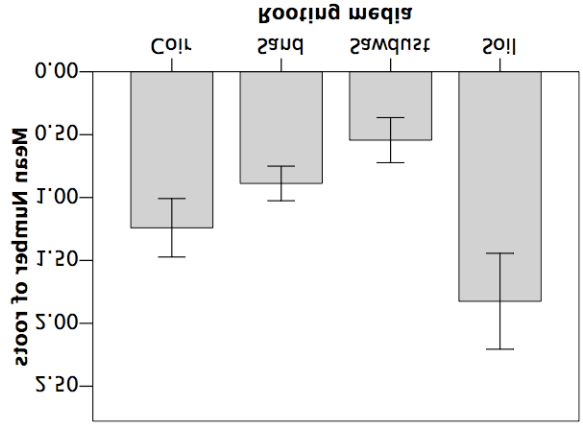
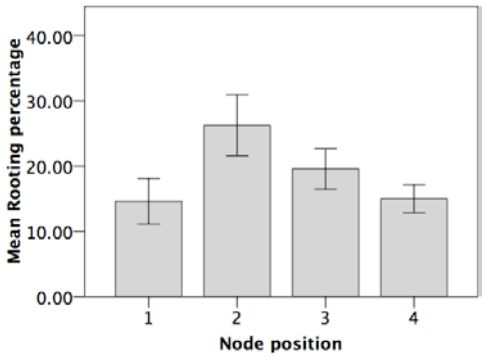


(e)

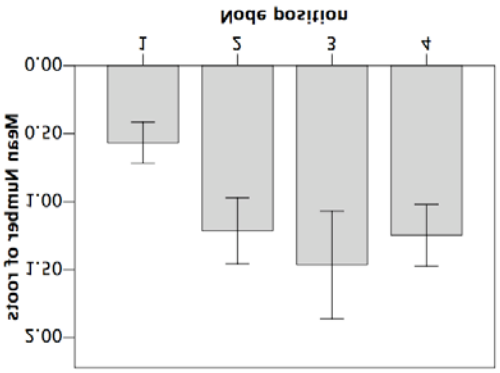


(f)

Figure 1. Effects of rooting media, cutting node position and IBA treatment on survival, rooting and eman number of roots of succulent cuttings of *Canarium indicum* (error bars indicate +/-1 standard error)



(g)



(h)

Figure 1. Effects of rooting media, cutting node position and IBA treatment on survival, rooting and eman number of roots of succulent cuttings of *Canarium indicum* (error bars indicate +/-1 standard error) (continued)

Experiment 2: leaf area, cutting length, rooting media

Survival percentage was 25.7%, overall rooting percentage was 16.9% and mean number of roots was 1.2. There were significant effects of leaf area and stem length on survival rate and rooting percentage, but no other significant effects.

The highest leaf area was associated with both the highest survival and the highest rooting percentage (Figure 2a,b). Similarly, the highest survival and highest rooting occurred with the largest cuttings (i.e. three-node cuttings) (Figure 2c,d).

The maximum rooting percentage (41.7%) was attained with three-node cuttings with 80cm^2 leaf area, struck in coir/gravel mix.

Experiment 3: leaf area and rooting media

After 3 months, survival percentage was 95.6%, rooting percentage of surviving cuttings was 94.4%, inclusive rooting percentage was 90.4%, percentage shoot incidence on surviving cuttings was 58.0% and mean length of the longest root was 18.0mm.

Rooting substrate significantly affected transformed survival percentage. Survival percentages were similar for soil, coir, and soil/sawdust, and and higher than those for soil/coir/sawdust mix, but were all >90%.

There were no other significant treatment or interaction effects.

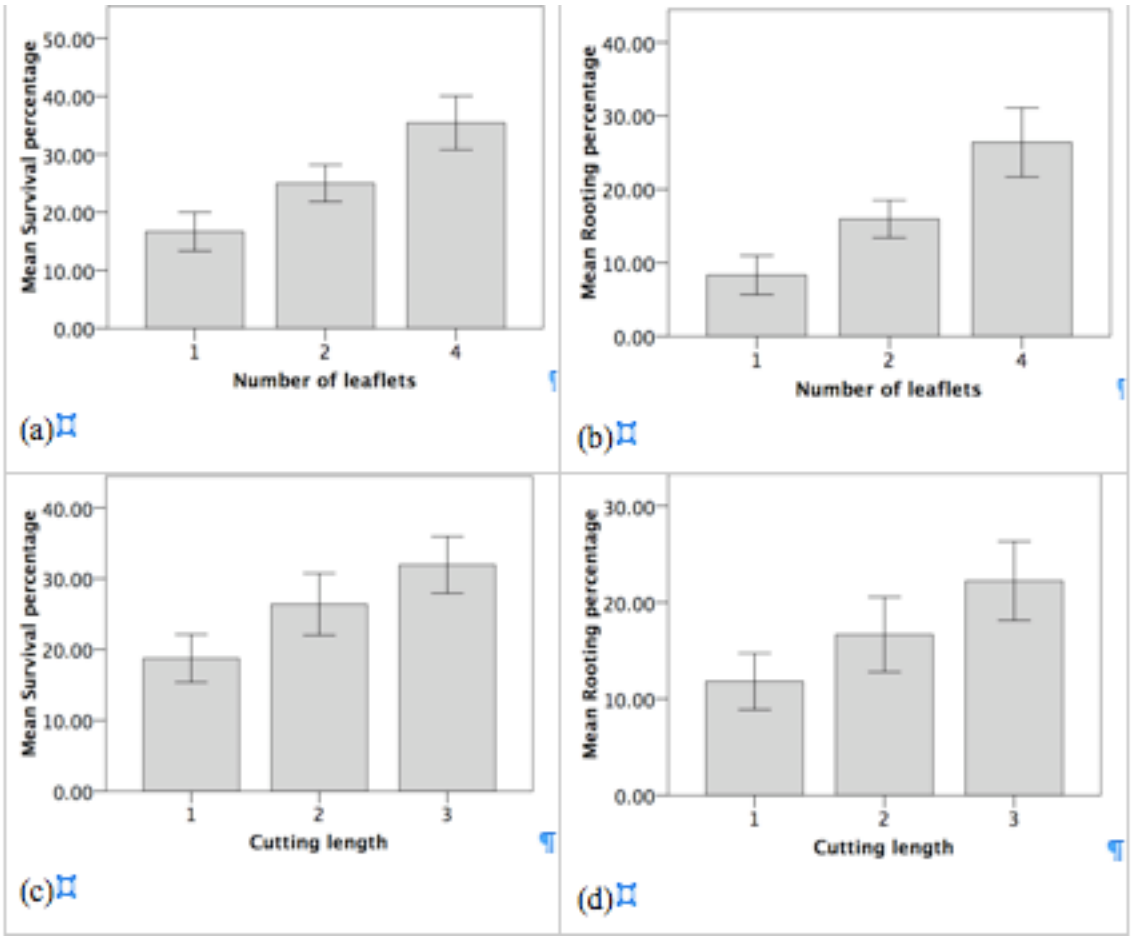


Figure 2. Effects of number of leaflets and cutting length on survival and rooting percentages of succulent cuttings of *Canarium indicum* (error bars indicate +/-1 standard error)

Experiment 4: irradiance

Overall survival percentage was 94.4%, rooting percentage was 94.2%, inclusive rooting percentage was 90.3% and 49.2% of surviving cuttings had produced new shoots within three months. Mean length of the longest root was 20.0mm. Survival percentage and length of the longest shoot were the same in the two treatments, whereas treatment means for the other variables were closely similar, with no significant differences.

Marcotting

Experiment 5

Overall percentage rooting was 29.2%; all marcots that rooted did so within 7 weeks (figure 3, left). IBA treatment had a significant positive effect on rooting percentage (figure 3, top right). Similarly, significant differences in percentage rooting were found between media; percentage rooting in coir was notably higher than for soil. By contrast, percentage rooting of marcots did not differ significantly different between clones nor between different stem positions.

Experiment 6: December to April

Overall, about one of every six marcots (15.8%) was successful. In most cases (84%) rooting did not occur until March or April. Success percentage varied greatly between trees: 92.1% in one tree, 30% in one, and 8.3% (one success) or zero in the remaining eight trees.

Experiment 6: June to November

Overall, about 1 in 12 marcots (8%) were successful. Rooting occurred from July to August, and was confined to three of the 10 trees.

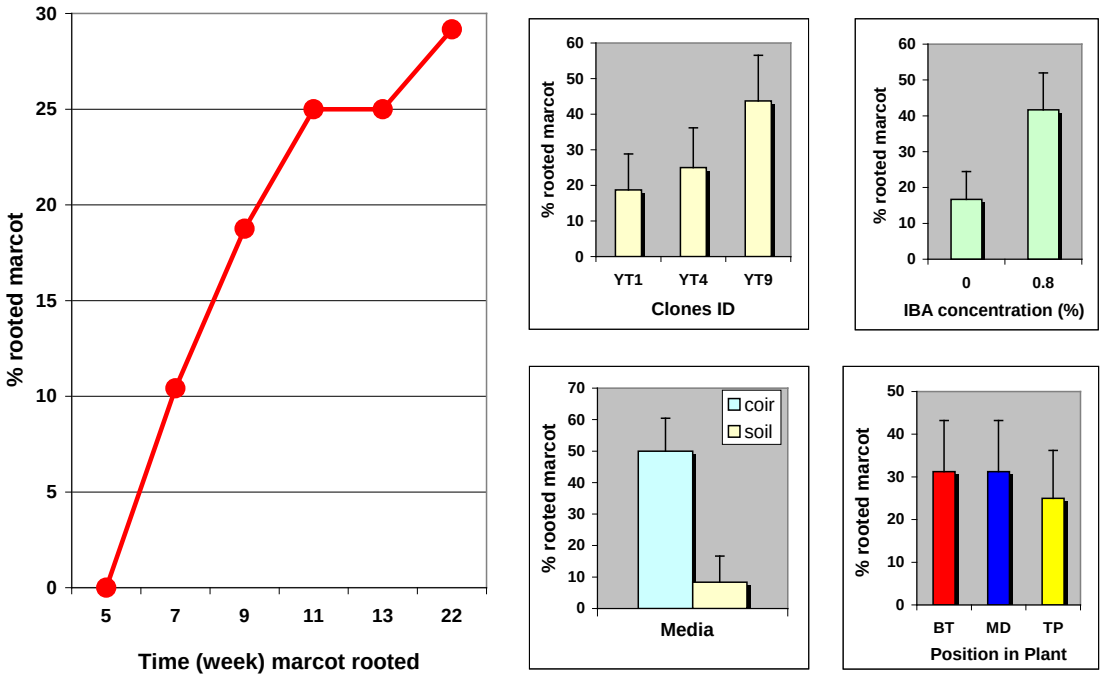


Fig 3. Results of an experiment on marcotting of *Canarium indicum*: left: percentage rooting with time, all treatments; top centre: percentage rooting by clone; top right: percentage rooting with and without IBA; bottom centre percentage rooting by media; bottom right: percentage rooting by marcot position on stem.

Combined results, December to November

As rooting success during each period was strongly concentrated on a relatively small number of trees, the data for both periods were pooled in an attempt to elucidate treatment effects.

Overall, there was at least one successful marcot on eight of the 14 trees. In general, percentage rooting and percentage mortality were similar between different treatment levels (Table 2) and differences were non-significant. However, stem position significantly affected percentage mortality (F=6.6, p.0.002); mortality rates in the upper crown were approximately one-third of those in middle and upper crown. The random effect of tree (block) was also significant for both rooting and mortality (F 3.81, p<0.000; F=7.7, p<0.000). There were no other significant main effects or interactions.

Discussion

Rooting of leafy stem cuttings

Our research has demonstrated the efficacy of non-mist propagators for propagation of *Canarium indicum*, hitherto considered a "difficult-to-root" species (Gunn et al. 2004). Rooting percentages of >90% can readily be achieved using succulent, three-node cuttings from shade-grown seedlings struck in either soil or coir, and following application of 0.8% IBA to cuttings.

Rooting percentages were notably lower in the cases of experiments 1 and 2. In part, this is attributable to particular treatment combinations that gave significantly inferior results, i.e. non-application of IBA, use of cuttings not from node 2 (experiment 1), leaf area < 80cm^2, use of cuttings of <3 nodes length (experiment 2; but note that single-node cuttings from node 2 performed as well in Experiment 1 as three-node cuttings in Experiment 2), use of sawdust as a rooting medium. However, even at optimum combinations of these variables (i.e. ostensibly in the same conditions as Experiments 3 and 4) maximum rooting was ⩾40%, suggesting that the use of healthy and vigorous stockplants is crucial to success in propagation.

Our research was aimed at developing working protocols, and was not designed to elucidate physiological explanations for the observed responses. The efficient rooting protocols that we have developed have already been applied in ENBP in multiplication of *C. indicum* germplasm for operational planting. However, the results of experiments 1 and 2 suggest that use of correct treatments may becomes more important when techniques are adapted to more challenging material, e.g. coppiced marcots; basic research into physiology of rooting may be of critical importance in developing protocols for such material.

Marcotting

Rooting percentage of marcots was both higher and less variable (i.e. between trees) in nursery-grown, mature material than in marcots set on mature trees in the field. In addition, treatment effects were stronger in nursery grown material (higher success rates after IBA application and in coir rather than soil). It appears that, in the field, treatment effects may be masked by the high variation between individual trees. The causes of this between-tree variation are unknown and will require further research to elucidate.

In spite of low per-marcot success rates, the research reported here has confirmed the utility of marcotting as a technique for "capturing" selected genotypes in the field. Approach grafting has also been applied as a supplementary technique. In spite of low success rate per marcot, success rate on a per-tree basis in East New Britain using marcotting or approach grafting (or both) has been close to 100%, facilitating the establishment in a field clone bank of 368 ramets of 223 East New Britain clones. We consider that the capture of genotypes of phenotypically superior individuals, rather than their mass-propagation, is the main application of marcotting in *C. indicum*. The approach may also be useful to villagers for cloning of individual trees. Indeed, in many villages in which NARI has carried out marcotting, community members have learned the technique and applied it to *C. indicum* and other fruit species, both native and exotic (Nevenimo, Page, Cornelius, personal observations). The current effectiveness of marcotting is already adequate for this purpose, and we suggest that future research should concentrate on techniques for mass propagation of material from such clones and on techniques for induction of flowering.

Acknowledgments

The work reported here was funded by the Australian Centre for International Agricultural Research (ACIAR) and the authors' own institutions. We gratefully acknowledge this generous support.

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10.3 Appendix 3: Post-Courier article "The Galip-nut Story"

THE GALIP NUT STORY

Dr John Moxon, Tio Nevenimo, Godfrey Hannet, Mathew Poienou, Kathy Yagau and Simon Minah *

New Export Industry for East New Britain

Galip nut is currently being developed as a new cash crop industry for the East New Britain Province by scientists at NARI Keravat. Over 100,000 elite seedlings have been produced and distributed to ENB farmers under an EU (STABEX) funded development project. These trees are expected to generate more than 36 million kina per annum in wholesale export and 20 million kina for ENB households. Requests have been received recently to assist the planting of a further 1 million trees on smallholder farms in ENB over the next two years. This will increase the above income to farmers and the province by ten fold. The good news comes at a critical time when the ENB rural sector and provincial economy is being seriously affected by the Cocoa Cod Borer pest.

Plate 1.Galip nuts (purple when ripe)

Background

Galip, Canarium indicum, is indigenous to Papua New Guinea, Solomon Islands and Vanuatu where it grows in the wet lowland forests. It is claimed to be the oldest domesticated species in Melanesia with archaeological records in the Sepik-Ramu area dating back 11, 000 years. It is called Gnali Nut in Solomon Islands and Nangai Nut in Vanuatu. A close relative is called Pili Nut in the Philippines. Galip is a tasty, highly nutritious nut containing protein, vitamins, healthy oils, and anti-oxidants. The unsaturated (omega) oils such as oleic acid and linoleic acid have medicinal properties including anti-inflammatory effects and benefits to the immune system. In parts of PNG and the Solomon Islands, the oil is traditionally used to treat osteoarthritis. The tree is also an A grade timber and is the 5th most common species in some areas of PNG. Resin from Canarium tree species can be distilled to produce Elemi Oil which is internationally traded for use in soaps, perfumes, cosmetics and paints. Galip is of cultural importance in many areas of the country such as Madang, Bougainville and West New Britain and a favored food throughout the wet lowlands. Nut-in-Shell can be sun dried and stored for about a year in the village and so contribute to food security. It is often made into a paste and mixed with taro or banana in traditional cooking and served at important cultural events. Galip is only sold in small quantities at roadside markets because most is consumed in the villages. However, it has the potential to be developed into a major cash crop for both domestic and export markets.

Commercial Development of Galip Nut

Galip was selected for large scale commercial development by the senior author in 2001. It was considered the most promising of a large range of fruit, nut, spice and other crops researched at the Lowlands Agricultural Experiment Station, Keravat (now NARI) over some 80 years. High quality nuts are universally perceived to be healthy and nutritious and are in high global demand. Galip is a high quality nut with a unique taste and has the potential to become a world commodity nut. An external horticultural review of PNG agriculture was commissioned by the Department of Agriculture and Livestock in 2002. The review supported the Keravat initiative and concluded "tree nuts offer the best horticultural prospect of any crop in PNG".

Table 1. World Nut Production (metric tonnes kernel)

Nut Species	1999	2009
Almond	*295,839*	*828,050*
Brazil	29,252	22,300
Cashew	850,000	490,000
Hazelnut	398,531	372,500
Macadamia	*19,160*	*30,416*
Pecan	97,856	95,039
Pistachio	243,632	497,800
Walnut	272,100	407,110
Total	2,206,370	2,743,215

A strategic research and development plan was designed. Establishment of a successful galip industry would need to address all major issues in the production and market chain. It would need to establish a reliable source of good quality nuts, good market access, commercial processing methods, product development, code of best practice, quality standards and identification of domestic and export markets. It also would need to engage private sector ownership in the R&D process – farmers, associations, processors and commodity traders. Substantial investment would be needed to establish a new major cash crop industry.

EU and ACIAR Support Galip Nut Research and Development

A series of R&D projects were designed to develop the new export crop. Financial support was generously provided by the European Union (K2.5 million) and the Australian Center for International Agricultural Research (K5 million). The ACIAR funded three scientific research projects. These were a Galip Feasibility Study in 2005, a Galip Domestication Project in 2006 and a Galip Processing Project in 2008. The EU funded three large development projects. The first project in 2003 identified galip and a number of other cash crops for development; the second in 2006 focused on identifying elite trees and establishing a horticultural base for commercialization; a third project commenced in 2010 to introduce elite galip seedlings to five more provinces and to pilot processing and product development. The informal synergistic combination of a donor specialist in research (ACIAR) and one specialist in development projects (EU) enabled progress on both essential components in parallel and so fast tracked the industry development process.

Supply of Galip nuts

Previous attempts to promote galip nut in PNG failed mainly because of an irregular supply of nuts of variable quality from the forest, poor market access and absence of experienced, well resourced commodity traders. A new successful industry would need to address these issues. A pilot project was initiated therefore in ENB where there is an efficient commodity chain of cocoa and coconut producers, processors, and exporters. The first step was to establish a reliable and substantial supply of good quality nuts. So, we focused on the integrated cocoa and coconut farming systems of some 20,000 rural households. If the pilot project worked in ENB where conditions are optimal then similar development initiatives could be attempted in other provinces.

Plate 2. Galip nursery at NARI Keravat funded by the EU

Plate 3. Small scale propagator used for multiplying galip and other fruit trees by cuttings at Keravat. Methods suitable for village use.

A source of good quality galip nuts had to be found. A search was made for 'elite' mother trees in six provinces. Many thousand trees were screened. An elite mother tree is one that has a high yield, large sized nuts, good kernel taste and a high kernel to shell ratio. Other selection criteria include early bearing habit, canopy diameter and vigor. Trees were selected with kernels over 3grams, kernel-to-shell ratio of over 24% and a tree yield over 60 kg nut-in shell/annum. Seed nuts were then collected from these elite mother trees and over 100,000 seedlings raised in nursery at the Keravat research station. The seedlings were distributed to farmers in ENB under the EU funded project. The development plan aims to establish a further 1 million elite seedlings in the province. Adaptive research has been conducted along the way focused on critical issues such as tree selection for yield and quality, propagation methods, germination, seed storage and galip / cocoa interactions. A number of scientific publications have been produced on the work.

Plate 4. Elite galip nut selections (nut-in-shell)

Cocoa Pod Borer Devastates Rural Household Incomes

The majority of rural households in ENB and some other provinces rely on cocoa and copra for their main source of income. A devastating cocoa pest called Cocoa Pod Borer (CPB) is present in Indonesia, Malaysia and Philippines. It was first detected in PNG in the ENBP in March 2006 but it is believed to have been present in the Sepik for a little longer. The pest rapidly

spread throughout ENB to other provinces and threatens to devastate the cocoa industry. Crop losses in ENB are already around 50% and may rise much higher over the next year or so. This represents a loss of over K 100 million/annum to cocoa households and a multiplier effect of about 1.5 times on the ENB economy. A new galip industry will diversify rural household income and so help reduce the socio-economic effects of the CPB crisis.

Galip as Dual Cash Crop and Shade Tree for Cocoa

Some five thousand galip trees inter-planted with cocoa were examined on three plantations in ENB. The galip trees are various ages up to 25 years old. The studies have shown that galip trees at low density (40 per hectare) provide good shade for cocoa, with no detriment to cocoa yield, and valuable extra income for the farmer. There are also benefits to the cocoa management. Gliricidea shade is needed for quick establishment of cocoa but requires regular pruning after about three years - this costs up to 10% of the cocoa farm labour input. Over-shading by gliricidea is one of the most common reasons for cocoa yield decline together with black pod and now CPB. Galip shade can be used to replace gliricidea after about three years and so eliminate the over-shading issue.

Plate 5. Cocoa growing well when inter-planted with 10 year old galip trees . No gliricidea shade trees are needed for the cocoa at this stage which helps to reduce the cocoa cost of production

Medium and High Density Galip Plantings

In ENB, the CPB problem may reduce 50, 000 hectares under cocoa to about 20,000 hectares. This is because some farmers will cease to grow cocoa and others reduce their cocoa blocks to a manageable size under intensive management. Galip can be planted at medium (80 trees/hectare) and high (160 trees/hectare) density and so presents a good solution for sustainable utilization of the 30,000 hectares of the impending vacant land. Intercropping of food and cash crops is still possible for several years and the option exists to thin out the galip trees at a later date if the land is need for continued intercropping.

Processing Galip Nuts

A major galip export industry will require high quality standards of products to be maintained. The kernels will need to be of the right size, colour, texture, taste, moisture content and free of contaminations such as aflotoxins. Galip oil will need to be as clear as possible, without contaminants and have very low levels of Free Fatty Acids. A four year ACIAR funded project based at NARI Keravat was sourced to research suitable processing methods. Much of the Australian macadamia small scale processing technology is relevant to galip nut. This information helped us to define the overall requirements for galip. The process involves husk removal, nut-in-shell drying, shell removal, testa removal, scalding and re-drying (critical control point), sorting/grading, product manufacture and finally packaging and storage.

Galip Factory Established

An EU project has funded the construction of a pilot galip processing factory at NARI Keravat. The factory will serve to commercially validate the galip processing methods produced by the ACIAR project and commercial processing equipments identified by the EU project. The pilot factory will then be used for stakeholder awareness, training and promotion of the new industry. The factory will be completed and fully equipped by mid 2010. It should be possible to process and produce a range of galip products for the domestic market by the end of the year. The products are likely to include dried/roasted/salted nuts, baking products such as cakes, stir-fry, chocolate coated, and a high grade edible oil. The pilot factory will operate until private enterprise assumes the role.

Plate 6. A range of macadamia kernel, oil and confectio products that also can be done for galip

Marketing Galip Nuts

Galip will be marketed as a high quality nut. The first range of products will be sold to a PNG domestic market where there is expected to be significant demand and low promotional costs. Processed galip nuts should be on the shelves in PNG supermarkets in 2010! As the PNG industry expands in volume, so galip is likely to progress to overseas niche markets and eventually become a world commodity. Strong support for the new galip nut industry and work at NARI, Keravat had been received from the private sector. Several major cocoa commodity traders in PNG have indicated their intention to construct processing factories. They have expertise in commodity trading, existing international marketing structures and local networks, cocoa buying points, shipping services etc that could readily and efficiently purchase galip nuts from farmers in all galip provinces. New traders may also emerge thus promoting competition and higher prices paid to farmers. The intention is to hand over galip nut development to the private sector as soon as possible.

Forest Resource

The new elite galip seedlings planted in ENB will commence bearing in 3 to 5 years time. The nuts will be of high quality and large size. However, there are an estimated 12 million galip trees in the PNG lowland forests that are immediately available. The forest nuts vary greatly in size and quality but there is potential to market this resource. Reforestation schemes could also consider establishing galip trees after logging as a source of cash for traditional land owners and eventually timber, though the nuts will be of much greater value. There is also scope for carbon trading.

Future Research and Development

A new EU funded project has just commenced that will introduce elite galip seedling varieties to five more cocoa provinces in 2010. The provinces are Madang, Sepik, New Ireland, West New Britain and Manus. Cocoa Pod Borer was recently confirmed in Bougainville. It is likely to cause extensive crop loss throughout the province within the next two years. Cash crop diversification is thus urgently needed there. A major galip initiative would be of great benefit to the province and should commence as soon as possible.

Galip is set to become a major export industry worth several hundred million kina per annum both at the farm gate and in export earnings. As such, a significant commitment to commodity research and development is needed with respect to agronomy, crop husbandry, breeding, plant protection, cocoa and coconut based farming systems, processing and marketing. This will need sustained support from the National Government and it's agricultural agencies in the short to medium term until export volume is sufficient to generate levies to make the industry self supporting.

Plate 7. A small sized galip close produced at NARI Keravat

Creation of a major cash crop industry for a nation is a considerable task. Rarely does a novel crop initiative consider the entire industry development requirement. Research is usually conducted piece-meal and inadequate attention paid to post harvest, value adding and market research. Private sector initiatives are usually under-capitalized and lack adequate institutional R&D support. Emerging agricultural industries have no effective association or governing body to parent them in their long journey to adulthood and usually flounder. A classic example is the rapid rise and demise of the PNG vanilla industry where virtually everything that could go wrong did so. The last successful attempt to establish a new cash crop commodity was oil palm some 40 years ago – a private enterprise initiative with a complete, fully resourced development package. Galip is just one of many quality indigenous PNG nuts with potential for domestication and commercialization. The way is open for realization of additional new export cash crop industries for PNG. However, a well coordinated, well resourced and fully comprehensive R&D process, under good parenthood is essential. Current research at NARI, Keravat is also examining the commercialization potential of a range of low management input crops, indigenous to PNG where we have a comparative advantage of diverse genetic resources such as Okari nut, Taun fruit, nutmeg, kava, noni, taro and pit pit.

Galip Nut Workshop

A two day workshop on galip nut was held at NARI Keravat in November 2009. The workshop comprised scientists from NARI Keravat, seven experts from the Australian macadamia industry and important stakeholders from the PNG Private and Public Sectors. It reviewed progress on the various galip projects at Keravat and concluded that a new significant galip nut industry is now well underway in ENB - the horticultural resource base of over 100,000 elite galip trees established by the EU project in ENB is now a commercial reality!

Macadamia nut, which is native to Australia, has been domesticated, commercialized and developed into a successful world commodity. Development and commercialization of galip nut is following a similar process. Much information, technology, and experiences is being transferred from the macadamia industry to develop the new galip industry. The Australian macadamia experts are part of the ACIAR donor projects at Keravat and provide ongoing valuable expert inputs to the galip programme. They include a successful grower/breeder/inventor/small scale processor, nut processing academics, agri-business expert and the Australian Macadamia Society industry development manager.

PNG Galip Association

Active stakeholder participation is key to successful development of any new crop. Following the galip workshop, a meeting was held at the PNG Growers' Association at Kokopo in East New Britain to establish a PNG Galip Association. The purpose of the Association is to coordinate the future development of the new emerging export crop industry. Farmers, potential processors, established cocoa and coconut commodity traders, ENB Provincial Government and National DAL attended the meeting. The meeting resolved to establish a new Galip Industry Association led by the Private Sector. The Association will be affiliated to and initially assisted by the PNG Growers Association based in Kokopo with technical back up from the scientific team at NARI Keravat.

Further Information

Information on galip cultivation, processing, crop budgets, industry forecasts and supply of elite planting materials can be obtained from:

* National Agricultural Research Institute, Islands Regional Centre, P. O. Box 204, Kokopo, ENBP, phone 9892002/145, fax 9892120, email narikip@nari.org.pg).

Information about the new PNG Galip Association can be obtained from: CEO, PNG Growers Association, P. O. Box, Rabaul, phone 9829123, fax 9828003, email growers@global.net.pg).

"Proudly sponsored by: PNG Growers Association, NGP Agronomic Group of Companies, East New Britain Development Corporation, and Keravat Cocoa Experts"

10.4 Appendix 4: Domestic marketing study

ACIAR Project FST 2004/055

Domestication and commercialization of Canarium indicum in Papua New Guinea

Potential for the Marketing of Galip Food Products in Papua New Guinea

May 2010

Acknowledgements

Report prepared by Colin Bunt

Macro Consulting Group Pty Ltd

The assistance of the following persons is gratefully acknowledged.

Mr. Ang Cheng Chooi, General Manager, RH Trading Ltd, PNG

Dr. Jonathan Cornelius, James Cook University, Australia

Mr. Kevin Dacey, Trade Commissioner, Austrade, PNG

Ms. Pamela Haslam, Senior Category Manager, Stop N Shop, PNG

Mr. Robert Hurst, Group General Manager, BNG Trading Company Ltd, PNG

Dr. John Moxon, NARI, Islands Regional Centre, Kokopo, PNG

Ms. Emily Ravusiro, Business Development Manager, Austrade, PNG

Mr. Albert Rocero, General Manager, Coral Investment Ltd, PNG

Mr. Ken Siminji, Senior Business Development Manager, Austrade, PNG

Mr. Geoff Shearer, General Manager, Boroko Foodworld Limited, PNG

The author also gratefully acknowledges the funding provided by the Australian Centre for International Agricultural Research (ACIAR).

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Study Objectives

The objectives of this Study were to research and provide a written report on the following:

- Estimate the size of the commercially produced Galip raw material supply. This would be based on the crop projections developed by NARI
- Identify current nut imports into PNG, for example, volumes by product, price range, origin, major importers and distributors
- Examine the current commercial market for nuts within PNG (for example; retail, food service companies, food manufacturing) including nut purchasing and consumption trends in PNG and any potential for future growth
- Provide an overview of packaging and labelling requirements
- Consider any potential for “suitcase export” via domestic market outlets

- Identify any Galip product differentiation and value adding options suitable for the PNG market
- Provide a preliminary strategy for the domestic marketing of commercial Galip products

Executive Summary

One of the biggest issues facing the Galip industry is that the product is virtually unknown outside Melanesia. Creating sufficient demand for Galip in export markets to match projected production volumes will therefore be a major industry challenge. Conversely, Galip potentially has significant commercial advantages within the domestic market. These domestic market advantages include:

- √ Very high consumer familiarity with Galip in its traditional forms
- √ Strong consumer interest in commercial Galip products, based on consumer surveys
- √ The very high price of most imported nut products in PNG (with the exception of Chinese peanuts)
- √ Import duties of 25% on imported nuts
- √ Increasing consumer demand for snack food products
- √ Strong consumer demand for locally produced products and PNG brands
- √ Proximity to market (relative to imported products)
- √ Existing cocoa distribution infrastructure can be utilized for Galip

Maximizing the domestic market potential of Galip will be a critical first step and long term cornerstone of the PNG Galip industry. The domestic market will be especially important in regards to:

- √ Establishing and implementing commercial processing, distribution and marketing systems
- √ Generating income and cash flows for growers and processors alike
- √ Product development and market testing for future export activity

In 2004-2005 a consumer study was carried out by Nevenimo et al. This study, which assessed the future potential of Galip as a commercially produced product in the PNG domestic market was found to be positive.

The 2004-2005 study interviewed *consumers*, both PNG Nationals and Expatriates. It therefore provides a relevant counterpoint to this current study, which has been based on discussions with *retailers*, *wholesalers*, *importers, merchandisers* and *distributors*.

Very little published data was found on food retailing in PNG, particularly data relating to the importation, sales, pricing and consumption of specific product lines. Because of the limited published data available, the primary research method used in this study involved interviews with various key people in the PNG retail and food service industries.

The methodology used in this study relied heavily on anecdotal evidence. Anecdotal information can be viewed as subjective and having limited value. However, there was a high degree of consistency in views expressed amongst the persons interviewed. Where applicable, these views were also generally consistent with the findings of the consumer research undertaken by Nevenimo et al in 2004-2005.

Similar views were evident amongst the persons interviewed in regards to:

- The very good potential for Galip as a commercial product in the PNG domestic market, mainly due to familiarity with the nut amongst consumers

- General characteristics and peculiarities of the food retailing sector in PNG
- Market demographics and variances between PNG market segments
- Particular aspects of the PNG market in terms of consumer buying patterns, product sizing preferences and critical price points
- The strong consumer demand in PNG for competitively priced snack foods
- The very limited demand in PNG for most imported nut lines
- Identification of key competitor snack food products already available in the PNG market that need to be benchmarked by the emerging Galip industry, particularly in regard to retail pricing
- Packaging preferences, labelling requirements and suggestions for initial Galip product offerings
- The effectiveness (or otherwise) of various product promotion strategies
- The importance of brands to PNG consumers and the very high degree of brand loyalty seen in the domestic market
- The necessity for the Galip industry to develop different, yet complementary domestic and export marketing strategies

Imported nuts (excluding Chinese manufactured packaged peanuts) were said to attract "miniscule" demand and achieve minimal sales in PNG. This was due to the high price of imported nuts and subsequent consumer resistance amongst both PNG Nationals and Expatriates. Packaged peanuts from China were the only imported nut that achieved significant retail sales and would likely be the major competitor to Galip.

Discussion as to the quality merits or otherwise of the Chinese peanut products relative to Galip was seen as basically irrelevant in the very price driven PNG retail market. The fact that consumers could buy a very popular, branded nut snack for an acceptable price (approximately 3 kina) was seen as the critical factor from a retail sales perspective.

All interviewees were adamant that a Galip snack food product would need to match the retail price of the Chinese peanuts. However, consumers would likely be less concerned with 'value for money' in terms of the volume of nuts per pack. Interestingly, approximately 3 kina for a 50 gram pack had been found to be the price threshold for Galip in the 2004-2005 consumer study.

The PNG market was described as very brand conscious and brand loyal, with significant brand loyalty afforded to PNG companies and multinationals with processing operations in PNG (such as Coca Cola). It was recommended that one dominant domestic Galip brand be developed and promoted, with this brand strongly and obviously "PNG." It was felt that once one brand had become established in the market it would be difficult for other competitors to capture its market share due to consumer brand loyalty.

It is impossible to accurately predict domestic market demand. However, an attempt at demand projection is needed for business feasibility purposes. Nut consumption in developed markets varies widely, but a per capita annual consumption rate of 1kg can be considered very achievable. If, due to income constraints and population demographics, only 20% of PNG's population of 6.6 million people consumed 1kg of product per annum this would still equate to a domestic market of 1320 tonnes. If retail snack products made up the vast majority of PNG nut consumption and Galip was able to capture 75% of this market (which may be feasible if the product can be marketed competitively against Chinese peanuts, the only manufactured nut snack product of commercial significance in

PNG), then this would equate to a potential PNG market for Galip of 990 tonnes per annum.

The Food Service and Food Manufacturing sectors prefer to test and evaluate actual product samples prior to offering any definitive comment. Therefore, Galip product samples of an acceptable standard will need to be developed for circulation and testing in these sectors in order to stimulate demand. HACCP plans must be in place and supply assured before Food Service and Food Manufacturing sectors will consider purchasing new ingredients.

Expatriates, though less price sensitive than PNG Nationals, were aware of and would expect to pay 'local' prices for food and beverage products in supermarkets. However, Expatriates and tourists would expect premiums to be charged at specialist venues such as Resorts, Hotels, Airport Lounges and Duty Free Shops. Given the current size of the Expatriate and tourist markets in PNG it was suggested that these not form the major component of the Galip domestic market strategy. However, Expatriates and tourists in PNG and the venues they frequent offer opportunities to test products, packaging and branding 'on-shore' as part of a broader export market strategy.

This report concludes with 10 recommendations regarding the future domestic marketing of Galip in PNG for industry consideration. Planning recommendations pertain to:

1.	Product Positioning	2.	Retail Price Point
3.	Packaging and Labelling	4.	Retail Product Form
5.	Creation of a Domestic Brand	6.	Domestic Market Promotion
7.	Processing Capacity v. Demand	8.	PNG Value Chains
9.	Food Service and Manufacturing	10.	Expatriate and Tourism Sectors

1. DOMESTIC MARKET OVERVIEW

Papua New Guinea (PNG)'s population is estimated at 6.6 million and is growing by an annual average rate of 2.7%. Approximately 40% of PNG's total population is under 15 years old.

Most of the population lives in rural communities based on the traditional village structure and dependent on subsistence farming supplemented by cash cropping. Around 13% of the Papua New Guinea population lives in urban areas

PNG has a relatively small dual economy, made up of formal and informal elements. The formal economy is dominated by large-scale resource projects, particularly in mining and petroleum, and provides a large proportion of government revenue. The informal economy supports 85% of the people through semi-subsistence agriculture. The formal sector employs around 15% of the workforce (AusAID 2010).

Table 1.1: PNG - Basic social and economic indicators

Indicator	Amount
Land area	462,800 square km
Sea area	3,120,000 square km
Capital	Port Moresby
Population (2007)	6.32 million
Population average growth rate	2.7 per cent a year
Urban population (2004)	13.3 per cent
GDP growth rate (2008)	6.6 per cent
Gross national income per capita	US$850

Source: AusAID

In regards to the food and beverage industry, Austrade reports an increase in food and beverage imports into PNG from Asia, including China. This is reportedly due to an increase in the size of the Asian business community in PNG.

Austrade also reports increased consumer demand in PNG for an increasing variety of food types. An indicator of this increased market diversity can be seen in the major opportunities for Australian exporters into PNG's food and beverage market currently nominated by Austrade (table 1.2).

Table 1.2: Nominated Food and Beverage Opportunities for Australian Exporters in the PNG Market

Fresh fruit and vegetables – fruits, exotic vegetables, salad greens
Dairy products – fresh milk, cheese, butter, ice cream
Meat – beef and lamb cuts
Beverages – wine, fruit juice, flavoured milk, sports and health drinks
Ethnic food – Asian, Indian, Italian and Mexican
Grocery products – pasta, breakfast cereal, snacks, condiments
Frozen foods – vegetables, pizza, pastry
Gourmet foods – salamis, flavoured cheese, dips and pates
Food ingredients for the manufacturing sector

Source: Austrade

PNG has a single rate value added tax (VAT) of 10 per cent. Papua New Guinea Customs use the single column based on the Harmonised system. Most duties are applied ad valorem using the World Trade Organisation (WTO) valuation code guidelines of CIF value. Imported nuts attract a tariff of 25%.

The PNG food and beverage market is described as a relatively unsophisticated, price-driven market in which exporters must be prepared to supply relatively small volumes on a relatively frequent basis. Companies supplying food and beverage products into PNG are also encouraged to fund promotional activities, such as media advertising, point-of-sale material and in-store promotions.

There are no major or regular trade fairs for the food and beverage industry in PNG, although retailers and food service companies conduct in-house and external promotions. Many of the major food retailers in PNG are involved in an

array of consumer retail categories for instance, hardware and groceries (Austrade 2010).

2. POTENTIAL CONSUMER DEMAND FOR GALIP IN PNG

In 2004-2005 a consumer study was carried out by Nevenimo et al as part of the ACIAR Project FST/2002/010 '*Domestication and Commercialization of Galip Nut Feasibility Study*'. This research assessed the future potential of Galip as a *commercially produced product* in the PNG domestic market. Section 2 summarises some of the key findings of the 2004-2005 study pertinent to the objectives of this report.

The 2004-2005 consumer research objectives were to:

- Determine the potential market demand at the consumer level for Galip nuts by conducting surveys in a range of urban centres in PNG Determine consumer opinions about any enhanced availability and their preferred means of consuming of Galip nut.
- Identify the potential opportunities and constraints to marketing of Galip commercially in the PNG domestic market

The 2004-2005 study exclusively surveyed *consumers*, both PNG Nationals and Expatriates. It therefore provides a relevant counterpoint to the study summarised in this report, which has been based on discussions with *retailers*, *wholesalers*, *importers, merchandisers* and *distributors*.

Nevenimo et al (2005) found that Galip is normally consumed in the form of fresh raw nuts, (this is when the nut is extracted from the shell when the nut is still fresh), as dried kernels, (this is when the nut in shell is sun dried stored and shells cracked), or as kernels extracted from the shells (fresh or dry) and roasted. Kernels (fresh or dry) were also used as ingredients in conjunction with other food products (for example, in baking).

This demonstrated the versatility of the product, even in its traditionally marketed form, with a large number of people consuming Galip nuts in a wide variety of ways and in the preparation of other foods.

Nevenimo et al (2005) found that many PNG Nationals were unfamiliar with many of the imported nuts available in supermarkets in PNG, with the notable exception of peanuts. Fifty seven percent of the respondents were not familiar with Cashew, 70 % with Macadamia, 69% with Hazelnuts, 73 % with Brazil nuts and 75% with Pistachio nuts. This made ranking of Galip in comparison to other nut products problematic. The study also identified that the imported nuts available for purchase in supermarkets were simply unaffordable for most PNG Nationals, especially those on average wage levels or less.

The 2004-2005 study considered the potential demand for Galip in terms of year round availability as well as the likely frequency of purchase by consumers. When asked if they would like to be able to buy more Galip nuts than they currently do, 64% of survey respondents said they would. The vast majority of the respondents (96%) said they would like to buy Galip nuts all year round if nuts were available for purchase.

Nevenimo et al (2005) concluded that this response demonstrated a significant demand for Galip nuts outside the normal (seasonal) production and marketing

window, which could be partially addressed by introduction of a coordinated Galip marketing system.

The preferred product form nominated by survey respondents for commercial Galip products were in its traditional form, that is, as raw kernels. Nevenimo et al (2005) concluded that raw kernels were preferred over dried kernels in part due to consumer familiarity and in part due to quality problems commonly found with dried kernels. Quality problems were likely due to technical constraints experienced by smallholders in attempting to dry nuts effectively.

The 2004-2005 consumer study found widespread willingness to purchase commercially processed and commercially packaged Galip (Figure 2.6), indicating there would not be any consumer resistance against the acceptance of a commercial Galip industry in PNG.

To test consumer response from a pricing perspective, consumers were shown 50g of Galip kernels in a clear plastic package and asked how much they were prepared to pay for the pack, should it be commercially available. The average price the respondents in the different geographic regions surveyed said they would pay for a commercial 50g pack of Galip is shown in Table 2.1.

Table 2.1: The nominated preferred price for a 50g packet of Galip by region

	Rabaul	Lae	Port Moresby	Average (all Locations)
Average price (Kina) 50gm pack	2.33	3.14	3.13	2.73

Source: Nevenimo et al 2005

There was a significant difference in the price respondents interviewed at supermarkets said they would pay for the 50g package than those at open markets. The average price the respondents at the different market outlets were willing to pay for a commercial 50g pack of Galip is shown in Table 2.2.

Table 2.2: The nominated preferred price for a 50g packet of Galip by market outlet

	Open market	Supermarket
Average price (Kina) 50gm pack	2.35	2.99

Source: Nevenimo et al 2005

There was also a significant difference in the price expatriates said they would pay for Galip than the PNG Nationals who were interviewed (Table 2.3)

Table 2.3: The nominated preferred price for a 50g packet of Galip by market outlet

	PNG Nationals	Expatriates
Average price (Kina) 50g pack	2.51	3.45

Source: Nevenimo et al 2005

There was a marked trend in the relationship between the amount PNG Nationals were willing to pay for a 50g pack of Galip and their income. Logically, the respondents with lower incomes would prefer to pay less for the Galip than those in the higher income range (Figure 2.6)

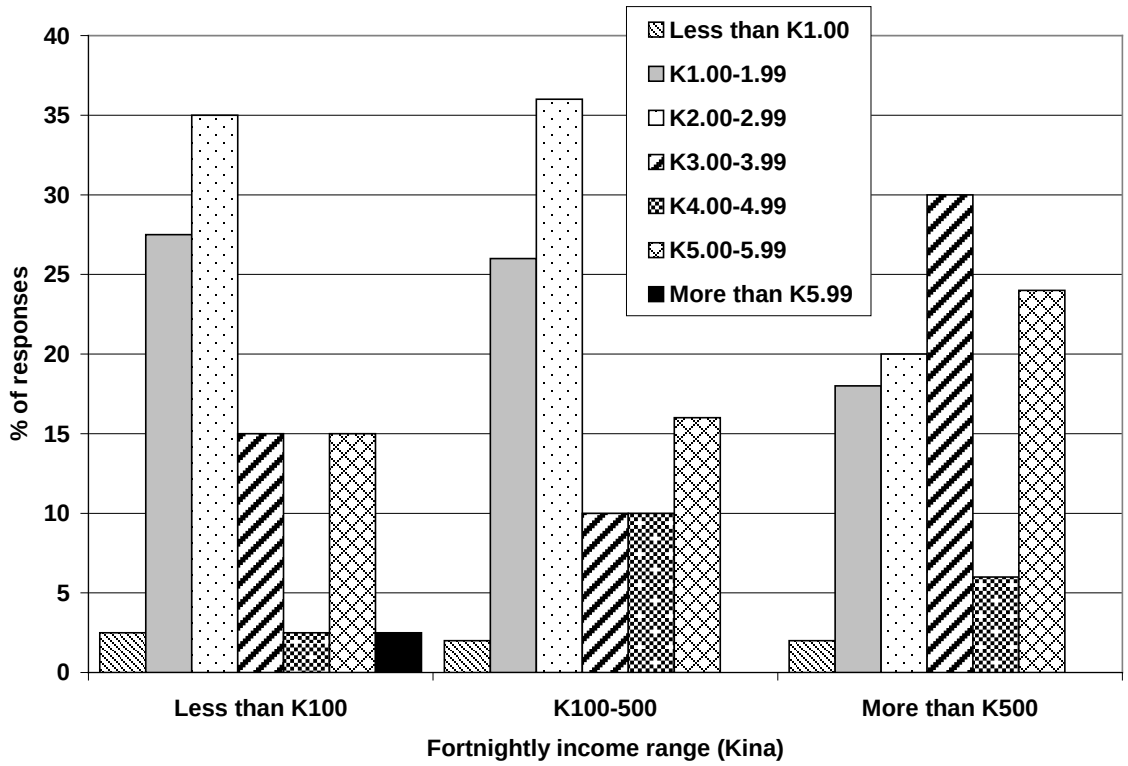

Figure 2.6: Price consumers willing to pay when comparing their family income

Source: Nevenimo et al 2005

Nevenimo et al (2005) concluded that the 2004-2005 study demonstrated that consumers would be willing to pay in the range of K40 to K70 per kilogram (cumulative retail value) for packaged Galip kernels depending on their location, socio-economic situation and ethnic background.

The 2004 - 2005 consumer study also found that the majority of the respondents, both PNG Nationals and Expatriates were willing to buy commercially processed and commercially packaged Galip nuts, indicating there would be little consumer

resistance to a commercial Galip nut industry in PNG. This suggested potential success for a commercial Galip industry targeting a domestic consumer base; assuming stated consumer requirements for pricing, quality and year round availability could be achieved.

3. SUMMARY OF THE PNG IN-MARKET STUDY

Very little published data was found on food retailing in PNG, particularly data relating to the importation, sales, pricing and consumption of specific product lines. Because of the limited published data identified, the primary research method used in this study involved interviews with a number of PNG retailers, wholesalers, importers, distributors and merchandisers. These persons and organisations were nominated by Austrade, based on the study objectives. Discussions were also held with Australian Trade officials based in PNG.

The methodology used in this study relied heavily on anecdotal evidence. Anecdotal information can be viewed as subjective and having limited value. However, there was a high degree of consistency in views expressed amongst the persons interviewed and these views also proved generally consistent with the findings of Nevenimo et al (2005), as outlined in Section 2 of this report.

The views expressed in the interviews undertaken in this study have been summarized under the following headings:

Market Categories

- Retail
- Food Service and Food Manufacturing

Discussion Points

- Domestic Market Potential for Commercial Galip Products
- Competitors
- Product Form
- Packaging and Labelling
- Pricing
- Marketing Strategy, Branding and Promotion
- Supply Chain Management

3.1 Retail

3.1.1 Domestic Market Potential for Commercial Galip Products

Interviewee response to the potential for Galip as a commercial product was very positive, but only if the product was positioned correctly from a marketing and pricing perspective.

Positive attributes of Galip that were nominated by interviewees included:

- The fondness PNG consumers have for Galip as an indigenous, versatile, tasty food product. There is a high degree of familiarity with Galip amongst PNG Nationals (and many Expatriates) in its traditional product form e.g. sold in karamaps during the Galip season
- There would be potential market advantages for domestically produced nut products due to the very high retail cost of most imported nuts. Also, imported nuts attract a duty of 25%

- Galip is seen in the market only when it is in season, yet the interviewees felt that the public would respond well to year round Galip availability
- PNG Nationals were said to be very loyal to local food products, PNG brands and PNG domiciled food manufacturing companies
- Demand for snack foods was said to be strong and growing in the PNG market. Particular opportunities exist for healthy snack food options which are positioned as tasty, affordable alternatives to less healthy snack products

3.1.2 Competitors

Imported nuts (excluding Chinese manufactured packaged peanuts) were said to attract "miniscule" demand and achieve minimal sales. This was due to the high price of imported nuts and subsequent consumer resistance amongst both PNG Nationals and Expatriates. Table 3.1 shows retail prices for a range of nut products found in various retail outlets in Port Moresby in May 2010.

Table 3.1: Sample of Imported Retail Nut Snack Products – Nut Type and Price

Nut Type	Pack Size (grams)	Retail Price (K)	Price per 100 grams (K)
Pistachios	**80**	**20**	**25.00**
Pecans	**125**	**29**	**23.20**
Macadamias	**110**	**14**	**12.72**
Walnuts	**150**	**18**	**12.00**
Hazelnuts	**120**	**13**	**10.83**
Cashews	**120**	**13**	**10.83**
Almonds	**130**	**12**	**9.23**
Australian Peanuts	**500**	**16**	**3.20**
Chinese Peanuts	**185**	**3.3**	**1.78**

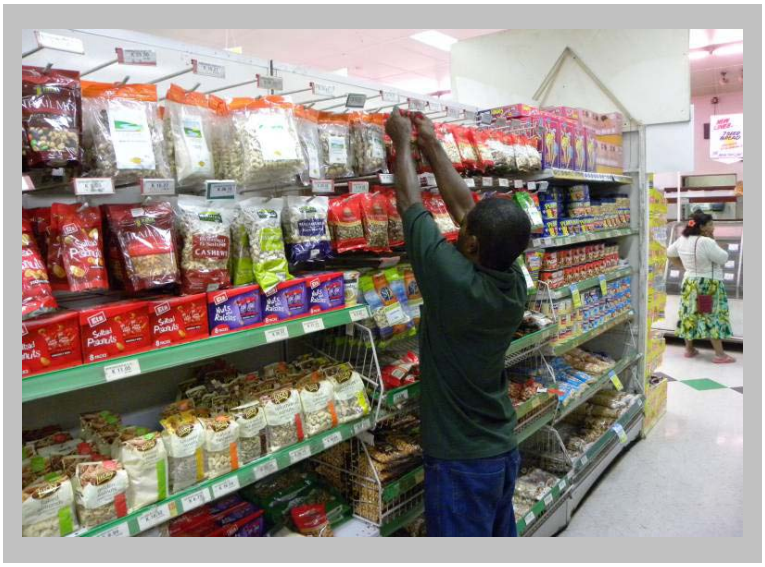

Figure 3.1: Imported nut display, retail environment, Port Moresby

All interviewees nominated packaged peanuts from China as the only imported nut that achieved significant retail sales and the major competitor to Galip. Discussion as to the quality merits or otherwise of the peanut product relative to Galip was seen as basically irrelevant in the very price driven PNG retail market. The fact that consumers could buy a very popular, branded nut snack for an acceptable price (approximately 3 kina) was seen as the critical factor from a retail sales perspective.

It is also worth noting that approximately 3 kina per pack was found to be the price threshold for Galip in the consumer study undertaken in 2004-2005 (Nevenimo et al 2005).

Figure 3.2: Imported Chinese peanuts, retail environment, Port Moresby

Actual volumes of nut imports into PNG could not be ascertained. However, all interviewees reported that nut products, excluding the Chinese peanuts, attracted very minimal sales. The volume of Chinese peanuts being imported into

PNG for retail sales was estimated to be in the region of 120t per annum; representing an annual retail value of approximately 2 million Kina for this product line.

Imported Chinese peanuts were available in two pack types, 100gm soft packs and (predominately) 185gm tins. The product was reportedly able to be purchased by PNG importers for between US15 to US20 cents per pack at the factory door (equivalent to 0.45 to 0.6 Kina) with the major import costs being transport and government duties *(note; these figures are anecdotal and could not be verified).*

3.1.3 Product Form

Interviewees suggested that the initial product offerings of Galip into the domestic market should be in forms consumers were already familiar with, that is raw, dried or roasted.

Sugar coated Galip nuts are said to be very popular in Vanuatu (pers. com. Mr. Charles Long Wah). However, PNG people were said by interviewees to view Galip as a healthy product and it was recommended that care should be taken that value adding initiatives should not contradict the perception of Galip as a tasty yet healthy snack food.

Interviewees felt that the type of value adding initiatives seen in the Macadamia industry were better suited to high value, sophisticated export markets rather than the PNG domestic market, although opportunities existed to 'test' value added products in carefully selected outlets in PNG, such as Airport Lounges, Hotels, Resorts and Duty Free shops.

There was no common view as to an ideal retail pack size, with recommendations ranging from 50gm to 200gm retail packs. However, all interviewees were adamant that the product would need to match the retail price of the Chinese peanuts, that is, approximately 3 kina per pack.

Interestingly, PNG consumers were said to be very price sensitive, but far less responsive to unit value savings available in higher volume, value packs. That is, small packs of food and beverage products priced at a low cost sold far better than larger packs at a higher cost, even if the larger packs represented significantly better overall value. Examples mentioned of category 'best sellers' by retailers were 250ml bottles of cooking oil, 50gm packs of milk powder, 750 ml bottles of cordial, 50gm packs of coffee and 1kg packs of rice.

3.1.4 Packaging and Labelling

Interviewees recommended choosing a low cost, simple packaging option (such as plastic soft packs) in which the nuts would be clearly visible. Consumers were reportedly very wary of packaging in which contents cannot be seen, especially when making 'first time' purchases.

Labelling requirements in PNG were reportedly as per Australian labelling requirements. This was confirmed by Austrade.

3.1.5 Pricing

Retailer margins for non-essential food and beverage products reportedly range from 30% to 50% plus VAT, depending on a range of factors including product type, sale volumes and retailer business policies.

As stated previously, all interviewees were adamant that a Galip snack food product would need to match the actual retail price of the Chinese peanuts, that is, approximately 3 kina per pack, yet consumers would be less concerned with 'value for money' in terms of volume.

Expatriates, though less price sensitive than PNG Nationals in general, were well aware of and would expect to pay 'local' prices for food and beverage products in retail (supermarket) environments. However, Expatriates and tourists would expect premiums to be charged at specialist venues such as Resorts, Hotels, Airport Lounges and Duty Free Shops. Given the current size of the Expatriate and tourist markets in PNG it was suggested that these not form the major component of the Galip domestic market strategy. However, Expatriates and tourists in PNG and the venues they frequent offer opportunities to test products, packaging and branding 'on-shore' as part of a broader export market strategy.

The 2004-2005 PNG consumer study utilized a 50gm pack of Galip in eliciting responses from both PNG Nationals and Expatriates. These responses were generally positive (Nevenimo et al 2005). Based on the consumer survey and the outcomes of interviews conducted in this study, initial costing studies for the domestic retail market should be based on producing 50gm soft packs of Galip.

Costs would need to be calculated for dried and roasted Galip products, which would be sold at retail for approximately 3 kina. This product sizing and pricing strategy (if found to be viable) would result in Galip achieving an overall retail value of approximately 60 kina per kilogram.

3.1.6 Marketing Strategy, Branding and Promotion

The industry persons interviewed in this study (all experienced and successful food industry business people) said that any PNG food manufacturing initiative and pricing strategy must be realistic and achievable. There needed to be a clearly defined yet dynamic correlation between available processing capacity, volumes being supplied to the market and the evolving market demand.

Interviewees highlighted the necessity for commercial Galip products to be positioned as 'manufactured snack food products' available year round at a standardized retail price and quality, rather than as a seasonally available, variable cash crop.

The PNG market was described as very brand conscious and brand loyal, with significant brand loyalty afforded to PNG companies and multinationals with processing operations in PNG (such as Coca Cola). It was recommended that one dominant domestic Galip brand be developed and promoted, with this brand strongly and obviously "PNG." It was felt that once one brand had become established in the market it would be difficult for other competitors to capture its market share due to consumer brand loyalty.

Figure 3.3: Examples of definably 'PNG' brands

Promotion was said to be very important in the PNG retail market, particularly when launching new products and brands. Taste testing, cooking demonstrations and point of sale displays and promotions were recommended as particularly effective, whilst print and multi-media advertising was said to be less effective and far more costly.

Specialist merchandisers are often employed in PNG to carry out promotional activities of behalf of food manufacturers and provide direct feedback to manufacturers on market trends and consumer responses to product offerings. Wholesalers and retailers can also be directly involved in developing and coordinating promotional activities, in partnership with suppliers.

4.1.7 Supply Chain Management

Wholesalers and distributors reportedly reward any exclusivity in supply arrangements with an appropriately enhanced effort in marketing and promotion of that product line. Interviewees suggested that the production end of the Galip industry (growers and processors) should select and work closely with their domestic Supply Chain partners (wholesalers, distributors, merchandisers and retail buyers). Issues for discussion would include options for product development, production planning, pricing, packaging, graphics, branding and promotions.

It was recommended that these consultations commence *prior* to launching products into the domestic market if the full commercial potential of Galip in PNG was to be achieved.

3.2 Food Service and Food Manufacturing

In general terms the food service and food manufacturing persons interviewed were much more cautious in their response to the potential for Galip in their markets. Reasons given for this were as follows:

- The Food Service and Food Manufacturing sectors prefer to test and evaluate actual product samples prior to offering any definitive comment. Therefore, Galip product samples of an acceptable standard will need to be developed for circulation and testing in these sectors in order to stimulate demand
- Raw materials used in these sectors must be fully 'guaranteed' in terms of food safety and surety of supply. HACCP plans must be in place and supply assured before Food Service and Food Manufacturing sectors will consider including new ingredients in meal plans, baking schedules etc.

The Food Service and Food Manufacturing sectors were said to be less price sensitive than the retail sector and expected to pay international prices for international quality products and supply arrangements.

PNG wholesalers and distributors serving the food service and food manufacturing industries work closely and collaboratively with their customers, to the extent of employing chefs and bakers to demonstrate product versatility and developing recipes for industry use.

Packaging in the Food Service and Food Manufacturing sectors was reportedly more simplistic (for example, less use of graphics) and volume orientated than retail, thereby reducing per unit manufacturing costs. Nut flakes and nut meals were generally sold in 1 kilo packs.

Branding of food manufacturing and food service supplies was also said to be far less important in comparison to supplying end products targeted at consumers within a retail environment.

4. THE COMMERCIALLY GROWN GALIP RESOURCE

The emerging commercial *Canarium indicum* industry in PNG has rapidly gained momentum, in large part due to the debilitating economic effects of the Cocoa Pod Borer crisis on the PNG cocoa industry.

The predicted planting of 1 million selected, elite Galip trees in East New Britain Province (ENBP) has the potential to produce 1,000 tonnes of kernel within the next 5 years, expanding to 20,000 tonnes of kernel within 15 years. Similar industry development is expected in Bougainville and to a lesser extent in other cocoa provinces (Moxon 2010).

Canarium is a high quality nut with nutritional and medicinal properties. Its soft texture and unique flavour are perceived to be quite different from other quality nuts on the world market thus presenting a particular niche market opportunity (Leakey et al 2005).

A very wide range of commercial food and non-food products could conceivably be produced using Galip. Based on products seen in the almond industry, Galip may ultimately be used in forms as diverse as:

Nut kernels (whole, slivered, diced, flakes, halves)

- Natural, roasted, or flavoured snacks
- Embedded or covered in chocolate
- Toppings for salads
- Ingredients for breakfast cereal
- Garnishing for baked goods and desserts
- Ingredients in stir-fries and other cooked dishes
- Ingredients in baked goods such as biscuits
- Texture for confectionery
- Toppings for prepared foods, salads
- Toppings for dairy items, baked goods
- Ingredients in stuffings
- Coating for ice cream bars
- Filling for bakery, confectionery
- Crust for meats, seafood

Nut Meal or Flour

- Sauce thickener
- Galip butter or marzipan
- Ingredient and filling for confectionery
- Flavour enhancer in baked goods
- Coating for fried foods

Nut Paste and Butter

- Alternative to other spreads
- Filling for chocolate, cereal bars, confectionery, and bakery

Nut Oil

- Salad dressings
- Non-food uses (e.g. cosmetics, moisturizer)

One of the biggest issues facing the Galip industry is that the product is virtually unknown outside Melanesia. Creating sufficient demand for Galip in export markets to match projected production volumes will therefore be a major industry challenge.

Conversely, Galip potentially has significant commercial advantages within the domestic market. These domestic market advantages include:

√ Very high consumer familiarity with Galip in its traditional forms
√ Strong consumer interest in commercial Galip products, based on consumer surveys
√ The very high price of most imported nut products in PNG (with the exception of Chinese manufactured peanut products)
√ Import duties of 25% on imported nuts
√ Increasing consumer demand for snack food products
√ Strong consumer demand for locally produced products and PNG brands
√ Proximity to market (relative to imported products)
√ Existing cocoa distribution infrastructure can be utilized for Galip

Maximizing the domestic market potential of Galip will be a critical 'first step' for the PNG Galip industry. The domestic market will be especially important in regards to:

√ Establishing and implementing commercial processing, distribution and marketing systems
√ Generating income and cash flows for growers and processors alike
√ Product development and market testing for export development

It is impossible to accurately predict domestic market demand. However, an attempted demand projection is needed (the potential size and value of the domestic market opportunity) for business feasibility purposes.

Nut consumption in developed markets varies widely, but based on available statistics, a per capita annual consumption rate of 1kg can be considered very achievable. If, due to income constraints and population demographics, only 20% of PNG's population of 6.6 million people consumed 1kg of product per annum this would still equate to a market of 1320 tonnes.

If retail snack products represented the vast majority of PNG nut consumption and Galip was able to capture 75% of this market (which may be feasible if the

product can be marketed competitively against Chinese peanuts, the only manufactured nut snack product of commercial significance in PNG), then this would equate to 990 tonnes of Galip per annum.

Table 4.1 illustrates the size (tonnes) of the potential resource from elite plants in ENBP, 2014 – 2024, based on industry projections (A), domestic demand for Galip nuts (tonnes) based on an assumed accrued increase of 10% per year due to increases in population and consumer spending (B) and the balance (tonnes) of the estimated commercially grown ENBP supply resource subsequently available for export or alternative use (C).

Table 4.1 Commercial ENBP Galip Production and Domestic Demand Estimates

Year	A. Kernels (t) *	B. Domestic Demand (t)	C. Balance of Resource (t)
2014	1000	990	10
2015	3000	1089	1911
2016	5200	1198	4002
2017	7400	1318	6082
2018	9500	1449	8051
2019	11600	1594	10006
2020	13700	1754	11946
2021	15800	1929	13871
2022	17800	2122	15678
2023	19400	2334	17066
2024	20000	2568	17432

** Source of production estimates, Dr. John Moxon*

5. RECOMMENDED ACTIONS

Significant commercial planting of Galip is currently taking place in PNG. This will result in considerable volumes of nuts becoming available in the short to medium term which must then be efficiently and economically harvested, processed and sold.

Maximising commercial opportunities in the domestic market will be critical to industry success; particularly in terms of product development, creation of cash flows and promoting industry coordination.

The following are 10 recommendations for *domestic marketing* of Galip, put forward for industry consideration:

1. Retail Product Positioning

Galip products should be positioned and then promoted in the PNG retail market as *'healthy, affordable PNG snack foods'* that are available year round at a standardized retail price and consistent quality.

2. Achieving a Competitive Retail Price Point

A domestic retail price point of approximately 3 kina per pack needs to be achieved, with pack size far less important than price.

Chinese peanuts sell in the 3 kina price range. These products are the only imported nut that achieve significant retail sales and they are therefore the major competitor to Galip. The quality merits or otherwise of the peanut product relative to Galip is basically irrelevant in the very price driven PNG retail environment.

3. Retail Packaging and Labelling

The domestic retail market requires a low cost, simple packaging option such as plastic soft packs, in which the nuts are clearly visible. PNG consumers are wary of packaging in which contents cannot be seen, especially when making 'first time' purchases. Labelling requirements in PNG are as per Australian labelling requirements.

4. Retail Product Form

Initial product offerings of Galip into the domestic market should be in forms consumers are already familiar with for example, dried and roasted.

Based on the 2004-2005 consumer survey and the results of this current study, initial costing studies for the domestic retail market should be carried out based on producing predominately 50gm 'snack packs' of Galip in soft plastic packaging.

Care should be taken that value adding initiatives do not contradict the perception of Galip as a tasty yet healthy snack food. Value adding as seen in the Macadamia industry may be better suited to high value, sophisticated export markets rather than the PNG domestic market. However, opportunities exist to 'test' export orientated Galip products in selected outlets in PNG, such as Airport Lounges, Hotels, Resorts and Duty Free shops.

5. Creation of a Strong Domestic PNG Brand

The PNG market is very brand conscious and brand loyal. A definitive domestic Galip brand should be developed and promoted, with this brand strongly 'PNG' orientated. The PNG domestic brand need not be relevant for future export marketing purposes.

6. Investing in PNG Market Promotions

Carefully targeted investment in promotion will be critical as part of launching the product and then stimulating increased sales.

Promotion is very important in PNG retail, particularly when launching new products and brands. Taste testing, cooking demonstrations and point of sale displays and promotions were recommended as particularly effective in PNG. Specialist merchandisers can be employed to carry out promotional activities on behalf of food manufacturers and provide direct feedback on market trends and consumer responses to product offerings.

Wholesalers and retailers can also be directly engaged in developing and coordinating promotional activities, in partnership with suppliers.

7. Carefully Matching Processing Capacity to Evolving Market Demand

Stimulating, yet then failing to adequately supply a market can be as damaging to business relationships within a Supply Chain and undermine consumer confidence in a brand as much as oversupplying a market can.

Investment in manufacturing capability, rolling out of marketing programs and pricing strategies must be realistic and appropriate, with a clearly defined yet dynamic correlation between processing capacity, volumes supplied to the market and evolving market demand.

8. Establishing Strong Domestic Value Chains

The production end of the Galip industry (growers and processors) should select and work closely with their domestic Supply Chain partners (wholesalers, distributors, merchandisers and retail buyers) *prior* to launching products into the domestic market if the full commercial potential of Galip in PNG is to be achieved.

Issues for discussion could include product development, production planning, pricing, package sizing, packaging materials, graphics, branding and promotional activities.

9. Stimulating PNG Food Service and Food Manufacturing Demand

These sectors need to test and evaluate actual product samples prior to offering any definitive feedback or making any commitment to purchase. Therefore, product samples of an acceptable standard will need to be developed for circulation and testing in these sectors in order to stimulate demand.

Food products used in these sectors must also be fully 'guaranteed' in terms of food safety and surety of supply. HACCP plans must therefore be developed and implemented and sufficient and reliable supplies assured before buyers will consider purchasing new ingredients for inclusion in meal plans, baking schedules etc.

10. Utilising Expatriate and Tourism Market Segments

Expatriates expect to pay 'local' prices for food and beverage products in PNG supermarkets. However, Expatriates and tourists also expect premiums to be charged at specialist venues such as Resorts, Hotels, Airport Lounges and Duty Free Shops.

Given the limited size of these specialist market segments in PNG it is suggested that these not form a major component of the *initial* domestic market strategy. However, these segments offer opportunities to test value added products, packaging and branding 'on-shore' as part of a broader export market strategy.

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10.5 Appendix 5: Guideliness, Vegetative Propagation

The following guidelines indications were prepared for project staff by Dr. Richard Pauku. Some modifications have been made for purposes of this report.

10.5.1 Managing a stockplant garden

- A stockplant garden must be managed properly or else it would not produce good quality cuttings for propagation.
- A small plot of land must be identified closer to the main nursery.
- Selectively fell trees within the plot, but spare medium sized trees to provide shade for the stockplants (that is if shade trees are not being planted).
- The level of irradiance required will depend on the chosen tree species (this can be determined by experimentation).
- Line and demarcate the area to create rows and blocks of stockplants. This will ease routine maintenance, identify clones and also create better access during the harvest of cuttings.
- Seedlings or clones may be planted at a spacing of either 0.5m x 0.5m or 1m x 1m.
- Allow the stockplants to grow between 3-6 months (or may be less depending on species) – they should produce enough cuttings at this age.
- Stump or trim the seedlings depending on the species. For example, stumping is suitable for galip nut and cutnut but chestnut may die if stumped so trimming is preferred. This operation will encourage regrowth from and within the severed parts of the plant and so produce shoots with good quality cuttings.
- You may need to apply inorganic fertiliser (NPK) on the stockplants – the need to do so and the rates to apply can be determined by experimentation as it may vary also between species.
- Regularly inspect stockplants for early detection of any pests and diseases infestation.
- Once pests and diseases are detected, treat them accordingly

10.5.2 Managing poly-propagators

- Poly-propagators (PP) must be well looked after because the success of the cutting experiments is partly dependent on the PP set up.
- Torn or loose plastics must be repaired immediately because the PP must remain air-tight and water-tight at all times to provide acceptable growth environment for the cuttings.
- Open the PP when absolutely necessary and if opened ensure to spray with water before closing it in order to maintain the level of humidity and temperature inside the PP.
- Do not spray directly onto the cuttings as it will hurt them and enhance loss of leaves. Instead spray above cuttings, high enough to allow mist filled the PP and subsequently settled onto the cuttings. Also, spray on the plastic walling to moist the surroundings.

- General cleanliness inside and outside of PP is desirable to minimize the risk of pests and diseases infestation. So, remove dead cuttings, fallen leaves and any foreign objects inside the PP. Likewise any rubbish found outside the PP should be disposed of properly.
- Check water level inside the PP daily and refill through the PVC pipe as and when required.
- Change rooting media on every 2-3 batches of cuttings raised or when moulds infested the media and persisted after treatment.

10.5.3 Managing leafy stem cuttings

- Collect cuttings from vigorous and healthy shoots from superior stockplants.
- Collect and set cuttings inside the PP when it is cool – either in early morning or late afternoon
- Regularly monitor cuttings inside the PP for early detection of pests and diseases infestation
- Rooted cuttings must be potted immediately using appropriate media
- Remove dead and fallen leaves from cuttings inside the PP
- Potted cuttings should be weaned progressively – vary shade in accordance with the condition of the clones.
- Maintain constant watering (mist desirable but manual watering can still do the job) for the first couple of days.
- Proper systematic record keeping is important to keep track of different selected trees which have been cloned through propagation by cuttings.

10.5.4 Managing marcots

- Cut back marcotted stem that are too long to about 30-50cm after rooting, and allow them to sprout and remain attached to mother plant for a few weeks before collection
- Collect rooted marcots from field on regular basis
- When collecting marcots trim leaves and small branches on stems to reduce water loss during transportation from field to the nursery
- Collect marcots using a container with some water. For long distance travelling, use wet cloth to wrap the marcots during transportation
- At the nursery, potted marcots should receive adequate water constantly for the first couple of days. Placing the potted marcot under a fine mist is preferred than manual watering or normal sprinklers to avoid over saturation of water on the media. Alternative is to use a humidity chamber.
- Protect potted marcots from direct sunlight by placing them under sufficient shade - this is critical for at least the first two weeks.
- Monitor potted marcots on daily basis for their performance and also for early detection of pest and disease infestation.
- Potted marcots that have produced true leaves can be considered for a transfer into the open to experience full sun.
- Maintain watering, especially when there is no rain on that day – this is critical for the survival of the marcots.

- You may need to apply fertiliser on potted marcots to boost growth prior to outplanting. Slow release fertilisers, e.g. Nutricote or Osmocote Plus can be considered.
- Plant out the marcots as and when they are fit to withstand field conditions. Note that vigorous vegetative growth does not necessarily reflect mass rooting system underground.
- Proper systematic record keeping is important to keep track of different selected trees which have been cloned through propagation by marcotting.

10.6 Appendix 6: Project newsletter

Newsletter 1 (June 2008), Domestication and Commercialisation of Galip-nut Project

Growing the Galip industry

GALIP-NUT: TRADITIONAL FOOD, INTERNATIONAL APPEAL

Galip-nut is one of the best known traditional foods in PNG, valued for its nutritional qualities, superb taste and multiple uses. Now these qualities are also being recognized abroad. NARI and its Australian partners have carried out studies that confirm that a Galip-based industry aimed both at local and export markets can be developed in PNG.

WORKING TOGETHER TO BUILD THE INDUSTRY

NARI has identified a number of challenges that need to be overcome in order to develop a successful industry. Some of the most important challenges are : the lack of high quality planting material, the need to develop an efficient supply chain from producers to retailers and the lack of knowledge of efficient processing techniques. The first two of these are being looked at by the Galip-nut Domestication and Commercialization Project, a joint project of NARI and James Cook University.

DEVELOPMENT OF BETTER GALIP-NUT PLANTS

Finding out "what's out there"

Not every Galip-nut tree is the same: for example, some are more productive or have bigger nuts than others.

Some of these characteristics may be shared by trees in a particular area. To find the best material, it is therefore impor-

The NARI/JCU/CCI Galip-nut project is funded partially by ACIAR (Australian Centre for International Agricultural Research)

tant to look at trees in different places. NARI and farmer collaborators have been exploring Galip tree populations in 5 provinces. In this way, they have located many trees with highly desirable characteristics.

"Capturing" and multiplying the best trees

Vegetative propagation techniques are being developed to multiply superior trees identified by farmers and NARI researchers.

GETTING TO KNOW EACH OTHER: DEVELOPMENT OF A MELANESIAN GALIP INDUSTRY NETWORK

The project is developing a database of persons and organizations either active or interested in participating in the Galip industry, from village based and plantation growers to marketers and retailers in PNG, Vanuatu and the Solomon Islands. As the harvest season varies from place to place, collaboration between growers, marketers and sellers in different countries is needed to establish a year-round industry.

PLANTATIONS AND PROCESSING

With support from the European Union, NARI is promoting establishment of a plantation resource in East New Britain. During 2008, more than 60,000 Galip plants will be distributed to interested farmers.

NARI has also just begun a collaborative project with the University of the Sunshine Coast, aimed at developing improved processing and packaging techniques.

THE FUTURE

Future activities include a joint workshop of the different projects in mid-2009 where progress will be shared with network members as a basis for the continued building of the industry.

JOIN US!

If you are interested in receiving future issues of this newsletter and joining the network, please send an email to colinbunt@macroconsulting.com.au or leave your details with Mr. Tio Nevenimo, Lowland Agricultural Experiment Station, Keravat.

The NARI/JCU/CCI Galip-nut project is funded partially by ACIAR (Australian Centre for International Agricultural Research)