Fruits and Nuts: Research and Development Issues in Papua New Guinea

Proceedings No. 9
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Fruits and Nuts: Research and Development Issues in Papua New Guinea

Papers presented at the Fruits and Nuts Workshop held at the IATP Farmer Training Centre, University of Natural Resource and Environment (formerly University of Vudal) from 11 – 13 October 2005

Edited by
Alan Quartermain and Barbara Tomi

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An overview of edible fruit and nuts in Papua New Guinea

R. Michael Bourke

Abstract

This paper provides an overview of what is known about edible fruit and nuts in Papua New Guinea (PNG). Firstly, a case is made as to why there needs to be more effort on research and development on fruit and nuts in PNG, focusing on both the domestic and overseas markets. A broad overview is given on current knowledge about fruit and nuts, including the species grown, where they grow, their altitudinal range, the population growing each species and number of trees per household. Aspects of production, consumption and marketing that are reviewed include crop agronomy, pest and disease problems, production levels, changes over time, general marketing constraints, consumption and consumer demand. Lastly, some main papers that review fruit and nut species in PNG are listed.

Introduction

This paper provides an overview of what is known about edible fruit and nuts in PNG. The focus is on information that development workers, researchers and planners can readily access, not on knowledge by villagers, which is extensive, but is not readily accessible to outsiders. The paper does not give a summary of all existing information nor claim to be comprehensive. There are some topics where we have a reasonable amount of available information and others where we have very little. Firstly, I want to make a case for greater research and development efforts on fruit and nuts in PNG.

Why more research and development effort on fruit and nuts in PNG?

There are a number of reasons why more effort needs to be directed at promoting fruit and nut production and sales within PNG and to overseas markets. I first consider the domestic market.

The domestic market within PNG

Production of fruit and nuts for sale within PNG is already a significant activity for many people. I suggest that this should be expanded for the following reasons:

1. There is a significant urban and non-village rural population and these people buy most of their food needs, either from locally grown or imported sources. Based on a growth rate of 2.7% per year, the total population of PNG will be six million in 2006 or 2007. Of these, 8% are rural villagers, 13% live in urban centres and six percent live in 'rural non-village' a location that is, in small stations, missions, plantations, schools, logging camps and mines. Thus there are a significant number of non-villagers (about one million people).

2. Domestically marketed food already provides significant amounts of cash income to rural villagers. More rural Papua New Guineans live in households where income is derived from selling food than from any other activity (Allen et al. 2001).

3. Imports of grains and other food into PNG are static or declining because of the low exchange rate of the PNG kina against the United States dollar. This has created greater opportunities for people to grow and sell food within PNG and villagers have responded to increased demand by producing more locally grown food.

4. There are marked ecological differences within PNG, especially between the highlands and lowlands, but also within the lowlands and within the highlands. This creates many opportunities for selling fresh food within PNG.
5. Most fruit in the highlands is not very sweet, for example, purple passionfruit, tamarillo (tree tomato), pineapple, pawpaw and strawberry. Highlanders like sweet foods and this explains why production of one fruit that is very sweet, suga prut (Passiflora ligularis), has expanded greatly over the past 30 years.

6. There is high demand for snack foods, especially in urban centres and in the highlands. The indigenous nuts can be processed and sold as snack foods.

7. Several of the indigenous edible nuts have been successfully developed commercially in Vanuatu and in the Solomon Islands. Galip (Canarium spp.) is sold as a processed snack food in Honiara and Port Vila. Sea almond or talis (Terminalia catappa) and pao (Barringtonia spp.) are also sold in Port Vila (Long Wah 1996).

Export markets

There is considerable potential for production of indigenous nuts to overseas markets. The case for much greater effort into developing these products is based on:

1. The current crop base for exports is narrow and is limited to several tree crops and a few spice crops. This can create economic instability as the prices of oil palm, coffee, cocoa and copra change over time. A broader economic base provides a greater buffer from such variation.

2. There is currently a strong focus on oil palm in PNG. However, oil palm is dependent on extensive areas of land and the conversion of high diversity tropical forest into very low diversity oil palm plantations. High value products, including some of the indigenous nuts, do not demand so much land and hence help conserve forests.

3. Land for further expansion of large-scale agriculture in PNG is limited. Currently, one-quarter of the total land mass of PNG (460,000 km2) is used for agriculture (including fallows). Most of the remainder is too mountainous, swampy, or too high for crop production. Future expansion will have to come mostly from more intensive land use, better quality produce and high-value crops. The indigenous nuts provide a high value product.

4. The village agricultural sector is growing reasonably fast, despite assertions to the contrary. Villagers are responsive to new economic opportunities, as demonstrated in recent years by the boom in vanilla production and the rapid expansion of domestically marketed food following the loss of value of the PNG kina in 1997.

5. Fruit and nut trees do not need large areas of land; they fit into existing agricultural systems and trees of certain species already exist in significant quantities in many locations.

6. Some of the indigenous edible nuts, including galip and okari, have received favourable reaction when market-tested in Australia, the USA and Europe.

Knowledge about fruit and nuts in PNG

The species being grown and where they grow in PNG

Species grown: The species of fruit and nuts that are grown and eaten in PNG are known. There is no single document that covers all species, but relevant information is available in a series of review papers. Some are more general and cover species used for other purposes, in particular Powell (1976) and French (1986). Others cover groups of fruit and nut species, for example, Bourke (1996) gives a list of 44 species of edible indigenous nuts with an indication of their significance in village agriculture and discusses six of these species in detail. The main papers which review the various fruits and nuts are listed in Table 1.

As well as knowing what is grown in PNG, and has been tried experimentally, we also have a good idea as to how well different species grow and what does not grow well.
For example, despite repeated attempts, we know that the following fruit do not grow well in PNG: apples, blueberries, date palms, grapes, kiwifruit, Mediterranean figs, nectarines, olives, persimmons and plums.

**Distribution:** The distribution of the more important species is known from the Mapping Agricultural Systems of PNG (MASP) database. This was a national-level survey of village agricultural systems conducted over a six-year period (1990–1995), where land used for agriculture was allocated to one of 342 agricultural systems (Bourke et al. 1998). Using this database, it is possible to generate maps showing where a given species is common or important (as distinct from being merely present). This is illustrated with maps showing the distribution of mango, marita pandanus, galip nut and karuka nut (Figures 1 to 4). There are some limitations in using this database to map the distribution of fruit and nuts. This is because the boundaries of the agricultural systems were drawn on criteria other than the distribution of fruit and nut species. As well, the decision as to whether a species is important or merely present in an agricultural system is subjective. Nevertheless, the patterns that emerge from this database are reasonably accurate, at least for the better-known species.

**Regional-level distribution:** There is some limited regional-level data on the relative importance of fruit and nuts that complements the MASP database. An exercise was conducted in 1995 on the island of New Britain, excluding the Gazelle Peninsula, where people in 16 villages were asked to rank the relative importance of fruit and nut trees in their diet (R.M. Bourke, unpublished data). The results are presented in Table 2. Allowing for some differences in species that are grown on New Britain and the New Guinea mainland (such as marita pandanus which is unimportant on New Britain) and the fact that this survey excluded non-tree species, the ranking by villagers is broadly similar to the national-level data derived from the MASP database. For example, breadfruit was ranked as the most important species by villagers on New Britain and the MASP exercise found that breadfruit was the most commonly grown nut species at the national level (Tables 2 and 3).

**Altitudinal range:** The altitudinal range of fruit and nuts in PNG is known from an extensive national-level survey conducted by the author from 1979 to 1984 (Bourke 1989). Results for 56 fruit and 20 nut species are presented in Tables 4 and 5 respectively. Data are presented for the usual range and the extreme range. The former figure is the mean of a number of observations (minimum four locations) of the minimum and maximum altitude at which a crop bears its main economic product. The extreme minimum or maximum is based on a single figure for a location where the crop was grown in an unusual situation. For example, pineapple is normally grown from sea level to an upper limit of 1800 m. The latter figure is the mean of observations at 25 locations and has a standard deviation of ±110 m. It is grown occasionally as high as 2380 m altitude (Table 4). Cashew grows from sea level up to 1400 m under extreme conditions, but we do not have sufficient observations to define its usual upper altitudinal limit (Table 5).

The data on crop altitudinal limits were recorded before the impact of global climatic change had a significant effect on PNG. Over the period 1970 to 1999, the mean temperature in the PNG lowlands and highlands increased at a rate of 0.2 °C per decade (R.M. Bourke and G. Humphreys, unpublished data). Since these data were collected, the upper limit of a number of species has increased by an amount that is consistent with the temperature rise in PNG over the past 30 years. Thus it is likely that the potential upper altitudinal limit of many crops could now be about 100 m higher than the figures in Tables 4 and 5 indicate.

**Population growing each species:** Because the MASP database is linked to spatial information on the rural population, it is possible to calculate the number of people...
who live in an agricultural system where a particular species is important (see Tables 3 and 6).1 Again, there are limitations to the accuracy of this exercise because of the subjective distinction between a species being important, present or unimportant. However, the ranking of the relative importance of species from such an exercise is likely to be reasonably accurate.

**Number of trees per household:** There is only limited information on the number of trees managed by households. A survey of the number of economic tree crops (coffee, fruit, nuts and highland betel nut) was done by the author for 20 households in two highland villages in 1984 (Bourke 1988:29–31, 44). The results are summarised in Table 7. For example, in Asiranka village in Kainantu District, there were an average of 176 karuka nut pandanus, 19 marita pandanus trees and 5 avocado trees per household.

**Production, consumption and marketing**

**Crop agronomy:** Many aspects of crop agronomy are poorly known for most introduced and traditional fruit and nut species in PNG. These include: propagation techniques, yield patterns, responses to fertiliser, storage processing and handling for commercial production. The paper titled ‘What we don’t know about indigenous nuts in Melanesia’ by Evans (1996b) unfortunately remains almost as true now as it was when written a decade ago.

**Pest and disease problems:** The most important insect pests and diseases of fruit and nuts in PNG are known. See papers or monographs by Brough (1982), Masamdu (1991), Smith and Thistleton (1982) and Kumar (2001) on insect pests; and those by Pearson (1982), Shaw (1984) and Philemon and Muthappa (1991) for plant pathogens. Despite having reasonably good information on the main pest and disease problems, economic impacts of the various insects and pathogens are poorly understood.

Superior cultivars selected by villagers. There is some scattered information on the location of superior cultivars that have been selected by villagers. Aburu (1982:104), for example, notes that there is a variety of galip nut with a soft shell on Misima Island; and Bourke (1996:53) makes the same comment for sea almond for Iwa Island in the Marshall Bennett Group in Milne Bay Province. More generally, it is clear that selection of superior cultivars has been made for various fruit and nut species on many small islands. This has happened on, for example, the Arawe Islands and Unea Island off New Britain; Nissan and Pinipel islands between Bougainville and New Ireland; Boisa (Aris) Island off the mouth of the Ramu River in Madang Province; and Mussau Island, the Feni (Anir) Islands and the Tanga Islands off New Ireland.

Superior introduced cultivars: Cultivars of a number of fruit species have been introduced into PNG for evaluation. These include avocado (Rogers 1992), carambola, durian, mango, pawpaw, rambutan (see papers by T. Neventino, B. Watson and S. Woodhouse in this proceedings), and various citrus species (Rogers and Movis 1991).

**Production patterns:** Information has been published on the production patterns, seasonal or otherwise, for 75 species of fruit and 25 species of nuts (Bourke et al. 2004). (Also see the paper in this volume: Production patterns for fruit and nut species in Papua New Guinea and some implications for marketing).

**Production levels:** With the exception of banana and galip nut, there is little information on the quantity of fruit and nuts produced in PNG. Bourke and Vlassak (2004) estimated production of banana (used in cooking and as fresh fruit) as 436,000

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1 More correctly, these figures are the proportion of rural villagers who live in agricultural systems where each fruit or nut species was classed as common or important. Not all people in any agricultural system grow each species and people living in other systems may grow them, so the figures are approximate.
tonnes per year in 2000. Banana provided 7 percent of the food energy derived from locally grown staple (energy) foods. Evans (1996b:17) estimated that there were one million edible Canarium (galip nut) trees in PNG, with total production of 7,200 tonnes of kernel per year. He assigned a farm gate value of US$22 million to this in 1996.

Changes in production and consumption over time: There is some information on changes in production over time. For example, in the highlands, production and consumption of avocado has increased over the past 40 years, as has that for suga prut. Durian was once shunned by Papua New Guineans at Keravat, but is now reported as being popular. Mangosteen is a recent introduction to food markets on the Gazelle Peninsula, where it has become a popular fruit (Tio Nevenimo, pers. comm. 2005). The quantity of fruit moved from the highlands to lowland urban centres has increased over the past 20 years. For example, banana passionfruit, tamarillo (tree tomato) and suga prut are now sold by highlanders to hotels in Madang, whereas these species were not sold there in the 1980s.

General marketing constraints for fresh food: A number of constraints affect marketing of fresh food in PNG and limit development of fruit and nuts as well as other fresh food. These constraints include:

- poor state of maintenance of many roads and bridges, especially away from main routes
- limited and expensive shipping within PNG
- low standards for handling fresh food
- inadequate linkages of individuals in the marketing chain, including poor communication, inadequate development of business skills in key individuals and insufficient intermediate traders (middlemen)
- limited propagation and distribution of improved planting material
- inadequate dissemination, to growers and those involved in marketing, of information on improved methods for production, handling and processing of fresh food.

Consumer demand: Information on demand for fruit and nuts is limited. We know in broad terms that there is unsatisfied demand for sweet fruit in the highlands and that sweet fruit, such as mandarins grown at 800–1200 m altitude, can be readily sold in highland markets. We also know that fruit and nuts are sold in significant quantities in urban markets. Beyond this, there is only limited information on volumes produced, volumes sold or consumer demand.

Consumption: Some data exists on consumption. I have not done a comprehensive literature survey, but my impression is that fruit and nuts are often classified as ‘other’ in nutrition surveys. The exception is for marita and karuka pandanus, where the quantities consumed are often significant. For example, on the Sirunki Plateau in Enga Province, males and females in different age brackets consumed an average of 1–17 grams of karuka nuts per day (Sinnett 1975:30).

Odani (2002) conducted a food intake study in a village on the Great Papuan Plateau in the Mt Bosavi area, Southern Highlands Province. He recorded that marita pandanus contributed almost half (44%) of the fat in the villagers’ diet, ahead of pig meat (22%) and bandicoot (8%). Marita also provided 15% of food energy, after banana (32%) and sago (27%); and 11% of protein, after banana (20%) and equal with bandicoot (11%). A study by Philip Harvey and Peter Heywood in a village in Sinasina District in Simbu Province found that karuka nut and marita pandanus (combined data) contributed 8% of energy and 8% of protein.

2 The intake of karuka nut is insignificant compared with sweet potato which was up to 1.1–1.7 kg per person per day for different age brackets of men and women. However, the intake of karuka nut varies greatly over time, so data from a survey conducted over a short period has little meaning. It is known that many villagers, especially those living at over 2000 m altitude, consume a lot of nuts of both the planted and wild karuka nut species when they are fruiting.
at the time of their 1981 study. The figures were 10% for protein and 6% for energy in a study in the same village in 1975 (Harvey and Heywood 1983:103).

**Experience elsewhere in Melanesia:** The experience with commercialisation of indigenous nuts in Solomon Islands and Vanuatu can be used as a guide for commercialisation in the future, as can the limited PNG experience with galip nut in New Britain (Evans 1994; Henderson 1996; Wissink 1996) and okari nut on the Managalas Plateau in Oro Province (Ase 1996; Houghton 1996; Olsson 1996).

**Literature on fruit and nuts in PNG**

Despite a large body of literature on fruit and nuts in PNG, there are numerous significant gaps in our knowledge, as noted above. As well as papers that review more than one species (Table 1), a number of papers cover aspects of individual crops, for example, for apple (Willson 1982), avocado (Rogers 1992; Watson et al. 2001), banana (Fooks 1991), cashew (Allen 1991), durian (Ngere 2002), galip nut (Akus 1996; Maima 1996), karuka nut (Rose 1982), mandarin and orange (Rogers and Movis 1991), mango (Tarepe 1991), naranjilla (Tarepe 1982), pineapple (Watson 2005), purple passionfruit (Nitsche 1971), rockmelon (Antonio 1986) and strawberry (Tarepe 1979).

There is much ethnobotanical material on village production from many locations in PNG. The following is an example of a description from Nissan Island in Bougainville Province:

People depend on garden food, various fruits and nuts and a little imported rice … Among the fruit, mango and golden apple (kalok) are very common. Other fruits include bukabuk, watery rose apple, orange, mandarin, pawpaw, pineapple, ton, pomelo, guava and lovilovi. Nut trees are very common and include pao, galip, Polynesian chestnut; sea almond and minor amounts of tulip seed. Both the flesh and seed of breadfruit are commonly eaten … People preserve the flesh of breadfruit by roasting it to form a biscuit. This is said to remain unspoilt for several years. People also preserve the kernels of galip, pao and sea almond nuts by smoking. Fruit of golden apple from Nissan is popular in Rabaul and Buka markets (Bourke and Betitis 2003:65).

No attempt is made to survey ethnobotanical literature here. A useful recent review of some of this kind of literature is given by Kennedy and Clarke (2004). From the MASP project, references cited in each provincial Working Paper are a useful entry point for ethnobotanical literature (for example, see Bourke, Allen et al. (2002) for East New Britain Province and Bourke, Hide et al. (2002) for West New Britain Province).

Increasingly, papers and monographs can be accessed from the World Wide Web, sometimes in unexpected locations. Bruce French’s (1986) book, for example, has been placed on a web site for Indonesian Papua (http://www.papuaweb.org/dlib/bk/french/).

Other papers cited here that can be located on the web include those in ACIAR Proceedings Numbers 69 and 99; the Mapping Agricultural Systems of PNG working papers and other papers produced by the Land Management Group at The Australian National University (for example, Bourke and Betitis 2003; Bourke and Vlassak 2004) and RMAP working papers (RSPAS, ANU). Typing the title of the paper or volume and the author’s name into a search engine will usually find the item.

There are a number of hard copy bibliographies on fruit and nuts in PNG as well as electronic literature databases that can be searched for particular species, locations or aspects. The most accessible of the published bibliographies is that by Walter et al. (1996) on the South Pacific indigenous nuts. Electronic bibliographies are being developed by the National Agricultural Research Institute; by the Land Management Group, ANU (the PNG Agriculture Literature Database), by Dr
Robin Hide in Canberra and by Professor Terry Hays in Rhode Island, USA. The ANU database is available as a CD and is being continually updated.

Acknowledgements

The MASP database was generated in association with Bryant Allen, Robin Hide and other colleagues in the Land Management Group at The Australian National University. Bryant Allen extracted the data from that database for Tables 3 and 6 and Figures 1 to 4. Tracy Harwood of the LMG did a fine job in editing my five papers in this volume.

References


of Human Geography, The Australian National University, Canberra.


Figure 1. Distribution of mango (*Mangifera indica*) in PNG. Source: MASP database.

Figure 2. Distribution of *marita* pandanus (*Pandanus conoideus*) in PNG. Source: MASP database.
Figure 3. Distribution of galip nut (*Canarium* spp.) in PNG. Source: MASP database.

Figure 4. Distribution of karuka nut (*Pandanus julianettii*) in PNG. Source: MASP database.
### Table 1. Review papers that cover fruit and nuts in PNG

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<th>Main focus</th>
<th>Approximate number of species</th>
<th>Author</th>
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<td>Ethnobotany in PNG</td>
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<tr>
<td></td>
<td>Nuts: -</td>
<td></td>
</tr>
<tr>
<td>Fruit and nuts, Keravat area</td>
<td>Fruit: 40</td>
<td>Aburu 1982</td>
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<td></td>
<td>Nuts: 10</td>
<td></td>
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<td>Fruit and nuts, Bulolo and Wau</td>
<td>Fruit: 29</td>
<td>Simpson and Arentz 1982</td>
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<td>Nuts: 9</td>
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<td>Food crops of PNG</td>
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<td>Fruit and nuts in Oceania</td>
<td>Fruit: 24</td>
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<td>Nuts: 26</td>
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<td>Horticulture in the highlands</td>
<td>Fruit: 16</td>
<td>Gunther and Wiles 2003</td>
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<td>Arboriculture in SW Pacific</td>
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<td>Crop production patterns</td>
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<td>Pacific Island agroforestry</td>
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<td>Fruit: 50</td>
<td>Tarepe and Bourke 1982</td>
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<td>Fruit in Enga Province</td>
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<td>Asian fruit in the lowlands</td>
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<td><em>Canarium</em> in Melanesia</td>
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### Table 2. Villagers’ ranking of the relative importance of fruit and nut trees on New Britain (excluding the Gazelle Peninsula)†

<table>
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<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Number of mentions</th>
<th>Score</th>
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<td>Breadfruit</td>
<td><em>Artocarpus altilis</em></td>
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<td>114</td>
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<td>Mango</td>
<td><em>Mangifera indica</em>/M. minor</td>
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<td>Galip</td>
<td><em>Canarium indicum</em></td>
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<td>Malay apple</td>
<td><em>Syzygium malaccense</em></td>
<td>14</td>
<td>84</td>
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<tr>
<td>Polynesian chestnut (<em>aila</em>)</td>
<td><em>Inocarpus fagifer</em></td>
<td>9</td>
<td>39</td>
</tr>
<tr>
<td>Parartocarpus</td>
<td><em>Parartocarpus venenosa</em></td>
<td>7</td>
<td>27</td>
</tr>
<tr>
<td>Ton</td>
<td><em>Pometia pinnata</em></td>
<td>7</td>
<td>24</td>
</tr>
<tr>
<td>Sis/Solomon</td>
<td><em>Pangium edule</em></td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>Sea almond (<em>talis</em>)</td>
<td><em>Terminalia catappa</em></td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td><em>Pao</em></td>
<td><em>Barringtonia spp.</em></td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Golden apple</td>
<td><em>Spondias cytherea</em></td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Guava</td>
<td><em>Psidium guajava</em></td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td><em>Bukabuk</em></td>
<td><em>Burckella obovata</em></td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Ficus</td>
<td><em>Ficus copiosa</em></td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

† This is based on a survey conducted by R.M. Bourke in 16 villages on New Britain in June–July 1995 during the fieldwork for the Mapping Agricultural Systems of PNG project (Bourke, Allen et al. 2002; Bourke, Hide et al. 2002). This survey was suggested by Will Akus of LAES Keravat. Surveyed villages were located on the south coast, north coast and interior of New Britain (but not the Gazelle Peninsula) and on Unea Island north of New Britain. Groups of village men and women were asked in Tok Pidgin to rank the relative importance of fruit and nut trees in their diet. The number of species mentioned ranged from four to eight per village. A score of 8 was allocated to the first-mentioned species in each village, a score of 7 to the second species etc. The maximum score is 128 (16 villages × 8) and the minimum is 1 (mentioned eighth in one village only). Thus the scores reflect both the number of times that a species was mentioned and the ranking assigned to it by the villagers.
Table 3. Proportion of rural population who grow certain edible nuts in PNG

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Proportion(^1) (%)</th>
<th>Provinces where nuts are most commonly grown(^2,3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breadfruit</td>
<td><em>Artocarpus altilis</em></td>
<td>57</td>
<td>ESP, Mor, Mad, MBP, ENB, Boug</td>
</tr>
<tr>
<td><em>Karuka</em>, planted</td>
<td><em>Pandanus julianettii</em></td>
<td>47</td>
<td>SHP, WHP, EHP, Enga, Simbu, Mad, ESP, ENB, Boug, Sandaun,</td>
</tr>
<tr>
<td><em>Galip</em></td>
<td><em>Canarium indicum</em></td>
<td>32</td>
<td>Mor</td>
</tr>
<tr>
<td><em>Karuka</em>, wild</td>
<td><em>Pandanus brosimos</em></td>
<td>32</td>
<td>WHP, SHP, Simbu, Enga, EHP</td>
</tr>
<tr>
<td>Polynesian chestnut (aila)</td>
<td><em>Inocarpus fagifer</em></td>
<td>15</td>
<td>MBP, ENB, WNB, NIP</td>
</tr>
<tr>
<td>Sea almond (<em>talis</em>)</td>
<td><em>Terminalia catappa</em></td>
<td>14</td>
<td>MBP, ENB, NIP, WNB</td>
</tr>
<tr>
<td><em>Pao</em></td>
<td><em>Barringtonia procera</em></td>
<td>13</td>
<td>ENB, Boug, NIP, WNB</td>
</tr>
<tr>
<td><em>Okari</em></td>
<td><em>Terminalia kaernbachii</em></td>
<td>13</td>
<td>Central, Oro, Gulf, Western</td>
</tr>
<tr>
<td><em>Okari</em></td>
<td><em>Terminalia impediens</em></td>
<td>8</td>
<td>ESP, Mad, Sandaun</td>
</tr>
<tr>
<td><em>Sis/Solomon</em></td>
<td><em>Pangium edule</em></td>
<td>8</td>
<td>MBP, WNB, Mad, SHP</td>
</tr>
<tr>
<td>Castanopsis</td>
<td><em>Castanopsis acuminatissima</em></td>
<td>7</td>
<td>SHP</td>
</tr>
<tr>
<td><em>Dausia</em></td>
<td><em>Terminalia megalocarpa</em></td>
<td>2</td>
<td>MBP</td>
</tr>
<tr>
<td><em>Tulip</em></td>
<td><em>Gnetum gnemon</em></td>
<td>2</td>
<td>MBP</td>
</tr>
</tbody>
</table>

1. The data are based on a nationwide survey of village agriculture (Mapping Agricultural Systems of PNG project), with most fieldwork conducted between 1990 and 1995 (Bourke et al. 1998). Figures are the proportion of rural villagers living in agricultural systems where each nut species was classed as common or important. The relative importance of 17 nut species was assessed as part of that survey. Because the number of plants per household is not great and the plants are spatially dispersed, relative importance is not easy to assess in the field and the figures are subject to large errors. Nevertheless, ranking of the relative importance of the species is likely to be fairly accurate.

2. The ranking of provinces is based on the number of people growing each nut species, not on the proportion of people who grow a species in each province. Thus, the more populous provinces are more likely to appear here.

3. Abbreviations for provinces are: Boug Bougainville; EHP Eastern Highlands; ENB East New Britain; ESP East Sepik; Mad Madang; MBP Milne Bay; Mor Morobe; NIP New Ireland; SHP Southern Highlands; WNB West New Britain; WHP Western Highlands.
Table 4. The altitudinal range of fruit species in Papua New Guinea

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
<th>Mean usual altitudinal range (m)</th>
<th>Extreme altitudinal range (m)</th>
<th>Number of observations/standard deviation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ananas comosus</td>
<td>Pineapple</td>
<td>0–1800</td>
<td>0–2380</td>
<td>25/110</td>
</tr>
<tr>
<td>Annona cherimolia</td>
<td>Cherimoya</td>
<td>0–1000</td>
<td>0–1460</td>
<td>7/100</td>
</tr>
<tr>
<td>Annona muricata</td>
<td>Soursop</td>
<td>0–1000</td>
<td>0–1210</td>
<td></td>
</tr>
<tr>
<td>Annona squamosa</td>
<td>Sweetsop (custard apple)</td>
<td>0–1000</td>
<td>0–1210</td>
<td></td>
</tr>
<tr>
<td>Citrus paradisi × C. reticulata?</td>
<td>Ugli</td>
<td>0–1800</td>
<td>0–1900</td>
<td>3/50</td>
</tr>
<tr>
<td>Citrus reticulata</td>
<td>Mandarin</td>
<td>0–1800</td>
<td>0–2260</td>
<td>9/50</td>
</tr>
<tr>
<td>Citrus sinensis</td>
<td>Orange</td>
<td>0–1800</td>
<td>0–2280</td>
<td>12/80</td>
</tr>
<tr>
<td>Cucumis melo</td>
<td>Rockmelon (cantaloupe)</td>
<td>0–1800</td>
<td>0–2180</td>
<td></td>
</tr>
<tr>
<td>Cyphomandra betacea</td>
<td>Tamarillo (tree tomato)</td>
<td>1050–2300</td>
<td>0–2600</td>
<td>8/160</td>
</tr>
<tr>
<td>Durio zibethinus</td>
<td>Durian</td>
<td>0–1800</td>
<td>0–1900</td>
<td>3/170</td>
</tr>
<tr>
<td>Eriobotrya japonica</td>
<td>Loquat</td>
<td>850–1800</td>
<td>0–2410</td>
<td>6/70</td>
</tr>
<tr>
<td>Eugenia uniflora</td>
<td>Brazil cherry</td>
<td>0–1750</td>
<td>0–1880</td>
<td>3/140</td>
</tr>
<tr>
<td>Fortunella sp.</td>
<td>Cumquat</td>
<td>0–1800</td>
<td>0–1160</td>
<td></td>
</tr>
<tr>
<td>Fragaria sp.</td>
<td>Strawberry</td>
<td>800–2450</td>
<td>660–2800</td>
<td>7/100</td>
</tr>
<tr>
<td>Fragaria vesca</td>
<td>Alpine strawberry</td>
<td>0–1700</td>
<td>0–2220</td>
<td>8/160</td>
</tr>
<tr>
<td>Garcinia mangostana</td>
<td>Mangosteen</td>
<td>0–1700</td>
<td>0–2220</td>
<td></td>
</tr>
<tr>
<td>Hibiscus sabdariffa</td>
<td>Rosella</td>
<td>0–1700</td>
<td>0–2220</td>
<td>8/160</td>
</tr>
<tr>
<td>Malus sp.</td>
<td>Apple</td>
<td>0–1700</td>
<td>0–2220</td>
<td></td>
</tr>
<tr>
<td>Mangifera indica</td>
<td>Mango</td>
<td>0–1600</td>
<td>0–1820</td>
<td>13/110</td>
</tr>
<tr>
<td>Mangifera minor</td>
<td>Traditional mango</td>
<td>0–1750</td>
<td>0–1900</td>
<td>6/100</td>
</tr>
<tr>
<td>Monstera delicosa</td>
<td>Ceriman</td>
<td>0–2200</td>
<td>0–2330</td>
<td>3/180</td>
</tr>
<tr>
<td>Morus nigra</td>
<td>Mulberry</td>
<td>800–2200</td>
<td>0–2760</td>
<td>6/100</td>
</tr>
<tr>
<td>Musa cvs</td>
<td>Triploid banana</td>
<td>0–2150</td>
<td>0–2580</td>
<td>30/130</td>
</tr>
<tr>
<td>Nephelium iappaceum</td>
<td>Rambutan</td>
<td>0–1700</td>
<td>0–1980</td>
<td>37/90</td>
</tr>
<tr>
<td>Pandanus conoideus</td>
<td>Marita</td>
<td>0–1700</td>
<td>0–1980</td>
<td></td>
</tr>
<tr>
<td>Passiflora edulis f. edulis</td>
<td>Purple passionfruit</td>
<td>800–2300</td>
<td>700–2520</td>
<td>7/90</td>
</tr>
<tr>
<td>Passiflora edulis f. flavicarpa</td>
<td>Lowland yellow passionfruit</td>
<td>0–850</td>
<td>0–960</td>
<td>5/80</td>
</tr>
<tr>
<td>Passiflora ligularis</td>
<td>Suga pru (Highland yellow passionfruit)</td>
<td>1350–2350</td>
<td>1300–2460</td>
<td>3/80</td>
</tr>
<tr>
<td>Passiflora mollissima</td>
<td>Banana passionfruit</td>
<td>1850–2800</td>
<td>2920</td>
<td>7/110</td>
</tr>
<tr>
<td>Passiflora quadrangularis</td>
<td>Granadilla</td>
<td>0–1000</td>
<td>0–1520</td>
<td>10/300</td>
</tr>
<tr>
<td>Persea americana</td>
<td>Avocado</td>
<td>0–2050</td>
<td>0–2430</td>
<td>16/160</td>
</tr>
</tbody>
</table>
Prunus sp. Plum ?–? 1590–2600 – –
Psidium cattleianum Cherry guava 0–1850 0–1900 – 3/90
Psidium guajava Guava 0–1850 0–2020 – 19/110
Punica granatum Pomegranate 0–? 0–1620 – –
Rubus laysiocarpus Black raspberry 950–2250 760–2830 5/150 11/180
Rubus moluccanus Red raspberry 0–2150 0–2250 – 3/120
Rubus rosifolius Red raspberry\textsuperscript{12} 950–2800 700–2900 8/180 5/60
Sambucus canadensis Elderberry\textsuperscript{13} 450–1900 0–2150 3/110 11/140
Spondias cytherea Golden apple 0–950 0–1070 – 4/110
Syzygium aqueum Watery rose apple 0–1600 0–1640 – 3/50
Syzygium malaccense Malay apple 0–850 0–1580 – 5/80

1. The source is an unpublished paper by Bourke (1989).
2. Both smooth leaf and rough leaf pineapple have the same usual upper altitudinal limit (1800 m). The rough leaf is less common above about 1500 m and produces the best quality fruit between about 400 and 1200 m.
3. Watermelon is not common above about 1200 m, but is grown up to a mean usual upper limit of 1700 m.
4. Lemon grows better above about 400 m. For a fuller discussion on the optimum altitudinal range for citrus species in PNG, see Bourke and Tarepe (1982).
5. Durian has failed to establish at Bulolo (750 m) (Simpson and Arentz 1982), suggesting that its upper limit may be below 750 m.
6. Cumquat would almost certainly bear at higher altitudes in Papua New Guinea as it is cold tolerant, but it has not been recorded above 1160 m.
7. Mangosteen failed to bear fruit at 550 m on the Managalas Plateau in Oro Province, suggesting that its upper limit may be below this.
8. Mango fruit quality is poor above about 1200 m and bearing is irregular above 1600 m.
9. \textit{Marita} pandanus is not usually planted near the ocean, but it is grown in inland areas at altitudes below 100 m, for example, near Kiunga, Popondetta, Gogol Valley and Aitape. It is more commonly planted above about 500 m.
10. Banana passionfruit plants grow as high as 3580 m but the highest that I recorded fruit was at 2920 m (Chimbu Valley) and 2850 m (Sirunki Plateau). Self-sown plants are not common below about 2000 m, although planted vines bear as low as 1640 m (Aiyura).
11. \textit{Pometia pinnata} bears edible fruit up to a mean upper limit of 800 m, but the tree grows at higher altitudes. It has been recorded at about 1700 m in the Nipa area by Sillitoe (1983:115).
12. Peekel (1984:202) implies that \textit{Rubus rosifolius} has been recorded as low as 300 m in New Ireland and New Britain. The Forest Research Institute has one identification from 200 m (Tufi), but all other specimens were collected at over 1000 m.
13. Elderberry grows up to about 2650 m, but does not usually bear fruit above 1900 m.
Table 5. The altitudinal range of edible nut species in Papua New Guinea

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
<th>Mean usual altitudinal range (m)</th>
<th>Extreme altitudinal range (m)</th>
<th>Number of observations/standard deviation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aleurites moluccana</strong></td>
<td>Candle nut</td>
<td>0–1800</td>
<td>0–2160</td>
<td>9/140</td>
</tr>
<tr>
<td><strong>Anacardium occidentale</strong></td>
<td>Cashew</td>
<td>0–2160</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><strong>Arachis hypogaea</strong></td>
<td>Peanut</td>
<td>0–1850</td>
<td>0–1940</td>
<td>21/70</td>
</tr>
<tr>
<td><strong>Artocarpus altitis</strong></td>
<td>Breadfruit</td>
<td>0–1250</td>
<td>0–1450</td>
<td>23/130</td>
</tr>
<tr>
<td><strong>Barringtonia procer</strong></td>
<td><em>Pa</em></td>
<td>0–500</td>
<td>0–620</td>
<td>4/90</td>
</tr>
<tr>
<td><strong>Canarium indicum</strong></td>
<td>Galip</td>
<td>0–700</td>
<td>0–930</td>
<td>5/160</td>
</tr>
<tr>
<td><strong>Carya illinoensis</strong></td>
<td>Pecan</td>
<td>?–?</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><strong>Castanopsis acuminatissima</strong></td>
<td>Castanopsis 2</td>
<td>700–2350</td>
<td>570–2440</td>
<td>6/80</td>
</tr>
<tr>
<td><strong>Cocos nucifera</strong></td>
<td>Coconut 1</td>
<td>0–950</td>
<td>0–1310</td>
<td>20/190</td>
</tr>
<tr>
<td><strong>Finschia chloroxantha</strong></td>
<td>Finschia 4</td>
<td>0–1850</td>
<td>0–2000</td>
<td>4/110</td>
</tr>
<tr>
<td><strong>Gnetum gnemon</strong></td>
<td>Tulip</td>
<td>0–1100</td>
<td>0–1330</td>
<td>10/150</td>
</tr>
<tr>
<td><strong>Inocarpus fagifer</strong></td>
<td>chestnut (aila)</td>
<td>0–400</td>
<td>0–870</td>
<td>4/90</td>
</tr>
<tr>
<td><strong>Macadamia integrifolia</strong></td>
<td>Macadamia 5</td>
<td>0–1750</td>
<td>0–1810</td>
<td>3/60</td>
</tr>
<tr>
<td><strong>M. tetraphylla</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pandanus antaresensis</strong></td>
<td>Wild karuka</td>
<td>1000–2350</td>
<td>850–2460</td>
<td>4/110</td>
</tr>
<tr>
<td><strong>Pandanus brosimos</strong></td>
<td>Wild karuka</td>
<td>2400–3100</td>
<td>1800–3300</td>
<td>20/150</td>
</tr>
<tr>
<td><strong>Pandanus julianettii</strong></td>
<td>Karuka</td>
<td>1800–2600</td>
<td>1450–2800</td>
<td>50/110</td>
</tr>
<tr>
<td><strong>Pangium edule</strong></td>
<td>Sis/Solomon</td>
<td>0–1050</td>
<td>0–1380</td>
<td>11/120</td>
</tr>
<tr>
<td><strong>Terminalia catappa</strong></td>
<td>Sea almond (talis)</td>
<td>0–300</td>
<td>0–460</td>
<td>4/100</td>
</tr>
<tr>
<td><strong>Terminalia impediens</strong></td>
<td>Okari</td>
<td>0–1000</td>
<td>0–1100</td>
<td>3/110</td>
</tr>
<tr>
<td><strong>Terminalia kaernbachii</strong></td>
<td>Okari</td>
<td>0–1100</td>
<td>0–1260</td>
<td>11/90</td>
</tr>
</tbody>
</table>

1. The source is an unpublished paper by Bourke (1989).
2. Self-sown castanopsis is more common above about 1100 m, although the usual mean lower limit is 700 m.
3. Coconut palms grow as high as 1760 m, but the highest palms that bore nuts in the period 1979–1984 were at Yonki, EHP (1310 m) and the Baiyer Valley, WHP (1220 m). By 1999, coconuts were bearing as high as 1370 m (Benabena Valley), 1420 m (Korofeigu, EHP) and 1450 m (Wahgi Valley).
4. The highest recording for Finschia (2000 m) is a Forest Research Institute record from Aseki in Morobe Province.
5. In its natural range in Australia, Macadamia *tetraphylla* occurs in a slightly cooler climate than *M. integrifolia* (Cull and Trochoulias 1982; Stephenson, this volume). The limited numbers of observations from Papua New Guinea do not indicate a separate range for the two species. Both species bear from sea level up to 1700–1800 m.
### Table 6. Proportion of rural population who grow certain fruit in PNG

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Proportion&lt;sup&gt;1&lt;/sup&gt; (%)</th>
<th>Provinces where fruit are most commonly grown&lt;sup&gt;2,3&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana&lt;sup&gt;3&lt;/sup&gt;</td>
<td><em>Musa cv</em></td>
<td>98</td>
<td>Mor, ENB, Central, Mad, ESP</td>
</tr>
<tr>
<td>Pawpaw</td>
<td><em>Carica papaya</em></td>
<td>64</td>
<td>WHP, Mad, ESP, Mor, MBP</td>
</tr>
<tr>
<td><em>Marita</em></td>
<td><em>Pandanus conoideus</em></td>
<td>59</td>
<td>EHP, Mor, WHP, SHP, ESP, Simbu, Mad</td>
</tr>
<tr>
<td>Pineapple</td>
<td><em>Ananas comosus</em></td>
<td>53</td>
<td>ESP, Mor, WHP, Mad</td>
</tr>
<tr>
<td>Mango</td>
<td><em>Mangifera indica</em></td>
<td>44</td>
<td>ESP, Mad, Mor, ENB, MBP, Bougain</td>
</tr>
<tr>
<td>Watermelon</td>
<td><em>Citrus lanatus</em></td>
<td>28</td>
<td>MBP, Bougain, Central, ENB, Oro</td>
</tr>
<tr>
<td><em>Tong</em></td>
<td><em>Pometia pinnata</em></td>
<td>23</td>
<td>ESP, ENB, Mad, Sandaun, NIP</td>
</tr>
<tr>
<td>Malay apple</td>
<td><em>Syzygium malaccense</em></td>
<td>22</td>
<td>NIP, Bougain, MBP, Central, WNB</td>
</tr>
<tr>
<td>Guava</td>
<td><em>Psidium guajava</em></td>
<td>18</td>
<td>Bougain, ENB, Mor, Mad, WNB</td>
</tr>
<tr>
<td>Orange</td>
<td><em>Citrus sinensis</em></td>
<td>13</td>
<td>Mor, Oro, Gulf, Central</td>
</tr>
<tr>
<td>Passionfruit</td>
<td><em>Passiflora spp.</em></td>
<td>11</td>
<td>Enga, SHP, Mor</td>
</tr>
<tr>
<td>Avocado</td>
<td><em>Persea americana</em></td>
<td>6</td>
<td>Central, Simbu, Mor, EHP</td>
</tr>
<tr>
<td><em>Bukabuk</em></td>
<td><em>Burckella obovata</em></td>
<td>6</td>
<td>MBP, New Ireland, Bougain</td>
</tr>
<tr>
<td><em>Mon</em></td>
<td><em>Dracontomelon dao</em></td>
<td>6</td>
<td>Madang</td>
</tr>
<tr>
<td>Golden apple</td>
<td><em>Spondias cytherea</em></td>
<td>4</td>
<td>MBP, Manus, NIP, Bougain</td>
</tr>
<tr>
<td>Mandarin</td>
<td><em>Citrus reticulata</em></td>
<td>4</td>
<td>Central, Mor, Bougain</td>
</tr>
<tr>
<td>Parartocarpus</td>
<td><em>Parartocarpus venenosa</em></td>
<td>4</td>
<td>WNB, ENB</td>
</tr>
<tr>
<td>Rukam</td>
<td><em>Flacourtia rukam</em></td>
<td>2</td>
<td>MBP</td>
</tr>
<tr>
<td>Pomelo</td>
<td><em>Citrus maxima</em></td>
<td>2</td>
<td>WNB, NIP</td>
</tr>
<tr>
<td>Tamarillo</td>
<td><em>Cyphomandra betacea</em></td>
<td>2</td>
<td>Mor, Central</td>
</tr>
<tr>
<td>Coastal pandanus</td>
<td><em>Pandanus tectorius</em></td>
<td>2</td>
<td>Manus</td>
</tr>
<tr>
<td>Pouteria</td>
<td><em>Pouteria maclayana</em></td>
<td>2</td>
<td>Madang</td>
</tr>
</tbody>
</table>

1. The data are based on a nationwide survey of village agriculture (Mapping Agricultural Systems of PNG project), with most fieldwork conducted between 1990 and 1995 (Bourke et al. 1998). Figures are the proportion of rural villagers living in agricultural systems where each fruit was classed as common or important. The relative importance of 35 fruit species was assessed as part of that survey. Because the number of plants per household is not great and the plants are spatially dispersed, relative importance is not easy to assess in the field and the figures are subject to large errors. Nevertheless, ranking of the relative importance of the species is likely to be fairly accurate.

2. The ranking of provinces is based on the number of people growing each fruit species, not on the proportion of people who grow a species in each province. Thus, the more populous provinces are more likely to appear here.

3. Abbreviations for provinces are: Bougain Bougainville; EHP Eastern Highlands; ENB East New Britain; ESP East Sepik; Mad Madang; MBP Milne Bay; Mor Morobe; NIP New Ireland; SHP Southern Highlands; WNB West New Britain; WHP Western Highlands.

4. Banana is grown by most households in PNG, up to 2600 m altitude. These data include banana used for cooking and for fresh fruit.
### Table 7. Number of planted economic tree crops per household in Asiranka village, Eastern Highlands, and Upa village, Southern Highlands

<table>
<thead>
<tr>
<th>Tree crop</th>
<th>Asiranka village</th>
<th>Upa village</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>% mature</td>
</tr>
<tr>
<td>Coffee (Coffea arabica)³</td>
<td>464</td>
<td>95</td>
</tr>
<tr>
<td>Karuka nut pandanus (P. julianettii)⁴</td>
<td>176</td>
<td>28</td>
</tr>
<tr>
<td>Highland betel nut (Areca macrocalyx)</td>
<td>137</td>
<td>23</td>
</tr>
<tr>
<td>Marita pandanus (P. conoideus)⁵</td>
<td>19</td>
<td>32</td>
</tr>
<tr>
<td>Ficus copiosa³</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Avocado (Persea americana)</td>
<td>5</td>
<td>35</td>
</tr>
</tbody>
</table>

1. The source is field counts of trees in 10 male-headed households in each community in September–November, 1984 (Bourke 1988). Asiranka village is in the Aiyura Basin, Kainantu District, Eastern Highlands Province, while Upa village is located on the Nembi Plateau, Nipa District, Southern Highlands Province. Household size in Upa (14.5 persons) is much larger than in Asiranka (3.9 persons), hence the number of trees per person is generally greater in Asiranka.

2. Casuarina oligodon is an important planted species in both villages, but trees of this species were not counted.

3. Coffee numbers at Upa exclude the large holdings of a single household head. There are 11.8 persons per household for coffee holdings at Upa.

4. The number of karuka trees was probably under-enumerated in Asiranka, as the people spoke of trees that I did not see.

5. Marita pandanus trees were not counted in the Wage Valley, and the figure for Upa is an underestimate.

6. Ficus trees were not recorded at Asiranka, but there are only a few trees.
Brief Overview: Fruit and Nut Research

Tio Nevenimo

Introduction

It was evident from the last farmer consultations in the provinces that there is considerable interest in alternative cash earning crops and people are trying a wide range of crops including spice, fruits, nuts, essential oils, medicinal crops, ornamentals and timber crops.

The main reasons for interest in growing fruits and nuts is to help address agricultural priority issues predominant amongst smallholders throughout the region, namely income generation, food and nutrition security.

Research work on fruits and nuts has always been an integral part of Agriculture Research in PNG. Formally DAL and now NARI has continued to do research and development work on fruits and nuts. As a result of the efforts in the past NARI now has a large collection of a wide range of both introduced and indigenous fruits and nuts. The biggest of the fruit and nut collection is held at LAES Keravat, with over 50 species and over 200 accessions. NARI also is now in possession of some of the commercial varieties of introduced fruits like Mango, Rambutan, Durian, Citrus, Avocado and Five Corner. Fruits like Mangosteen, Abiu, and Jackfruit are gaining popularity rapidly while fruits like Sour soap, Rollinia, Canistel, Lanset and Maboro have yet to be realised by consumers.

While all NARI research stations have a fruit and nut research component, much of the research on fruits and nuts is currently done at LAES Keravat.

Current Research Activities

Research in fruits and nuts at LAES can be divided into two main components.
1. Indigenous fruits and nuts
2. Introduced tropical fruits and nuts

Indigenous fruit and nuts

Work in indigenous fruits and nuts can be divided into two areas:
• Domestification; and
• Commercialisation of indigenous fruit and nuts

Domestification work involves prospections for trees with superior characters in the natural and semi domesticated population. Once these are identified they are vegetatively reproduced and planted on station for further evaluation and selection. Vegetative reproduction of selected trees is vital. Therefore the next part of domestification work is to develop methods that will allow us to reproduce these selections. Vegetative reproduction not only reproduces identical trees but also reduces age to first bearing and having a dwarfing effect on the trees.

Commercialisation looks at commercial evaluation of the various indigenous species where information to assist large scale commercial planting, management and utilisation of various products is generated. Post harvest, downstream processing, marketing and markets intelligence are some of the work done under commercialisation.

The overall aim of research in indigenous fruits and nuts is to ascertain whether, they can be domesticated and commercialised. NARI has identified domestication and commercialisation of indigenous fruits and nuts as high priority in this Area of Research Opportunity (ARO).

Current research on indigenous fruit and nuts

1. Prospection and identification of superior planting material;
2. Development of vegetative propagation techniques;
3 Evaluation of superior selections for commercial cultivation
4 Conducting general agronomic research

**Important areas of research not covered**

1 Evaluation and development of post harvest and processing techniques
2 Markets and market intelligence
3 Socio-economics of domestication and commercialisation of indigenous crops

**Achievements to date at LAES**

1 A total of 41 galip selections have been made for evaluation on a commercial scale.
2 Some success has been made in marcotting galip nuts and grafting okari nut.
3 Prospection and collection of Okari was done in Oro province.
4 Prospection and collection of Taun is being done in Duke Of York Islands.
5 Prospection and collection of various fruits and nuts is being done under atolls project.
6 At present NARI has three, donor funded projects that look at domestication and commercialisation of PNG indigenous nuts in one way or another.
   - The first is an ACIAR funded project on galip nut which was completed in June 2005 and a new project is in the pipeline.
   - The second project is funded by the European Union. It is mainly aimed at developing NARI LAES commercial capacity. One component of the project is evaluating indigenous nuts on a commercial scale. LAES will plant a total of 15 hectares of indigenous nuts, (Galip Okari and Pau). The evaluation will include both agronomic and economic assessments of various nuts. At the end of the evaluation, it is hoped that NARI will have a baseline information to support commercial scale development of these nuts.
   - The third project is the EU Atolls project. It is funded by EU and mainly aimed at addressing atoll community problems in food and cash requirements. One of its component is to collect and establish a collection of fruits and nuts from the atolls, which are then used for distribution to other areas. It is hoped that some superior cultivars will be collected for use in the domestication and commercialisation program.

**Introduced Tropical Fruit and Nuts**

Research work on fruits and nut has always been an integral part of LAES Keravat. Formally DAL and now NARI has invested a lot of resources into the introduction and evaluation of introduced tropical fruit and nuts. As a result of 77 years of effort and investment, LAES now has probably the biggest collection of both introduced and indigenous fruit and nuts.

The main activities in introduced fruits and nuts have been the maintenance of collection and propagation and distribution of selected fruits and nuts. Some of the introductions have been evaluated and recommendations made while many have not yet been evaluated formally.

Introduced fruits considered as having potential for commercial development in the Islands Region are; Mango, Rambutan, Durian and Mangosteen followed by Abiu, Avocado and Five Corner.

**Achievements to Date**

1 LAES collection has some commercial cultivars of promising fruit and nuts like rambutan, durian, mango, five corner and cashew nuts. There are; 13 Cultivars of Rambutan, 8 clones of Durian, 15 varieties of mango, 8 cultivars of Five Corner and 8 clones of Cashew nut. Good quality Mangosteen
and Abiu are also held in the collection. Most of these have not been recommended for distribution because they have not yet been tested outside LAES.

2 LAES has released 3 clones of rambutan in 2004 and eight clones of Durian in 2005.

3 NARI stations continue to maintain introduced fruit collection eg Laloki, mango collection, and Aiyura, Citrus collection.

4 Two donor projects at LAES Keravat lasted three years
   • ACIAR funded Fruit Fly project.
   • ACIAR funded Red Banded Mango Caterpillar project.

**Issues**

The issues for nuts are
   • Crop improvement (propagation, selections, distribution)
   • Post harvest handling and processing
   • Markets and market intelligence on indigenous nuts

The issues for Introduced Fruit and nuts are:
   • Lack of information and planting material,
   • Lack of post harvest and processing facilities
   • Pest, disease and quarantine
   • Markets and market intelligence

**Major constraints in carrying out research in NARI are:**
   • Funding
   • Manpower
Developing Fruit and Nut in Papua New Guinea

Ario Movis

Abstract

Department of Agriculture and Livestock (DAL) and National Agriculture Research Institute (NARI) introduced many temperate, subtropical and tropical fruit species into Papua New Guinea during the last decade. These fruit species are established as germplasm collections for agriculture research stations.

In the Highlands provinces, Oranges, Tangelos, and Mandarins are important cash crops apart from Pineapple and Avocado grown in large quantity for the fresh produce market. Fruits like Cavendish banana, papaya, strawberry, and passion fruit are also grown; however, production has been declining over the years.

In the Lowlands, Mango, Papaya, Watermelon and Cavendish banana are grown for the market. Asian fruits, such as Durian, Jackfruit and Mangosteen are inferior in the local markets however; all these fruits have huge potential for the informal and formal markets. The diverse agro-ecological zones in PNG indicate that almost any fruit species grown in other parts of the world can be grown successfully in selected regions throughout PNG.

Introduction

During the last decade, DAL through its Marketed Fruits and Vegetable Programme has been implementing the Tree Fruit Development activities. Citrus development was given priority in the Highlands, especially Western Highlands (WHP), Simbu (SP) and Eastern Highlands (EHP). Improved citrus cultivars from America were propagated and distributed to 300 smallholders, 20 semi commercial farmers and one commercial farm was established. There are 17 American and five Israeli citrus cultivars maintained in the germplasm collection at Menifo in the Eastern Highlands Province. In the Lowlands, development of Mango and Cashew were given priority especially in the semi arid areas like the Markham Valley and parts of Central province. Asian fruits were selected for the wetter regions. There are seven improved mango and five cashew varieties held in the fruit germplasm collection at Erap in the Morobe province, six mango cultivars at Laloki (NARI) in the Central province.

A large collection of Tropical, Asian exotic and Indigenous fruits and nuts are held in the germplasm collection in Kerevat (NARI), East New Britain Province. These include over 40 species and over 300 accessions.

Currently, there are 10 private nurseries operating throughout the highlands, (Western Highlands Province, Simbu Province and EHP) to provide planting materials for the increasing number of smallholders. These nurseries are monitored and certified by DAL before distributing materials to farmers. Central nurseries operated by DAL and NARI are located in Menifo, Erap, Bubia (Morobe Province), Laloki and Kerevat. While these nurseries exists the NARI 2001 provincial consultation revealed that stakeholders from various sectors are willing to try investing in fruit and nuts but they do not have easy access to basic production/marketing information and quality planting materials.

There is very little progress in developing the fruit industry in PNG by all stakeholders concerned. Although, the demand for planting materials is increasing they are not easily accessible. The government’s reform program to decentralise the functions of DAL to districts and local level governments and the Provincial Governments priorities in
implementing the horticulture program is having negative impact on the industry.

**Tree Fruit Development**

**Development in the last decade**

The Tree Fruit Development Programme was implemented by DAL as a Public Investment Project (PIP) from 1985 to 1990 with a broad objective to;

- Improve nutrition and provide alternative cash income for the rural population,
- Be self-sufficient in fresh fruits and processed products, and
- Be net exporter of fresh fruits and processed products.

**Table 1. Provinces comprising the PNG citrus industry**

<table>
<thead>
<tr>
<th>Province</th>
<th>Small Holder</th>
<th>Commercial</th>
<th>Total Hectares</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. WHP</td>
<td>72</td>
<td>3</td>
<td>27</td>
</tr>
<tr>
<td>2. EHP</td>
<td>10</td>
<td>5</td>
<td>32</td>
</tr>
<tr>
<td>3. SIMBU</td>
<td>5</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>4. ENGA</td>
<td>2</td>
<td>1</td>
<td>21</td>
</tr>
<tr>
<td>5. CENTRAL</td>
<td>-</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>6. MOROBE</td>
<td>-</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

Under this programme priority crops were identified and attempts made to source improved cultivars and establish and promote these crops in agro-ecological zones with potential. This included citrus in the highlands and mangos and tropical fruits and nuts in the lowlands.

**Citrus Development in the Highlands**

High quality planting materials were sourced from Willet and Newcomb Inc, University of California (USA). This included importation of varieties for scion wood as well as rootstock.

The scion wood imported include,

- **Navel Oranges** - Parent Washington, Gillette, Fisher and Lane’s late navels.
- **Valencia Oranges** - Frost, Cutter and Campbell Valencia.

From the central nursery, a total of 30,000 grafted seedlings were distributed in 1985 to 1990. The expected yield from the trees at full production would produce from 800 to 1,000 tonnes per fruiting season (i.e., 10 t/Ha). In 1990 PNG imported 600 tonnes of fresh citrus fruits annually, 80% of which were oranges, 1.4 million litres of juice and 30 tonnes of marmalade. The Provincial DAL in WHP and Simbu distributed 12,000 seedlings in both provinces. There are no records of the origins of planting materials. The fruit production from the latter distribution was a disaster to the industry because 70% of fruits produced were of poor quality. All locally produced citrus was rejected by supermarkets in all major centres and are now importing from Australia and New Zealand.

From the central nursery, seeds and propagated planting materials were distributed throughout the New Guinea Islands and the mainland regions (data not...
available). Number of growers with Asian fruits in the 1990’s is given in Table 2.

Recommended Israeli varieties include; New Hall, Lane Late, Fortune, Ortanique and Trovita.

**Table 2. Number of Growers with Asian Fruits in Rabaul**

<table>
<thead>
<tr>
<th>Grower</th>
<th>No. of Trees</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Vunakanau Plt’n</td>
<td>200</td>
<td>Durian</td>
</tr>
<tr>
<td>“”</td>
<td>40</td>
<td>Langsat</td>
</tr>
<tr>
<td>“”</td>
<td>64</td>
<td>Mangosteen</td>
</tr>
<tr>
<td>“”</td>
<td>24</td>
<td>Rambutan</td>
</tr>
<tr>
<td>2. M.Henderson (Ulatawa)</td>
<td>76</td>
<td>Vietnam Guava</td>
</tr>
<tr>
<td>3. COMDEV</td>
<td>105</td>
<td>Mangosteen</td>
</tr>
<tr>
<td>4. C. Watz (Kurakakaul)</td>
<td>21</td>
<td>Rambutan</td>
</tr>
<tr>
<td>5. C.I.S (Kerevat)</td>
<td>350</td>
<td>Vietnam Guava</td>
</tr>
</tbody>
</table>

In the Momase and Southern regions, mango and cashew were distribution from nurseries at Erap and Laloki (No records available). A proper survey and records of distribution will determine the number of smallholders and semi commercial growers in the region. The number of growers in Lae may have obtained planting materials from other centres. Survey in 2000 shows smallholder and commercial establishment in the Morobe province (Table 3).

**Table 3. Smallholder and commercial establishment in the Morobe Province**

<table>
<thead>
<tr>
<th>Grower</th>
<th>No. of Trees</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. NARI (Bubia)</td>
<td>10</td>
<td>Citrus (Oranges)</td>
</tr>
<tr>
<td>“”</td>
<td>20</td>
<td>Carambola</td>
</tr>
<tr>
<td>“”</td>
<td>20</td>
<td>Rambutan</td>
</tr>
<tr>
<td>“”</td>
<td>50</td>
<td>Pawpaw</td>
</tr>
<tr>
<td>2. Zenag</td>
<td>2,000</td>
<td>Citrus</td>
</tr>
<tr>
<td>3. Peter Samuel (Mutzing)</td>
<td>60</td>
<td>Mango</td>
</tr>
<tr>
<td>4. Bewapi Estate</td>
<td>20</td>
<td>Mangosteen</td>
</tr>
<tr>
<td>“”</td>
<td>10</td>
<td>Durian</td>
</tr>
<tr>
<td>“”</td>
<td>20</td>
<td>Rambutan</td>
</tr>
<tr>
<td>“”</td>
<td>10</td>
<td>Carambola</td>
</tr>
<tr>
<td>5. Utula Samana</td>
<td>20</td>
<td>Rambutan</td>
</tr>
<tr>
<td>6. Markham Farm</td>
<td>100</td>
<td>Vietnam Guava</td>
</tr>
</tbody>
</table>

**Recent development in Fruit production**

**Highlands**

In the highlands, tree fruit development is predominantly citrus. Improved varieties from America and Israel are propagated and distributed to small holders and semi commercial farmers. Recommended American citrus varieties include; *Navel oranges, Valencia oranges, Mandarins, Tangelos, Grape fruit, Lemon and Lime.*

All the rootstock is sourced from Willet and New Comb Inc., University of California, USA. It is expensive to import rootstock at the current exchange rate however in a recent survey, the following rootstock were found to be bearing fruit in Mt. Hagen (WHP) and Goroka (EHP). These are recommended rootstock and can be sourced from within the country to save costs. These are; Cleopatra mandarin, Carrizto citrange, Citrumelo, Volkameriana and Poncirus trifoliata.

Other potential tree fruits suitable for the highlands are Avocado, Apple and Macadamia nuts. Avocado mainly Mexican and Guatamalan types are grown from seeds in many villages throughout the highlands. Suitable Avocado cultivars worth importing include, Hass, Fuerte, Hazzard, Sharwil and Adrenol.

Apple is growing well in Henganofi (EHP). The farmer has gradually increased his orchard to 1,000 trees. Improved varieties
with low chilling hour requirements will grow well at altitudes 1,000 – 1,200m. Some potential varieties suitable in this range include, Rome Beauty, Jonathan, Granny smith and Gala.

Macadamia nut grown at Menifo has borne heavy fruiting and is also a potential candidate for developing in the highlands.

**Momase**
The Momase region comprises of the coast, mainland and the highlands. It has temperate and tropical agro climatic zones suitable for growing many types of fruits.

The Markham plains is drier having semi arid conditions and is best suited to Mango and Cashew. The Erap station (DAL) has improved varieties of mango and cashew. Mango cultivars, Kensington pride, Erwin, Glen, Banana kalo, Karabao, Nam dok mai and the local Rabaul tatopuri are available. Early establishment of mango and cashew in smallholder orchards have been destroyed in bush fires but some still exist as backyard trees, which the villagers sell in the market with their local mango varieties.

Cashew is a new crop that is very popular in villages and consumed at household level. The bulk of the cashew seeds are supplied to Madang and East Sepik provinces respectively at the request of Provincial DAL.

Commercial mango production and downstream processing proposed by Rumion Piggery in the Markham Valley will be developed. DAL will assist in developing the plantation because it will create employment and open up markets for the farmers when this establishment goes into downstream processing.

**Southern**
The Southern region comprises of the mainland, highlands and islands in Milne Bay. The agro climatic conditions around Port Moresby are generally dry for most parts of the year. Mango and Cashew can be grown. Mango propagated and supplied from Laloki (NARI) to some small holders, Launakalana and the Pacific Adventist University (PAU) has come into production and sold in the local markets in Port Moresby.

In the Sogeri plateau, 2,000 citrus trees supplied from Kuk are producing good quality fruits and all are sold in supermarkets. Other potential fruits and nuts for the southern region include: Avocado, Cashew, Macadamia, Banana and Pawpaw in the drier areas.

Asian fruits can be developed in the wetter areas like Oro, Gulf and Western provinces. Some 5,000 mango seeds were supplied to Ok Tedi Mining for propagation and distribution with assistance from DAL in the Western province.

**Islands**
There has been little progress in tree fruit development in the Islands region except for New Ireland, Buka and East New Britain. Citrus was distributed to the Lelet plateau in the late 1990’s. The Islands agro climate is best suited for Asian fruit development. Tree fruits such as Durian, Mangosteen, Rambutan, Carambola, *Annona spp*, Vietnam Guava etc will grow successfully. The islands region has a huge potential to develop the indigenous fruits and nuts of PNG. A central nursery and a vast germplasm collection of tropical and Asian fruits are kept at Keravat (NARI).

**Tree Fruit germplasm collections**

1. Citrus collection at Menifo (DAL – Goroka) has 20 American cultivars consisting of Navel oranges, Valencia, Mandarins, and Tangelo. Grape fruit, Lemon and Limes. There are six Israeli cultivars of Oranges (Newhall, Lane late, Trovita), Mandarins (Ortanique, Fortune) and West Indian Lime. Citrus rootstock trees bearing (Ex USA) – Volkameriana, Citrumelo, Carrizo citrange Apple rootstock - 20 plants and three Macadamia nut cultivars.
2. Tree fruit germplasm collection at Erap (DAL – Lae). 7 Mango cultivars, Kensington pride, Erwin, Glen, Banana kalo, Karabao, Nam dok mai and Rabaul tatopuri. 5 Cashew cultivars, 4 citrus cultivars, Jackfruit varieties, Soursop, Custard apple, Avocado, Vietnam Guava, carambola, canistel and Pawpaw.


4. Mango germplasm collection at Laloki (NARI - Port Moresby) Mango collection consists of Kensington pride, Erwin, Glen and Nam dok mai. It is understood that new mango varieties are also introduced at PAU.

The Future and Research opportunities in Fruit Development

There are many indigenous and exotic fruit species in PNG which all stakeholders from government and private sector should focus their attention towards developing the industry. The indigenous fruits and nuts have huge potential to be commercialised. With the introduced fruits, many smallholder orchards are neglected due to lack of extension and training program in place, high cost of agro chemicals and lack of market infrastructure. A participatory extension and training approach must be targeted for extensionists and farmers to maintain sustainable production, subsidised cost of agro chemicals and lack of market infrastructure. A systematic training program must be adopted and private sector investment in various production chains will enhance development of competitive and sustainable horticulture industry.

Research opportunities for developing the industry, lies in fruit and nut species that are already existing in the country. For indigenous fruit and nuts, there is a need for collection and domestication of superior cultivars, propagation techniques to enhance multiplication and distribution, Genotype and environment interactions, Agronomy, Pest & disease control and marketing. For the introduced fruits and nuts, research opportunities include increasing gene pool for selection of high yielding cultivars, rootstock and scion interaction to improve fruit quality, genotype and environment assessments, post harvest quality control and downstream processing.

Conclusion

PNG has long term benefits in developing a tree fruit industry. In the short term, it will enhance employment, nutrition and food security. It is a potential income earner at national and household levels. In the long term, it will have an impact on the economy of the country in substituting imports and export fresh and processed products.

The Agro climatic conditions in PNG are ideal for developing the exotic and indigenous fruit and nuts. NARI, DAL, NGO, private investors and farmers would be cohesive partners in developing the industry through collaboration, networking and capacity building. The government must set up an agency that could specifically address the needs and requirements to develop the industry. An agency that will oversee processes of propagation of planting material, production, extension and training, quality control to marketing and processing as a package. A good example is Fresh Produce Development Agency (FPDA) mandated to the vegetable industry in PNG.
Production patterns for fruit and nut species in Papua New Guinea and some implications for marketing

R. Michael Bourke

Abstract

The supply of a particular fruit or nut varies over time for a number of reasons, one of which is seasonal or non-seasonal changes in the supply from the plants. This is termed the production pattern. This paper builds on a major study of the production patterns of 180 economic crops in PNG and a subsidiary study that compared the period of plentiful supply of 57 fruit and five nut-bearing species in PNG with the patterns in Australia, Indonesia, the Philippines and Thailand.

A brief overview of the production patterns for a number of fruit and nut-bearing species is given. There are three major physical environmental factors that initiate the onset of flowering. These are changes in day length, temperature and moisture. The different influences that these environmental factors have on the flowering of some species is described.

The prospects for exploiting differences in the production patterns for marketing within PNG and overseas is examined. There are some theoretical prospects for exploiting seasonal differences between PNG and both Australian and nearby Northern Hemisphere countries for a number of crops, particularly for durian, langsat, mangosteen, pulasan and rambutan. In practice, the possibilities of exploiting seasonal differences in the producing period between Australia or nearby Northern Hemisphere countries are remote because of significant constraints. There are better prospects for exploiting differences for certain fruit and nut species within PNG.

Production patterns

This paper gives an overview of the production patterns of fruit and edible nut species grown in PNG. Some of the implications of those patterns for marketing fruit and nuts within PNG and to overseas markets will be summarised.

The supply of a particular species varies over time for one or more of the following reasons:
1. Changes in the rate of planting. This is more true for annual crops than for fruit and nut crops, which are mostly perennial.
2. Changes in the yield per unit area over time. This is responsible for much of the variation for perennial species.
3. Changes in harvesting and marketing behaviour by villagers.

Changes in the production pattern or supply are commonly referred to as the seasonal pattern – someone might say, for example, that it is a good season for sweet potato. The term ‘seasonality’ is used in this paper in a more technical sense and refers to regular and predictable changes in the supply. Thus, if a particular fruit or nut produces at about the same time each year, we can describe that pattern in terms of the producing season. For example, we can say that the producing season for marita pandanus fruit in the main highland valleys is January to April.

However, the observed patterns are more complicated. The period of regular supply for any given species may change from year to year; supply can depend on the variety and it often depends on the physical environment where the crop is grown. The environmental variables day length, temperature and rainfall are particularly influential. Such differences between locations and between years have implications for commercial marketing of fruit and nuts.
Data sources

This paper is based on a major study of the production patterns of 180 economic crops in PNG (Bourke et al. 2004). That study included data on 75 fruit and 25 nut species from various locations in PNG. The main sources of the study were:

1. Weekly or fortnightly surveys of five highlands markets over a three-year period. Four of the markets were in Eastern Highlands Province (Goroka, Kainantu, Aiyura and Ukarumpa) and one was in a remote location in Southern Highlands Province (Hol market on the Nenbi Plateau, Nipa District). As well, fortnightly market survey data was available for one year for Wau market in Morobe Province.

2. Purchase records of the Food Marketing Corporation (FMC) for Port Moresby, Lae, Wau, Kainantu, Goroka and Mt Hagen. The Goroka data was for a five-year period and that for the other centres was for a two-year period.

3. Market prices of 15 foods for a 22-year period for Port Moresby, Lae, Rabaul, Madang and Goroka markets. These prices are recorded by PNG Division of Primary Industries staff and used by the National Statistical Office to help compute the Consumer Price Index.

4. Records of experimental plantings of nine fruit and nut species from Keravat, East New Britain Province, pineapple from Keravat and pineapple from Saiho, Oro Province.

5. Records by observers on the producing season of mango for Rabaul, East New Britain Province; Markham Valley, Morobe Province; and Port Moresby over a six-year period.

6. Records by observers on the producing season of karuka nut pandanus for Kainantu, Goroka, Wabag, Mendi, Tari and Oksapmin areas over a 6–10 year period.

7. Villagers’ statements and literature. Villagers were asked about the producing season for certain crops and their responses were summarised. As well, statements in the literature based on observations by geographers, anthropologists and agriculturalists were compiled.

The quality and quantity of the available data is quite uneven. For some species, such as avocado, mango, mandarin, marita pandanus, pineapple, galip nut, karuka nut and okari nut, we have a lot of data. In contrast, there is little data for many lesser-known species, including those confined to experimental plantings at Lowlands Agricultural Experiment Station (LAES) Keravat and some of the minor indigenous species.

For example, for avocado, there is longitudinal data from:
- Locations in the seasonally dry lowlands (Port Moresby area)
- A seasonally dry intermediate altitude location (Wau)
- Certain seasonally dry highlands areas (Kainantu and Goroka)
- One non-seasonal highlands location (Mt Hagen).

The datasets for avocado are: surveys of three markets in Kainantu area (3 years); a survey of Goroka market (3 years); FMC purchases, Goroka (5 years); FMC purchases, Port Moresby, Wau, Lae, Kainantu and Mt Hagen (2 years); and general statements in the literature. Despite the fact that there are some differences between the patterns in these datasets and that the start and duration of the main producing period for avocado varies from year to year, we can be confident in the conclusions based on these data. In contrast, where the only observations are from experimental plantings at LAES Keravat or single published statements about minor indigenous species, conclusions about the overall production pattern are tentative.

For most of PNG, seasonal differences in day length and temperature are small to negligible. Rainfall seasonality varies from negligible to marked. Hence, the start and finish of the producing season for most
crops is not well defined. Even for crops that have a markedly seasonal producing pattern, it is important to note that there is usually some variation in the pattern between years.

A subsidiary study by Camarotto and Bourke (1994) compared the period of most plentiful supply of 57 fruit and five nut species in the PNG highlands, PNG lowlands, tropical Australia (Northern Territory and north Queensland), subtropical Australia (New South Wales), Indonesia, the Philippines and Thailand. Thus, the data came from three nations in the Southern Hemisphere (PNG, Australia and Indonesia) and two in the Northern Hemisphere (the Philippines and Thailand).

That study examined the potential for exporting fruit and nuts from PNG to nearby nations when the supply is plentiful in PNG and scarce in the nearby countries. The markets considered were the Southern Hemisphere ones of Australia and New Zealand; and the Northern Hemisphere markets of Singapore and Hong Kong, which are normally supplied from nearby Northern Hemisphere countries. The study examined the seasonal production pattern only and did not consider other important factors including demand, quality and competition from other markets.

Production patterns of fruit and nuts

Of the fruit trees described in Bourke et al. (2004), about two-thirds (44) fruit seasonally in PNG and the remainder fruit non-seasonally. Of the 21 species where the information does not indicate a seasonal pattern, 12 are restricted to experimental plantings in a weakly seasonal environment at Keravat and it is possible that they may bear seasonally in other environments.

Five highlands species do not bear seasonally. These are cape gooseberry (Physalis peruviana), elder (Sambucus nigra), naranjilla (Solanum quitoense), highland yellow passionfruit (suga prut) (Passiflora ligularis) and black raspberry (Rubus lasiocarpus). Other non-seasonal fruit species are Parartocarpus venenosa on New Britain Island, rukam (Flacourtia rukam) in Milne Bay Province, and soursop (Annona muricata) and pomelo (Citrus maxima) in the lowlands.

For a number of fruit species, the pattern varies between environments. Pawpaw (Carica papaya), guava (Psidium guajava) and carambola (Averrhoa carambola) are non-seasonal in the lowlands, but produce seasonally in the highlands. It seems that the supply of lime (Citrus aurantifolia) is weakly seasonal in seasonally dry locations from the lowlands to the highlands, but production is not seasonal where rainfall is uniform throughout the year.

Most species that produce an edible nut bear seasonally (13 species). Pao nut (Barringtonia procera) bears in an intermittent, but non-seasonal manner. Breadfruit (Artocarpus altillis), Polynesian chestnut (Inocarpus fagifer) and karuka nut (Pandanus julianettii) bear seasonally in some environments, but not in others. Karuka bears in a more-or-less regular manner in the seasonally dry Eastern Highlands Province, but in a more irregular manner in Enga and Southern Highlands provinces and in the Oksapmin area of Sandaun Province, where the rainfall pattern is non-seasonal (see Figure 91 in Bourke et al. 2004:154).

Environmental influences on flowering and fruiting

Three major physical environmental factors instigate the onset of flowering. These are changes in photoperiod (day length), temperature and moisture (Rathcke and Lacey 1985:190). It is possible to make some suggestions as to the influence of these environmental factors on the production patterns where we have long-term data from a range of environments in PNG.

For species where the start of the producing period is quite regular from year to year, it is most likely that flowering is induced by
changes in day length, as this is regular from year to year, whereas changes in temperature and rainfall vary from year to year. Species that have a regular production pattern in PNG include purple passionfruit (*Passiflora edulis f. edulis*), sis nut (*Pangium edule*) and marita pandanus (*Pandanus conoideus*). There is no predictable producing season for breadfruit and Polynesian chestnut in much of PNG but, for locations south of about latitude 8°S, the producing season is predictable and regular. It is likely that this happens because changes in day length are great enough at this distance from the equator to initiate flowering at about the same time each year.

There is a clear relationship between latitude and the start of the harvesting period for okari nut (*Terminalia kaernbachii*) and galip nut (*Canarium indicum*). The producing season commences earlier near the equator and progressively later at locations further south of the equator. For galip nut, this pattern is more apparent at latitudes south of 6°S. It is likely that this pattern is caused by differences in day length (see Figure 93 in Bourke et al. 2004:156).

Altitude has the greatest influence on temperature in PNG (McAlpine et al. 1983). Above 500 m, temperature falls at a regular rate of 0.5 °C for every 100 m increase in altitude. Seasonal temperature differences are generally small, with larger seasonal differences at locations further from the equator. These differences are reinforced where most rainfall occurs in the south-east season (May to September), which coincides with the Southern Hemisphere winter.

For many crops, altitude (temperature) has no apparent influence on the start and duration of the production period. This is the case for avocado, mandarin, orange and purple passionfruit. However, there is a relationship between temperature and the start and duration of the fruiting period for marita pandanus. Near sea level, production is continuous throughout the year and non-seasonal. The producing period becomes shorter with increasing altitude and is only four months long at 1,600–1,700 m near the crop’s upper altitudinal limit (see Figure 92 in Bourke et al. 2004:155). An experimental study on rough leaf pineapple at Keravat concluded that flowering is initiated by low night-time temperature, and not by other environmental factors (Bourke 1976). That conclusion was supported by non-experimental data compiled by Bourke et al. (2004).

Mean annual rainfall in PNG varies from about 1,000 mm (near Port Moresby) to nearly 10,000 mm, with most of the population living in locations where the rainfall is 1,000 to 3,500 mm per year. Three broad patterns of rainfall distribution can be distinguished. In most of PNG, rainfall distribution is seasonal with the maximum from January to April and the minimum from May to August. Parts of PNG have the reverse pattern, with the highest rainfall from May to August. In the third pattern, there is little rainfall seasonality, that is, all months are wet (McAlpine et al. 1983). Changes in the rainfall seasonality occur over short distances, often with all three patterns occurring in nearby locations. This allows us to examine the impact of rainfall seasonality on the supply of fruit and nuts, knowing that seasonal changes in day length and temperature are negligible.

In general, rainfall seasonality has only a limited effect on the flowering and fruiting behaviour of fruit and nut species. For example, in Milne Bay Province, the producing period for many fruit and nut species is the same in locations that receive more rain in January–April as it is in locations that receive more rain in May–August. For a few annual crops, rainfall seasonality influences the incidence of diseases and insect pests and thus determines the optimum time for planting. This seems to be the situation for a number of cucurbits, including watermelon (*Citrullus lanatus*) and rockmelon (*Cucumis melo*).

Development and maturation of mango (*Mangifera indica*) fruit is dependent on
both seasonal temperature and rainfall changes (Cull 1991). In PNG, mango bears during the same period (October–January) in all locations, irrespective of the timing of the rainfall seasonality pattern, although the pattern varies from year to year for any location. Rainfall has an influence in that the highest yields occur in locations with a marked dry season, such as coastal Central Province, the southern part of Western Province, the Rabaraba–Cape Vogel area of Milne Bay Province, the upper Markham Valley, the Sialum area on the Huon Peninsula, the western end of Umboi Island and the eastern part of the north-east Gazelle Peninsula of East New Britain Province. For the three locations where observations are available for a six-year period (Rabaul, Markham Valley and Port Moresby areas), a relationship exists between the period of lower rainfall and the start of the harvesting period. For example, in the Port Moresby area, the harvest period starts 5–6 months after the start of the drier months in any given year (see Figure 90 in Bourke et al. 2004:153).

**Some implications for marketing within PNG**

Within PNG, differences in the production pattern between locations may present some opportunity to market produce so as to exploit these differences. In general, however, there are only limited opportunities to do so.

In contrast, there are many opportunities for marketing produce within PNG for crops that perform better in certain environments than in others. In PNG, environmental differences are often large, sometimes over short distances. These differences are associated with changes in rainfall patterns and altitude. For example, certain crops that thrive in the Markham and Ramu valleys, such as mango, watermelon, coconut and peanuts, cannot be grown in the highlands, or do not perform as well there. In the north-east lowlands of the Gazelle Peninsula, there are differences in crop performance in seasonally dry locations, such as near Blanche Bay, and locations where rainfall is only weakly seasonal, such as in the Keravat–Vudal area.

It is worth noting that there are large and consistent differences in the supply pattern of betel nut (a narcotic) between certain locations. The most obvious is that the best supply in the Madang area occurs in January–March, and this is the period of poorest supply in the Port Moresby area. This creates a commercial opportunity in that betel nut can be moved from a location where it is abundant and cheap to one where it is scarce and hence expensive.

As noted above, the start of the producing period for both okari nut and galip nut tends to occur later with increasing distance from the equator. This presents the opportunity for a larger processor to obtain supplies from different locations over a longer period and thus extend the processing season. This is hypothetical at this stage, as there is no commercial processing of these edible nuts in PNG.

The producing period for marita pandanus commences later and is shorter with increasing altitude in PNG. This is exploited by villagers who live at lower altitude locations in the highlands, as their marita fruit is ready for harvest and can be sold or given as a gift to people who live at higher altitudes. Towards the end of the calendar year, villagers who live at 1,200–1,500 m commonly carry fruit to markets and to individuals who live at 1,600–1,800 m. This production pattern could be commercially exploited in the future.

Two other crops have a production pattern that varies from year to year, but also between locations. The first is karuka nut, for which the pattern varies considerably both between years and between locations. The producing period tends to be more regular in Eastern Highlands Province, where there is a regular dryer season, than in the western part of the highlands where rainfall is not seasonally distributed. This creates the possibility of moving the highly
sought-after karuka nuts within the highlands. The other crop is mango. The start and duration of the season varies somewhat from year to year. It tends to commence earlier where the dry period is earlier. Again, this creates the potential to move fruit from locations where fruiting has commenced to those where the production season has not yet started or where the fruit does not grow. The potential to move mango within PNG is limited by the highly perishable nature of the fruit and the poor transport system at many of the locations where it grows well, for example, at the Sialum area on the Huon Peninsula and on western Siassi Island.

Some implications for marketing outside PNG

The study by Camarotto and Bourke (1994), which examined the potential for exporting fruit from PNG to overseas markets during their off-seasons, found a number of differences in the production patterns which could theoretically be exploited by PNG producers. There are clear and consistent differences in the main producing period between the Northern and Southern Hemispheres for some species, including durian (*Durio zibethinus*), rambutan (*Nephelium lappaceum*) and mandarin (*Citrus reticulata*). For other species, such as avocado and watermelon, the production period is somewhat different, but overlaps in the two hemispheres.

Camarotto and Bourke concluded that the best prospects for exporting fruit from PNG so as to exploit seasonal differences are for durian, langsat, mangosteen, pulasan and rambutan to certain Asian markets during the Northern Hemisphere non-production period.

There is theoretical potential for exporting some other fruit species to both Northern Hemisphere (Asian) and Southern Hemisphere (Australian) markets, based on seasonal differences. This is the case for avocado, grapefruit, lime, mandarin, mango, pomelo, raspberry and strawberry. For example, production of avocado occurs throughout the year in Australia, but the supply is light from January to March. The period of poorest supply in Australia coincides with the period of peak production in the PNG lowlands and highlands. The producing season for strawberry in the PNG highlands (June to September) coincides with the off-season in nearby Northern Hemisphere countries, suggesting the possibility of exporting strawberries from PNG to Singapore, for example.

Conclusions

There are differences in the producing patterns for a number of fruit species grown in PNG compared with both Australia and nearby Northern Hemisphere countries. However, there are few realistic possibilities for PNG to export fruit to Australia, New Zealand or South-East Asian markets to exploit different seasonal production patterns. The fruit and nut industries in PNG are poorly developed commercially. Other significant constraints include:

1. The poor quality of much fruit in PNG
2. The highly perishable nature of many fruits
3. Poor communication and transport links within PNG
4. The absence of marketing systems that move high quality fruit within PNG
5. Quarantine restrictions that would prevent fruit being imported from PNG, especially high levels of fruit fly infestation

A few specialist producers may be able to exploit seasonal differences, but this is not a realistic option in the short to medium term for most PNG producers.

There are better prospects for exploiting differences in production patterns for certain fruit and nut species within PNG.

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Nema, Tevo Tarepe, Steve Woodhouse and 25 others. Staff of various Divisions of Primary Industry recorded market price data used to compile the Consumer Price Index. Numerous villagers throughout PNG provided information on production patterns of crops in their areas. Some, but not all, of those who provided information are acknowledged in the monograph by Bourke et al. (2004).

References


Quarantine and Market Access for Fruits and Nuts Exports in Papua New Guinea

Roy Masamdu and David Tenakanai

Abstract

Quarantine has been identified as an impediment to market access for many of Papua New Guinea’s horticultural products especially fruits and nuts. However, galip nut (Canarium indicum); cashew nut (Anacardium occidentale); pineapple, (Ananas comosus) have had market access, while others such as karuka (Pandanus julianettii); mango (Mangifera indica); banana (Musa sp.); okari nut (Terminalia kaernbachii) can have market access if a coordinated approach is made between the private sector and relevant state agencies to encourage and develop production and marketing strategies, conduct research on field pest management, post harvest handling and treatments to maintain consistency in quality and supply.

Introduction

The policy of the Government of Papua New Guinea (PNG) is to have an export driven economic growth. The Horticulture sector can have an important role to achieve this goal through export of commodities that have niche markets. Fruits and nuts are no exception.

Quarantine issues have been recognised as a barrier to export of fruits and nuts from Papua New Guinea. The National Agriculture Quarantine and Inspection Authority (NAQIA) has been trying to ensure that quarantine issues do not become a barrier if they can be resolved through provision and exchange of adequate information between countries. Specific quarantine issues such as the risk of entry of fruit flies, giant African snail on commodities and regulated articles continued to be used as barriers against PNG products.

PNG has not been exporting many fruits and nuts, except for cashew nut, galip nuts and pineapples which have had market access. PNG needs to broaden the range of fruit and nuts for export. Apart from quarantine there are other issues such as consistent production, marketing infrastructure, market access, quality control and assurance and pest and disease management that have been identified in a study conducted by McGregor et al, (2003). The lack of industry associations to coordinate market access was also identified as a constraint in many Pacific Island countries including Papua New Guinea (Landos, 2000).

This paper outlines the current status of exports of fruits and nuts and the quarantine requirements for market access.

Current status of market access to exports of fruits and nuts

There are some commodities that already have market access. Pineapples were already accepted into New Zealand after market access was sought and bilateral quarantine arrangement (BQA) was established. However, production and shipping arrangements were inadequate and the market was lost. Cashew nut has been exported in small quantities. The Livestock Development Corporation and the PNG Sustainable Development Company have two projects to further develop cashew and NAQIA has been assisting them to acquire high yielding materials from Australia. The galip nut has been exported in small quantities but again consistency of supply to meet the demand is required. The three are either non hosts of fruit flies or are sold as processed products.
Commodities that should have market access

A number of horticultural products could have market access if various issues are solved. These include mango, rambutan (*Nephelium lappaceum*); banana, pawpaw (*Carica papaya*); bread fruit, (*Artocarpus altilis*); karuka nuts, (*Pandanus sp.*) taun (*Pometia pinnata*), Okari nuts (*Terminalia sp.*), Tahitian chestnut (*Inocarpus fagifer*) and the cut nuts (*Barringtonia sp.*).

Durian (*Durio zibethius*) is a potential fruit for the domestic market targeting the vast South East Asian population in PNG and eventually targeting the off season markets in Asia. It can store up to three weeks at 15oC, therefore, packing and transportation can be simplistic. The odour though can be nauseating for some (QDPI, 1984).

It is important that the private sector or industry must have associations which must drive the production and marketing.

Quarantine requirements for market access

NAQIA together with NARI could assist industry associations or marketing agents to provide information on; non host status of various commodities for specific pests such as fruit flies, low pest prevalence in production areas, effective field pest management, effective post harvest treatments, regular pest surveillance and monitoring, pest list of commodities through the national pest list database and technical data on pest management.

The role of quarantine

NAQIA could assist in the following ways; request market access during trade negotiations or in writing, negotiate quarantine requirements/protocols with importing country, ensure importing country’s requirements are met through inspection and certification (SPS) from farm gate to marketing outlet, inform other countries of pest outbreaks, pest eradication and containment through International Plant Protection Convention (IPPC) etc and collaborative research into quarantine treatments.

Collaborations

Working in isolation is a recipe for failure and PNG may not be able to produce good quality and maintain production both for domestic and international markets. Cooperation between relevant institutions and organisations is essential to achieve goals set for the expansion and exportation of fruits and nuts in PNG.

Research, extension, quarantine, trade relations and promotions in PNG are responsibilities and mandates of different institutions specifically NARI, FPDC/DAL, NAQIA, Department of Trade and Industries and Culture and Tourism Promotions respectively. These organisations must collaborate and support each other in their endeavours to produce and promote export quality produces and establish guidelines for both the domestic and international markets.

Future prospects

Fruits and nuts trade can be fostered if; High Temperature Forced Air (HTFA) and research on other types of treatments should be conducted by NARI, FPDC and NAQIA. This technical information will be provided to quarantine authorities in potential importing countries to convince them and to arrange trial shipments of these potential commodities.

PNG must identify and select commodities where it has the competitive advantage and develop production and marketing strategies for export.

PNG must have its private sector and or associations organise production and marketing infrastructure,

PNG should concentrate on processed products to have a better chance of market
access than raw products that may be difficult to have market access,

NAQIA can facilitate importation of new planting material for improved yield and other desirable qualities.

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**References**


Indigenous Fruit in Papua New Guinea

R. Michael Bourke

Abstract

This paper describes some of the indigenous fruit species of Papua New Guinea (PNG), that is, species which were grown and eaten prior to settlement by other Pacific islanders, Europeans and Asians from about 1870 AD onwards. A list of 40 species that are eaten as fruit in PNG is presented, but the list is by no means complete. Information is given on 10 of the most commonly eaten indigenous fruits grown by the rural population, and six other indigenous fruit species. The following attributes are covered for each species: how the fruit is consumed; global distribution; distribution within PNG; altitudinal range in PNG; the number of rural people who live in locations where the species is common; production pattern (crop seasonality); marketing; and potential for further development.

The species discussed are bukabuk (Burckella obovata), coastal pandanus (Pandanus tectorius), golden apple (Spondias cytherea), kumu musong (Ficus copiosa), Ficus dammaropsis, Ficus tinctoria, Ficus wassa, Malay apple (Syzygium malaccense), marita (Pandanus conoides), mon (Dracontomelon dao), parartocarpus (Parartocarpus venenosa), pouteria (Pouteria maclayana), rukam (Flacourtia rukam), ton (Pometia pinnata), watery rose apple (Syzygium aqueum) and traditional mango (Mangifera minor).

Introduction

Indigenous fruits are defined here as species that were grown and eaten by Papua New Guineans prior to settlement by other Pacific islanders, Europeans and Asians from about 1870 AD onwards. The species include fruits that are endemic, native or introductions from other locations prior to 1870. Villagers eat a significant number of indigenous fruit species that are local to the area in which they live, but are poorly known elsewhere. For example, in the Cape Vogel area of Milne Bay Province, villagers eat fruit of more than 10 self-sown species, including Antidesma platyphyllum and A. ghaesembilla (J. Mogina, UPNG, pers. comm. 2005).

There is no single complete list of the indigenous fruit species grown and eaten in PNG. The most complete sources are Table 3.1 (‘Plants used as food’) in Powell (1976); the listings of fruit species in French’s (1986) book, Food Plants of Papua New Guinea; and the table ‘Fruits and nuts eaten from New Guinea to the Cook Islands’ in Fruits of Oceania (Walter and Sam 2002:277–82). A list of 40 species that are eaten as fruit in PNG is given in Table 1. This is drawn from my fieldwork (with identifications by staff from the former Division of Botany, Department of Forests in Lae), supplemented by the three sources named above. The list is by no means complete and the sources cited above list other species. The botanical names can be confusing for a non-specialist as there are many synonyms and many species are obscure and poorly described.

The purpose of this paper is to give some information about the most commonly grown species. It is not clear what potential there is for commercialisation of the indigenous fruit species. The flavour of some species suggests that the fruit is unlikely to be widely accepted outside PNG or even by people in PNG who are not familiar with the fruit. Ton (Pometia pinnata) is seen by many as having significant potential for further commercialisation in PNG. There may well be non-food products which could be developed. For example, participants at the Fruit and Nut Workshop identified marita pandanus fruit (Pandanus conoides) as worth testing for the properties of its oil.
Information is given here on 10 of the most commonly eaten indigenous fruits in PNG, and six other indigenous fruit species. Those 10 species were selected as they are grown by two percent or more of the rural population (Table 6).\(^1\) Banana is an indigenous fruit, but it is included in my paper on introduced fruit in this volume rather than here, as the cultivars with the greatest potential for further sales are introduced cultivars. Breadfruit (Artocarpus altilis) is an indigenous species with both the flesh and seed eaten. It is considered in my paper on indigenous nuts in this volume.

Where available, information is given on the following attributes for each species: how the fruit is consumed; global distribution; distribution within PNG; altitudinal range in PNG; the number of rural people who live in locations where the species is common; production pattern (crop seasonality); marketing; and potential for further development. The distribution data is from the Mapping Agricultural Systems of PNG (MASP) database (Bourke et al. 1998) and the author’s field observations; data on altitudinal range is from Bourke (1989) (see Table 4); and data on production patterns is from Bourke et al. (2004). The figures for the number of people who grow each species are from the MASP database (see Table 6). I use the term New Guinea to refer to the island and Papua New Guinea (PNG) to the state. Similarly, New Britain is an island, while East or West New Britain are provinces on that island.

**Some commonly grown indigenous fruit species**

**Bukabuk (Burckella obovata)**

Bukabuk is consumed as uncooked ripe fruit. It is distributed from the Moluccas Islands (west of New Guinea) through the island chains as far east as Vanuatu (Walter and Sam 2002:125). In PNG, it is mainly grown on small to medium sized islands, although it does occur on larger islands. It is most common in the islands of Milne Bay Province. It is also grown on New Ireland, the island groups north and east of New Ireland, on Buka and nearby small islands in Bougainville Province, on the Duke of York Islands in East New Britain and on the islands west of Manus. It grows from sea level to about 300 m. The highest bearing plant that I recorded was at 390 m on the Gazelle Peninsula of East New Britain Province.

Bukabuk is commonly grown by about 230,000 people or six percent of the rural PNG population. There is no recorded longitudinal data on the production pattern, but reports by villagers in Milne Bay, East New Britain and West New Britain provinces indicate that the harvesting season occurs between December and March each year. This seems to be fairly consistent from year to year.

Small quantities are sold in local markets in the island provinces of Milne Bay, New Ireland, Bougainville and New Britain. It is a pleasant fruit, although the aroma may not suit everybody. It may have some potential for sales on the New Guinea mainland, including the highlands. The fruit is moderately resistant to bruising when unripe, but it would still require careful handling to move fruit from small islands to the highlands or urban centres.

**Coastal pandanus (Pandanus tectorius)**

The globular fruit of coastal pandanus is sucked when fully ripe to obtain a sweet juice, perhaps more by children than by adults. The use of this fruit seems to be less common than in past decades as villagers now have access to sweet drinks, either carbonated (soft drinks, cola, etc.) or non-carbonated (cordial). In recent years, I have only seen it being used on remote islands where people do not have access to

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\(^1\) With the exception of Table 1, references to tables and figures in this paper are to those in the paper ‘An overview of edible fruit and nuts in Papua New Guinea’ in this volume.

\(^2\) Population figures are derived from the 2000 census data, with a total rural village population of 4.2 million people.
purchased drinks. The species (actually a complex of species) is distributed from the Philippines in the north-west to eastern Polynesia and from the Caroline Islands in the north to the tropical coast of northern Australia (Walter and Sam 2002:217). Within PNG, it is used on Manus, the south coast of New Britain, on Bougainville, New Ireland and in a few locations on the New Guinea mainland, for example, near Daru Island off Western Province and near Tufi in Oro Province. It commonly grows as self-sown plants on the shoreline, but I have seen trees up to an altitude of 240 m on Umboi Island, Morobe Province.

The MASP database indicates that some 66,000 people (1.6% of rural villagers) use it as a minor snack food. However, this figure probably overestimates its use. There is no data on the production pattern, but it is probably non-seasonal. The fruit is not sold in food markets as far as I know. There is probably further potential for use of coastal pandanus as it is currently consumed, but there may be other uses for the fruit.

**Golden apple (Spondias cytherea)**

The flesh of golden apple is eaten raw. It is widely distributed in the region from Malaysia and the Philippines through New Guinea and the islands as far east as Tahiti (Walter and Sam 2002:245). Within PNG it is mostly confined to the islands, although it does occur on the New Guinea mainland. It is commonly grown in the islands of Milne Bay Province, Manus Province and New Ireland. It is also grown on Bougainville and New Britain. Golden apple grows from sea level up to a mean of 950 m, and occasionally as high as 1,070 m.

It is commonly grown by about 177,000 people or four percent of the rural PNG population. Information from Milne Bay, Pomio on New Britain and Musau Island north of New Ireland indicate that fruit ripens in about December to February each year. Small quantities of golden apple are sold in food markets in Milne Bay and in the Islands Region. It has potential for processing into jams and chutneys. It is not known whether it could be sold in the highlands, but some fruit could probably be sold in Port Moresby and other urban centres on the New Guinea mainland.

**Kumu musong (Ficus copiosa) and other Ficus species**

The main economic product of the indigenous figs in PNG is the young leaves which are used as a green vegetable, but the fruit of a number of species is also eaten, particularly fruit of *Ficus copiosa*. (This species is known as kumu musong in Tok Pisin, literally, hairy vegetable). Other Ficus species with edible fruit include *F. dammaropsis*, *F. tinctoria* and *F. wassa* (Table 1). *F. dammaropsis* is a highland species, and the others grow in the lowlands and highlands. All species are self-sown and I am not aware of villagers planting trees, but they may protect self-sown seedlings. Fruit of *F. copiosa* is eaten raw. Fruit of *F. wassa* is either cooked or eaten raw in the Nipa area of Southern Highlands Province (Sillitoe 1983:75). Fruit of *F. dammaropsis* is rarely eaten, but can be used as an emergency food.

*F. copiosa* grows widely within PNG, in the Islands Region, in the New Guinea lowlands and in the highlands. *Ficus wassa* has a distribution that extends from east Indonesia through New Guinea, the Bismarck Archipelago and the Solomon Islands to Vanuatu (Walter and Sam 2002:168). *F. dammaropsis* is restricted to the highlands and highlands fringe of New Guinea. The altitudinal range of *F. copiosa* is sea level to 2,200 m (and occasionally up to 2,450 m); the usual range for *F. dammaropsis* is 800–2,750 m (and the extreme range is from sea level up to 2,820 m). *F. wassa* grows from sea level to 2,520 m, under extreme conditions. The usual upper altitudinal limit of *F. wassa* is not known, but is probably about 2,200 m (Bourke 1989).

Leaves of *F. copiosa* in particular are widely used as a green vegetable. There are no
estimates of the number of people who consume the fruit. It is likely that many people consume small quantities of fruit occasionally. For example, in Upa village in the Nipa area, one survey recorded eight *F. copiosa* trees per household (Table 7). In Milne Bay Province, fruit of *F. copiosa* are available in about January–February. Fruit of the various Ficus species are not sold in markets. I do not see any potential for commercial development of the fruit of any of the PNG Ficus species, but there may be novel non-food uses such as for medicinal purposes.

**Malay apple (*Syzygium malaccense*)**

The fruit of Malay apple is eaten fresh, generally soon after being harvested. The species is widely distributed from South-East Asia to the eastern Pacific (Whistler and Elevitch 2005). The pre-European distribution was from Malaysia, the Philippines and Indonesia in the west through New Guinea and the Pacific Islands as far east as Samoa and north to Hawaii (Walter and Sam 2002:251). It is widely grown in the lowlands of PNG, especially in the Islands Region and Milne Bay Province, but it is also grown in some locations on the New Guinea mainland. It is common in the following provinces: East New Britain, Bougainville, Milne Bay, Central, West New Britain, Morobe, New Ireland and Manus. On the island of New Britain, villagers ranked it as the fourth-most important fruit or nut tree in one survey (Table 2). It grows from sea level to a mean of 850 m, and occasionally as high as 1,580 m (Table 4).

An estimated 909,000 people grow the crop, which represents 22 percent of the rural population (Table 6). The fruit ripens sometime between September and February, particularly in December–January. However, the available information is somewhat diverse, suggesting that the seasonal production pattern is not well defined (Bourke et al. 2004:26–7). Malay apple is widely consumed in the lowlands, especially in the Islands Region and fruit is commonly sold in fresh food markets. There is probably some potential for further sales, particularly if clones with sweeter fruit were available.

**Marita (*Pandanus conoideus*)**

Marita fruit is cylindrical in shape, up to a metre long, usually red in colour, but sometimes yellow. The pericarp (outer layer) of the fruit is rich in oil. The fruit is cut into pieces then boiled, roasted or cooked in a stone oven. The pulp and seeds are removed from the core, mashed with water and strained to produce a thick, rich red sauce. This is used to flavour other foods such as sweet potato, banana and green vegetables. Marita grows best in moist locations, often under shade, and tolerates waterlogged soils (Tarepe and Bourke 1982:92–3). Villagers maintain a number of named cultivars. For example, in a community west of Nipa in Southern Highlands Province, people have four cultivars, with people living at lower altitudes growing more cultivars (Sillitoe 1983:112–13).

Distribution of *P. conoideus* is limited to New Guinea and some of the islands to the west (Ceram, Buru and Ternate) (Walter and Sam 2002:211). It is present on Manus Island, but it is not clear whether this is a recent or an ancient introduction from New Guinea (Kennedy and Clarke 2004:20–21). In recent decades it has been introduced to West New Britain from the New Guinea mainland by settlers on oil palm blocks. A number of related species are grown on New Guinea and the islands to the east and west (Kennedy and Clarke 2004:19–21).

Within PNG, marita is grown in all mainland provinces, particularly in the highlands and in the Momase Region, and sometimes on Manus and West New Britain. It is most common in the following provinces: Eastern Highlands, Morobe, Western Highlands, Southern Highlands, East Sepik, Simbu, Madang and Sandaun (Table 6 and Figure 2). It is not usually grown near the ocean, but grows from low
altitudes in inland situations (10–50 m altitude) up to 1,700 m. It occasionally is grown as high as 1980 m (Table 4). Marita is most common over the altitudinal range of 500 m to 1,400 m. It is an important dietary item as coconut is uncommon or does not grow in that zone and there are few other sources of oil or fat in villagers’ diets.

Marita is grown by 1.5 million people, which is 59% of the rural population. This makes it the third-most commonly grown fruit in PNG, behind banana and pawpaw (Table 6). There is a clear relationship between the length of the fruiting season and altitude in PNG. Near sea level, production is continuous and non-seasonal. With increasing altitude, the producing period becomes increasingly shorter. Near the top of its altitudinal range at 1,500–1,700 m, fruit ripens over a four-month period, usually January to April (Bourke et al. 2004:29–30). The number of marita trees per household is often high, especially in the 500–1,400 m zone. For example, in one area near Simbai in Madang Province at 700–1,100 m, Clarke (1971:81, 157) recorded that there were about 400 m² of marita per person. Even at 1,600–1,700 m near the crop’s upper altitudinal limit, there were 19–29 trees per person in two highland villages (Table 7).

The importance of marita in villagers’ diets in the intermediate altitude zone is highlighted by one consumption survey in a community on the Great Papuan Plateau. Marita pandanus contributed 44% of fat in the diet, 15% of food energy and 11% of protein (Odani 2002). (See the section on consumption in my overview paper in this volume for more detail on this and other consumption studies). Marita fruit is commonly sold in food markets on the New Guinea mainland, especially in the highlands.

There may be some limited potential for further sales in urban locations, especially to people who are familiar with the food and live in Port Moresby. It is unlikely to be adopted by people who have not grown up with the taste. There may be non-food uses for the oil or other extracts from the fruit.

**Mon (Dracontomelon dao)**

The fruit is consumed fresh. Globally, the species is distributed from India, through South-East Asia to New Guinea and Solomon Islands (Walter and Sam 2002:158). In PNG it is widely distributed, but not widely consumed, except in Madang Province where it is commonly eaten. It is also eaten in some of the small islands of Manus Province, some of the islands in the south-east of Milne Bay Province, on Nissan Island in Bougainville Province, on the Duke of York Islands in East New Britain and on the Schouten Islands off the mouth of the Sepik River. It is a lowland species and its upper altitudinal limit is not known.

The MASP database indicates that some 230,000 people live in locations where the species is moderately common, and most of those live in Madang Province (83%). The very limited available information on the production patterns suggests that fruit is available in October–December. The fruit is commonly eaten in the lowland part of Madang Province and appears in Madang town market. The limited geographic consumption suggests that it does not have much potential for expansion, but that might depend on the availability of clones with superior flavour.

**Parartocarpus (Parartocarpus venenosus)**

This self-sown species produces a fruit with an irregular shape. The fruit is eaten ripe. It is grown on New Guinea, the Bismarck Archipelago and Solomon Islands. I do not know if it is grown on islands to the west of New Guinea. In PNG it is most common on New Britain, except on the north-east lowlands of the Gazelle Peninsula. The fruit is eaten on a number of small islands off the

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3 As with all crops, there is some variation in the altitudinal range between locations, as indicated by the standard variation figures in Table 4. The altitudinal ranges of *P. conoideus* (marita) and *P. julianettii* (karuka nut pandanus) rarely overlap, with the lower limit for karuka typically about 100 m higher than the upper limit for marita.
north and south coast of Manus and some islands off the New Guinea north coast, including Kairiru Island (Borrell 1989:109) and those in the Schouten group in East Sepik Province. It is a lowland species, but the upper altitudinal limit is not known.

The MASP database indicates that 145,000 people live in locations where the fruit is eaten, mostly on the island of New Britain (4% of all rural villagers in PNG). There is only scattered information on the production pattern, but the species appears to fruit in a discontinuous and non-seasonal manner. Parartocarpus is a minor food source on New Britain, where villagers rank it as a moderately important fruit species (Table 2). It is not sold in food markets and probably has very limited potential for commercial development.

**Pouteria (Pouteria maclayana)**

The yellow-fleshed fruit of this self-sown species is occasionally eaten raw. The species grows on several small islands off Sumatra in Indonesia, as well as on New Guinea, on small islands north of New Guinea and in the southern Solomon Islands (Walter and Sam 2002:233). Within PNG it is eaten on Karkar Island, along the Rai Coast and in the Schrader Range of Madang Province; and on Kairiru Island and in the Schouten Islands in East Sepik Province. The species grows near sea level and its upper altitudinal limit is unknown. The MASP database indicates that a little over 100,000 people live in locations where it is eaten. This is two percent of the rural population (Table 6). However, rukam is eaten only by some people, so the MASP figure exaggerates the number who consumes it. Information gathered on four islands in Milne Bay Province suggests that fruiting is discontinuous, but not seasonal. It is not sold in local markets as far as I know. It probably has limited potential for commercial production, but it may be possible to sell fruit in some urban markets.

**Rukam (Flacourtia rukam)**

The fruit of this self-sown tree is eaten raw occasionally. The species is native from Malaysia, the Philippines through New Guinea to the Solomon Islands (Walter and Sam 2002:174). In PNG it is a minor fruit and is consumed mainly in the islands and on the mainland of Milne Bay Province. It grows near sea level and its upper altitudinal limit in PNG is unknown. The MASP database indicates that a little over 100,000 people live in locations where it is eaten. This is two percent of the rural population (Table 6). However, rukam is eaten only by some people, so the MASP figure exaggerates the number who consumes it. Information gathered on four islands in Milne Bay Province suggests that fruiting is discontinuous, but not seasonal. It is not sold in local markets as far as I know. It probably has limited potential for commercial production, but it may be possible to sell fruit in some urban markets.

**Ton (Pometia pinnata)**

This fruit belongs to the same botanical family (Sapindaceae) as the litchi, rambutan and pulasan. Taun is an alternative spelling for its common name, but ton is adopted here as this better reflects the pronunciation in Tok Pisin. The fruit is eaten raw. The species is distributed from Sri Lanka, Thailand, southern Yunnan (China), Indonesia and Taiwan through Indonesia, New Guinea and the Pacific Islands as far as Tonga (Walter and Sam 2002:229). Within PNG, ton is common along the New Guinea north coast and in the Islands Region. In Momase Region, it is frequently grown in East Sepik, Madang and Sandaun Provinces, and to a lesser extent in coastal or inland locations in Morobe and Oro Provinces. In the Islands Region, it is most common in
East New Britain, New Ireland and Manus and less common in West New Britain and in Bougainville provinces. Unlike some other indigenous fruit, it is commonly grown on the larger islands (New Guinea, New Britain, New Ireland) as well as the smaller islands.

The tree grows from sea level up to about 1,700 m, but the usual upper altitudinal limit where the fruit is eaten in PNG is 800 m. The highest that I recorded the fruit being grown and eaten was at 1,120 m on the Karimui Plateau in Simbu Province. Above about 800 m, villagers say that the tree bears fruit, but the fruit is ‘not sweet’ and hence they do not eat it. Superior large fruit is reported from the Tanga Island group off New Ireland, as well as other locations in the South Pacific (Thomson and Thaman 2005).

Almost a million people live in locations where ton fruit is commonly eaten (955,000 people according to the MASP database). This represented 23% of the rural population in 2000. Fruit is available seasonally for about two or three months at some time between August and April each year, most commonly in the period November to February. Ton is widely eaten along the north coast of New Guinea, the inland areas of the north coast (up to 800 m altitude) and throughout the Islands Region. It is sold in markets in those locations. Many observers consider that ton has excellent potential for commercialisation for sale within PNG and possibly overseas. Ton has been bottled in sugar syrup in Fiji experimentally, but there was no follow-up and no commercial interest, so this did not advance to a commercial product (Bill Aalbersberg, University of South Pacific, Suva, pers. comm. 2005).

**Watery rose apple (Syzygium aqueum)**

The species produces a white, pink or red bell-shaped fruit which is eaten raw. The species is distributed from Thailand to Solomon Islands (Walter and Sam 2002:251). Within PNG it is grown and eaten occasionally in the lowlands and the intermediate altitude zone, for example, in New Ireland, New Britain and Milne Bay Province. It bears up to 1,600 m altitude. Overall, it is a minor fruit species in PNG and is not eaten by many people. The limited available information on the production pattern indicates that the supply is discontinuous and non-seasonal in both the lowlands and the highlands. The fruit is sold in some lowland markets. It may have some potential for further sales in urban locations as the appearance is attractive, although most fruit in PNG have a rather insipid taste. As with other fruit species, the potential for further sales would be greater if clones with superior fruit were available.

**Traditional mango (Mangifera minor)**

This minor fruit is widespread in PNG. The introduced mango (Mangifera indica) is preferred to the traditional one, but the traditional species is still consumed. The introduced species needs a drier period each year to bear, whereas the traditional species does not. Hence *M. minor* is mainly eaten in locations where *M. indica* does not bear regularly. *Mangifera minor* is found in the Celebes, Moluccas, Lesser Sunda Islands, Luzon, New Guinea, Solomon Islands and Carolines (Kostermans and Bompard 1993:132–5). Within PNG, traditional mango is widely dispersed in the lowlands and highlands on the New Guinea mainland, on New Britain and on the islands in Milne Bay Province. It grows from sea level to 1,750 m, and occasionally up to 1,900 m. Fruit ripens at about the same time as for the introduced species, that is, in about September to December.

The number of people who consume traditional mango is not known, but more people eat the introduced species. It is not sold in markets. It is unlikely that the fruit

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4 There are two species of traditional mango in PNG, *Mangifera minor* and *M. foetida*. The former seems to be more common and our observations are presumed to be on the former, but it is possible that some relate to the latter species as trees were not identified by a botanist from botanical specimens.
could be developed for commercial production.

Discussion

Sixteen indigenous fruits have been discussed here, out of more than 40 that are consumed in PNG. Some are consumed in a limited number of locations, while others, including marita pandanus, ton and Malay apple are widely consumed in PNG. There is probably limited potential for a significant expansion in production and sale for most species. It is possible that more fruit of bukabuk, golden apple, Malay apple, mon, ton and watery rose apple could be sold in urban lowland and highland markets, especially if the fruit came from selected, sweeter clones.

The species that perhaps has the greatest potential for expanded production and sales, including for an export market, is ton (taun). The flavour is comparable with some of the better-known fruit from South-East Asia. The oily extract from marita pandanus may have uses other than for consumption (Roger Leakey, pers. comm. 2005). The oily extract needs to be evaluated so that this possibility can be explored. It is important that the use of the lesser-known species is documented. Particular note should be made of any clones selected by villagers that may have potential for production and sale in other parts of PNG, including the highlands and urban areas and, in the longer term, for the export market.

References


Table 1. Some of the indigenous fruit species grown in Papua New Guinea

<table>
<thead>
<tr>
<th>Family</th>
<th>Scientific name</th>
<th>Common name</th>
</tr>
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<tbody>
<tr>
<td>Elaeocarpaceae</td>
<td><em>Aceratium oppositifolium</em></td>
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<td>Euphorbiaceae</td>
<td><em>Antidesma ghaesembilla</em></td>
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<tr>
<td>Euphorbiaceae</td>
<td><em>Antidesma platyphyllum</em></td>
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<tr>
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<td>Breadfruit</td>
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<td><em>Baccaurea papuana</em></td>
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<td>Euphorbiaceae</td>
<td><em>Bridelia tomentosa</em></td>
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<td>Rhizophoraceae</td>
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<td><em>Bukabuk</em></td>
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<tr>
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<td><em>Clymenia polyandra</em></td>
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<td>Corynocarpaceae</td>
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<tr>
<td>Anacardiaceae</td>
<td><em>Dracontomelon dao</em></td>
<td><em>Mon</em></td>
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<tr>
<td>Moraceae</td>
<td><em>Ficus copiosa</em></td>
<td><em>Kumu musong</em></td>
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<td><em>Ficus dammaropsis</em></td>
<td><em>Kapiak</em> (Highlands Tok Pisin)</td>
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<td>Moraceae</td>
<td><em>Ficus tinctoria</em></td>
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<td>Moraceae</td>
<td><em>Ficus wassa</em></td>
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<td><em>Syzygium aqueum</em></td>
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<td><em>Syzygium samarangense</em></td>
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<td><em>Dausia</em> (Kiriwina name)</td>
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</table>
Exotic Fruits with Potential in the Lowlands

Tio Nevenimo

Introduction

Fruits and nuts have played an integral part of PNG’s smallholder farming systems. They are grown and consumed because they are tasty and healthy. Some fruits and nuts are rich in protein and energy. While other fruits and nuts such as (Banana, Bread-fruit and Aila [chestnut]) are staple food crops in some areas of PNG.

Collecting, assessing and promoting fruits and nuts has been an ongoing activity of LAES Keravat since its establishment. Some of the fruits and nuts introduced and distributed from LAES, have become every day household food items, some are becoming popular as alternative cash crops while others have remain unpopular. This paper lists some of the exotic fruits that LAES Keravat has in its collection, which are becoming very popular and the ones that LAES believes have potential to develop into commercial crops. The assessments of the fruits are not based on scientific evaluation but on current interest in planting and consumer demand for these fruits during the season. It is also based on the appearance of these fruits into the local markets and on shelves in local supermarkets.

Fruits with potential

NARI Keravat sees four introduced fruits as having greater potential and three others with potential in the Islands Region and parts of PNG lowlands.

The four fruits with greater potential are Mango (*Mangifera indica*), Rambutan (*Nephelium lappaceum*), Durian (*Durio zibethinus*), and Mangosteen (*Garcinia mangostana*).

The three with potential are (*Averrhoa carambola*), Citrus (mainly mandarin) and Abiu (*Pouteria caimito*) have potential to a lesser extent.

Rambutan

Rambutan (*Nephelium lappaceum*) is an important fruit tree species in the humid tropics and is a member of the Sapindaceae. Rambutan trees were introduced into Papua New Guinea mainly in the Bismarck Archipelago before 1929. Subsequent introductions were established in Morobe, Central, West Sepik and Madang Provinces. Much of these introductions have been from seeds.

Work on Rambutan at LAES dates back to the early 60s. In 1982 a clonal evaluation trial was established and, after 10 years of data collection, three good quality clones (in terms of taste, juiciness, clingstone characteristics) were selected. They were K1, K2 and K6.

Two further introductions were made by LAES. In 1982 seeds from four varieties were introduced and evaluated. In 1992, 12 clones off Asian origin were introduced and evaluated. From the seed line evaluation, two seed-lines were selected as having good fruit quality. The introductions selected were NG 8288 and NG 8280.

The 1992 introductions have not been evaluated but this introduction includes eight commercial varieties overseas. They all have very good fruit characteristics, and yield well here at Keravat. They are: R3, R7, R9, R156, R134, R162, Jitlee and Rupiah.

These eight good quality clones are available at LAES Keravat but they have not been promoted widely mainly because they have yet to be formally tested on station and outside Keravat.

In 2004, LAES Keravat released three superior clones, which have been selected
after 10 years of evaluation and from which planting material have been distributed over the last 10 years. The three clones were assigned the following clonal identities: KNL1, KNL2 and KNL6. Grafted or marcotted seedlings of the selected three clones are available for distribution to anyone in PNG as improved material from Keravat.

List of cultivars available

<table>
<thead>
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<tr>
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<td>(K6)*</td>
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<tr>
<td>R234</td>
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<tr>
<td>R156</td>
<td></td>
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<tr>
<td>Rupiah</td>
<td></td>
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<tr>
<td>Jitlee</td>
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<tr>
<td>NG 8288</td>
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<tr>
<td>NG 8280</td>
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</tbody>
</table>

* = Cultivars released by NARI released as clones, ( ) = Clone name before release

Durian

Durian (*Durio zibethinus*) Murr, is an important fruit tree species in the humid tropics and is a member of the family Bombacaceae. It grows extensively in South East Asia (SEA) where it originates with Thailand, Malaysia and Indonesia being the major producers.

Durian is well known for its unique smell of the ripe fruit, which is often unpleasant to many who come across the fruit for the first time. The arid, which is the edible part of the fruit, however has a distinctive and delicious flavor.

Durians were introduced into Papua New Guinea as seeds from South East Asia and planted at LAES Keravat in the early 1940s. Since than seedlings from seed and grafted planting material have been distributed to all parts of PNG.

Evaluation of over 20 seedling trees between 1980 and 1992 has lead to selection of trees with outstanding fruit qualities (yield, taste and flesh color). The selections were named as K5, K7, K8, K9, K11, K12, K15 and K20. The selections on average produced 108–198 kg per year while within the average yields of commercial clone in Thailand and Malaysia. Commercial clone produce up to 400 kg per year and on average 100-200 kg per year. LAES Keravat has distributed these selections widely as superior planting material for the last 12 years.

New introductions of five commercial SEA varieties were made by LAES via Australia in 1999. The introductions included Thai variety Luang, Chompoosee and Gumpun, Malaysian variety D123 and Australian selection Limberlost. These have not yet been distributed by LAES as they are yet to be evaluated formally.

List of Durian cultivars available at LAES Keravat

<table>
<thead>
<tr>
<th>Clone</th>
<th>Name</th>
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<tbody>
<tr>
<td>KDZ5</td>
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<td>KDZ20</td>
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<tr>
<td>Luang, Chompoosee and Gumpun, Malaysian variety D123 and Limberlost Australian selection</td>
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Mango

Introduction

Mango is probably one of the most important fruits in PNG and one which has been accepted to become one of the popular household items during the season. Mangoes are common in the dry coastal areas of PNG. Most of these trees are local stringy varieties, which are propagated by seed.
Trees normally bear prolifically in the period October - December, but off-season flowering results in fruit sometimes being produced at other times of year. Many different individuals and institutions including DAL have introduced improved varieties of mango into the country. As a result of these efforts a wide range of varieties and cultivars of mango currently exist in country.

While mango has established well in PNG much of the commercial planting has been restricted to the Central province and to some extent in the Morobe province. This may be because of the ideal climatic conditions and easy excess to market.

DAL introduced the following varieties to Laloki in 1982:

Banana Calo
Carabauo
Glenn
Irwin
Kensington
Nam Dok Mai

In 1992 three additional varieties were introduced from Malaysia:

MA 123,
MA 194,
MA 200
Gundu (or Tok Boon) Apple mango
Malgoa

Some of these cultivars were established in ENBP and Morobe Province in the late 1980s and early 1990s.

In ENBP all the introductions were established off station due to the fact that mango does not bear in LAES environment. However, attempts were made to establish a collection on station in the late 1990s. LAES now has over 15 improved cultivars/varieties of mango on station.

Mango cultivars/varieties currently available from LAES Keravat:

Banana Calo,
Nam Dok Mai
Totapuri (Rabaul mango)
Kensington
Irwin
Carabauo
Apple mango
Brooks
Tommy Atkins
Bowin
Kew Savoey
RRE2
Julie
Spooner
Kent

Mangosteen

Mangosteen (*Garcinia mangostana*) is a small, slow growing, pyramid shaped evergreen tree that grows to about 10m in height and has opposite, unifoliate, thick leather leaves.

It is dioecious but female trees produce fruit with apomictic seeds when grown in isolation. Male trees are rare to non-existent. When damaged all plant parts excrete a yellow latex. Flowers are white to cream-coloured and terminal with 4 sepals, 4 petals (Alexander 1984)

Unlike mango they require equatorial climate, high event temperatures with high humidity and grow well in a wide range of soils.

LAES Keravat has a 1.hac bearing trees and several large trees which were planted in the early 1970s. Seedlings of mangosteen have been distributed as early as 1982 and LAES continues to supply seedlings.

During the season mangosteen has just become very popular. In the last two seasons we have observed mangosteen being sold at local markets and in local supermarkets. These fruits are coming from the planting material supplied by LAES in the early
1980s and 1990s. LAES Keravat currently sells mangosteen at K6.00 with Super markets charging up to K12 – K16.00 per kg.

Material available from LAES
- Mangosteen is available only as seed during season and as seedlings

**Fruits with potential, Abiu, Five Corner and Citrus**

As for the above three fruits with potential, citrus, mainly mandarin could be elevated as fruit with greater potential. Mandarin is very popular and at times very expensive items at the local markets. Five corner although very common in villages the demand for planting material has not be high and that very little is sold in local markets. Abiu is not as popular but recently we have seen more and more appearing in the roadside markets.

**Cultivars available**

Five corner
- Eight sweet cultivars available from LAES

Abiu
- Seeds and Seedlings only

Citrus
- LAES does not have any known cultivars on station
- Introduced good quality cultivars of citrus are available in PNG (mainly highlands) a direct result of DAL in the past to develop a citrus industry in PNG
- Much of the commercial citrus planting is in the Eastern, Simbu and Western Highlands.
Potential Exotic Fruits and Nuts for the Highlands

Martin Gunther

Introduction

Papua New Guinea is one of many neo-equatorial countries. Many of these countries have highland areas similar to the PNG highlands. We don't have to relearn what other countries have already spent time and effort finding out. We can look at our near neighbours, Indonesia and Malaysia, southern India and Sri Lanka, the highland areas of central Africa and Central and South America.

In this day and age, information is readily available. There is a range of locally produced material. There is also on-line access to international journals, internet search engines such as Google and Alta Vista that will identify a wide range of information on almost anything you ask for, and access via email or other contact information for people working in the area of interest. Almost any published book can be located somewhere in the world and can be received within a week if the need is there, and the money to pay for it. Information is not necessarily a major constraint. A bigger problem is working out what information is really needed, then sorting out the relevant from the irrelevant.

In this paper, I will take a broad approach to "exotic". I think "exotic management practices" of indigenous fruits and nuts are very relevant to these discussions. From this point of view, banana has been included.

So as not to re-learn what has been dealt with in earlier forums, I draw your attention to the Proceedings of the Highlands Horticulture Workshop held in Mount Hagen in 1999. There has been a number of other forums mentioned in the last few days. Issues brought out in these remain and need to be addressed. The situation has not changed.

People have different reasons for wanting to grow crops. Some are purely economic and some are aesthetic – to make money, to find something that nobody else can grow, try something different … Clearly defining the reasons for wanting to grow a particular crop helps to determine what resources could be directed towards the effort. With the crops I discuss in this paper, I will try to define where a particular crop may fit. As part of this consideration, whether a crop is to be grown for home use, local market, urban market within PNG or possibly for export to world markets, will have a big effect on what should be done and how competitive a farmer has to be with other producers. Cost of production for the open world market has to be competitive with other world producers. Markets which may give some preferential access give some level of protection, production for local markets gives some addition protection, and production for personal use removes many of the economic considerations. What is required is to identify where there is a competitive advantage. This may be in labour cost, climate which allows production outside of competitors' normal production period, proximity to the market enabling more timely or better quality product.

Taking this approach, I will split the crops into three categories. The first are crops which I think could potentially be produced and put on the world market using existing technologies with a minimum of adaptation. The second are crops which have some potential to develop into significant crops but development of significant local adaptation of technology could be required to enable an industry to develop. The third are crops which have some potential for development of local industries but I would not consider that they have potential in the international arena in the foreseeable future.
Crops with good potential

**Avocado** grows well throughout the highlands. Selection of suitable varieties for selected markets would be required. Pest and disease issues are not insurmountable. People do not understand the right stage for harvesting for commercial production, but this could be quickly learnt. One advantage PNG would have is less seasonality of production than areas of higher latitude.

**Banana** is grown throughout the tropical and subtropical world. The technology for production of common dessert varieties is well known and could be readily applied. For common varieties, there is significant competition by major world players. PNG could develop niche markets for selected varieties of dessert and cooking bananas. Technologies for handling and ripening would have to be determined, but should be fairly easily overcome. In recent years there has been a small niche market developed for the variety Sucrrier, a small fruited variety favoured by south east Asian immigrants. There has recently been a New Zealand delegation looking at importing cooking bananas. Some effort would be needed to adapt technologies to selected varieties, but as with Sucrrier in Australia, this could be easily done if there was a will to do it. New Zealand would be the first market to be developed, but Australia, US and Europe could be developed in time.

**Pineapple** is also produced throughout the tropical and subtropical world. Technology is well understood and could be readily adopted within PNG. Treatment of plants with "Etherel" to overcome seasonal production would be an integral part of the system. This is not new to PNG. In the early 1970's a Sepik farmer in Situm out of Lae was treating his crop of about one hectare and capitalising on off-season high prices. The world market would be difficult to access, but the New Zealand delegation mentioned earlier was also interested in pineapple. This market could allow limited preferential market access.

**Citrus** is widely grown in PNG. PNG is not well situated to be able to compete on the world market due to more temperate areas being more suitable for production. However, the local market has potential for much greater development. There are issues of pest and disease, better flavoured varieties and suitable rootstock/scion combinations for both agronomic and quality issues. However, the bigger issue is getting fruit to market in good condition and widening the period during which the product can be placed on the market. Use of varieties and storage is needed for this. The biggest potential seems to be with mandarins. Oranges have a lower market acceptance, but the inability producers to identify maturity, particularly with Navel types, leads to poor quality fruit being placed on the market. This restricts market development. There is some potential to develop a local juice industry, but this would have to compete with imported product. There could be a niche market for "fresh juice" if the quality was acceptable.

**Macadamia** - Some people may be surprised by my inclusion of this crop. However, there are a number of trees scattered throughout the highlands, and reasonable production has been achieved. A seedling tree located at Kuk Agricultural Research Station in Mount Hagen produced 54 kg of nut in shell in its first year. Unfortunately, no weights were obtained in subsequent years due to young boys having acquired a liking for the nuts. There are producing trees in the Waghi and Baiyer areas. Work is needed to determine whether better adapted varieties are available, but an industry could start using accepted cultivars. Management practices and approaches to pest and disease control used in other producing countries would need to be implemented in PNG.

**Strawberry** - Already strawberries are produced in small quantities at many locations. Prices are generally high and sold to a limited market. The market could expand if correct post harvest handling and marketing issues could be addressed. Export
is probably not an option but processing would expand the market opportunities, but, at a much lower price.

**Guava** is widely grown with the small fruited type most common. The large fruited types could be developed into a useful industry both as fresh fruit and as processed product. The large fruited types appear to be more susceptible to fruit fly attack, but there are control recommendations available. I would consider this to be an industry for the local market rather than a serious prospect for international trade.

**Crops with some potential but production technologies need further development**

**Passionfruit.** The black passion fruit (*Passiflora edulis*) was produced for the export of pulp in the 1960s and early 70s. Unfortunately, a little commercial sculdery resulted in a major price drop, growers lost interest and the processor went off-shore for the source of supply. Production in days gone by was through extensive village plantings. I suspect today producers would want to plant on a more intensive scale which could introduce a range of new problems that would have to be addressed. Potential exists for both pulp and export of fresh fruit. One advantage that PNG could have is out of season production. Marketing and quarantine issues would have to be sorted out.

**Sugar fruit** (*Passiflora ligularis*) is widely grown in the highlands. It would appear that there could be a market for this crop in Europe. Last year a South American agent was trying to source material in PNG, presumably due to a shortfall from his normal suppliers. Ability to access markets and to ship the product reliably to such markets would need sorting out.

**Raspberry** - The black raspberry (*Rubus fraxinifolius*) grows widely as a volunteer plant. This could complement the strawberry market with many of the same issues in marketing, but agronomically a little easier to manage.

**Grapes** are grown in small quantities throughout the country. There is a small market which could be developed. For varieties that will flower in the tropics, pruning is the stimulus to force flowering. This technology needs to be learnt. Mildew would become a major issue for large scale production, but would be manageable for small holdings.

**Apples** - There are many seedling apple trees and a few of recognised varieties producing throughout PNG. Production is sporadic and unlikely to be commercially viable without the adoption of better tree management practices. Apples are produced in other similar countries, so it can be done. However, there are much easier crops. The best producing tree I have come across is at Tomba village (altitude 2,500 metres) near Tambul. This was purchased as a grafted tree in Lae. The fruit produced was not of a recognised variety. My inclination is that it was the rootstock that had survived, another suggestion being that this could be from a locally selected seedling. This tree would suffice as a backyard producer, but whether it could be commercialised is something else.

**Pepino** (*Solanum muricatum*) grows well, is generally well accepted but has not entered the market place as yet. This will remain the case until somebody grows it successfully and makes some money out of it. I feel that this crop will develop very rapidly once this hurdle has been overcome.

**Possible crops which require significant work to enable development**

**Peach and nectarine** - These are growing and producing at Taluma in the Enga Province (altitude 2,600 metres). They are of unknown varieties, but presumably with low chilling requirement. Fruit quality leaves something to be desired, but could get wider acceptance if an active distribution program was in place.
Plums - Two types of unknown varieties are producing at Taluma (two myrobalan? types and one Japanese type). The place where plums may best fit in on a commercial scale is in the processing industry. Plums make good jam, either alone, or in mixtures with other fruits.

Lychee - I am aware of two Lychee trees in the highlands. One at Aiyura which I don't think has ever produced fruit. There was another tree at Wapenamanda in Enga Province. It was said to have carried such a large crop that the weight of the crop caused the tree to break off (at the graft?) and died. A wide range of varieties would need to be evaluated over a range of environments to ascertain the real potential. The potential exists to identify areas which can produce outside of the main production seasons for overseas competitors (altitude and areas with a south east season).

Many other crops could be considered, but growers' interest, market demand, planting material availability etc will govern what may be tried in the future.

General issues

The biggest problem with the development of all fruits is for people to see a good production example. If someone can produce a crop successfully, then others will be more inclined to follow suit.

Labour is plentiful and cheap by world standards. Labourers are unskilled in the management of the new crops, but this can be easily overcome with some diligence by managers. Horticultural crops will generally be on a small to moderate scale so the pool of labour that needs training is relatively small.

Marketing on a commercial scale with no well established wholesale marketing system is a significant drawback. The producer has to be his own marketer.

Post harvest handling of all crops is a major issue. Issues such as stage of maturity to harvest, how to handle the crop, correct temperature to hold fruit, how to package etc all need to be addressed. This information is available, but has to be applied.

Expectations are often to get into the world market. It would generally be better to build up on the local market which is a bit more forgiving. Once systems are well in place, decisions can then be made as to whether the world market should be tackled.

For many crops there is a very limited range of varieties within PNG. To develop industries, new varieties need to be evaluated. Currently, quarantine requirements pose a major constraint. The cost of a Pest Risk Analysis is a major problem in itself. However, the need for a quarantine officer to visit a potential source of supply will generally put the cost beyond possibility. There has to be a much cheaper way of applying good sensible quarantine which does not stop development. Much material has been introduced without quarantine control. Food items imported correctly often have seed or are themselves propagules. A lot more material is imported surreptitiously by travellers or through the post office. If restrictions are too severe, the risk of deliberate breaches of quarantine laws increases, resulting in greater risks to the industry.

Quarantine requirements for entry of fruits to overseas markets can be addressed. There are generally protocols in place for common pests and diseases. There may be specific work required for establishing suitable protocols for a specific pest or disease, but this has been done elsewhere to establish the protocols that do exist.

Within country, cost of production does not necessarily have to match costs in other countries. Whether or not a grower decides to grow a particular crop will depend on whether he thinks there is a profit to be had, and whether he thinks that the investment of his resources in one crop will give a better return than an alternative.
For any new crop, it is not just a matter of planting it and hoping it will grow. It is important to be aware of what production problems may occur and how these have been addressed by other producers, whether in country or overseas. Information has to be sourced and with the internet, this is not too difficult. This does not mean that all necessary information will be available, but much of the basics will be. Do not relearn the wheel!!!
Potential for further commercial development of introduced fruit

By Michael Bourke

Abstract

Many fruit species are grown and eaten in Papua New Guinea (PNG) and significant quantities of fruit are produced for both subsistence consumption and sale. The main growers are villagers, who produce only a limited quantity of each species. There is still considerable potential for expansion of production for sale, with the sale of sweet fruit into the highlands and in Port Moresby having the most potential. It is critical that further development of fruit production takes place in locations with better access to the Highlands Highway and to Port Moresby, as well as having suitable climatic conditions.

Fruit species with potential for further commercial production are identified and notes given on the major constraints that need to be addressed so that this potential can be realised. Four species in particular – mandarin, mango, mangosteen and rambutan – have significant potential for expanded production. Five well-established species could also be further developed and marketed. These are avocado, banana, orange, pawpaw and pineapple. A group of less common species have some limited potential for further production and marketing. In the lowlands, these are carambola, durian, guava, langsat, longan, pomelo, pulasan, rockmelon (cantaloupe), sweetsop (custard apple) and watermelon. Highland species in this group are banana passionfruit, cape gooseberry, cherimoya, naranjilla, purple passionfruit, black raspberry, strawberry, suga prut (*Passiflora ligularis*) and tamarillo (*tree tomato*).

Introduction

Many fruit species are grown and eaten in Papua New Guinea (PNG). These include well-known fruits that are eaten everywhere in the tropics, such as banana, mango, pineapple and pawpaw, as well as indigenous species that are important in PNG and the Pacific, but not elsewhere, including marita pandanus, ton, bukabuk, mon and golden apple. As well, some fruit species are grown on research stations, particularly at the Lowlands Agricultural Experiment Station (LAES) at Keravat, but are not grown for subsistence use or sale by villagers.

There is no single complete list of all fruit species grown and eaten in PNG. The most complete listing is by French (1986), who provides information on 102 species (Table 1). Other species are mentioned by other authors, for example Bourke et al. (2004) give information on the production patterns of 75 species, and information on some of the minor indigenous species is scattered in the ethnobotanical literature. It is likely that 120–150 fruit species are grown and eaten in PNG.

Significant quantities of fruit are produced in PNG for both subsistence consumption and sale. Fruits are mainly grown by villagers, who produce a limited quantity of each species and are not particularly oriented to the requirements of the market. Nevertheless, villagers are the most important commercial producers. Future expansion can come from both villagers who grow small quantities as well as from dedicated producers who grow larger quantities.

Considerable potential exists for expansion of production for sale. There is some potential for further sales of fruit in local urban and rural markets, but the biggest potential is for sale of sweet fruit into the highlands and in Port Moresby. There are over two million highlanders, who are fond of sweet fruit, but have only limited access to it. The Port Moresby market has over

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1 References to tables and figures in this paper are to those in the paper ‘An overview of edible fruit and nuts in Papua New Guinea’ in this volume.
300,000 potential consumers who are undersupplied with fruit at a reasonable price and in sufficient quantity.

There are many transport, handling and marketing constraints to overcome for this potential to be realised. Hence it is critical that further development of fruit production takes place in locations with better access to the Highlands Highway and to Port Moresby, as well as having suitable climatic conditions. These locations are in general coastal Central Province and the Markham and Ramu valleys for species that require a distinct dry period, such as mango. For species that do better in weakly seasonal or non-seasonal rainfall environments, locations with reasonable access to the Highlands Highway include coastal areas near Madang and Lae. The most accessible locations to Port Moresby that have a weakly seasonal rainfall distribution are the Cape Rodney to Kupiano area of Central Province and the Malalaua to Kerema area of Gulf Province. For mandarin and orange, the best locations are intermediate altitude locations at 800–1400 m.

Hypothetically, it is possible to export fruit from PNG to nearby countries such as Australia, New Zealand and Singapore, to exploit differences in the peak production period. In practice, there is little realistic possibility of this occurring in the short to medium term because of major constraints of handling, transport, communication and production in PNG. If these constraints could be reduced as production for the domestic market increased, there might be some prospects for export in the future, but that is some time away. (See paper ‘Production patterns for fruit and nut species in Papua New Guinea and some implications for marketing’ in this volume).

In this paper I identify fruit species that have potential for further commercial production and note the major constraints which have to be overcome. For the main species described here, a condensed statement is made on the producing season, but see Bourke et al. (2004) for fuller information. A review of what is known about each species is not provided, although that would be a valuable exercise. Four species in particular have significant potential for expanded production – mandarin, mango, mangosteen and rambutan. There is also potential for further production and marketing of five of the well-established species – avocado, banana, orange, pawpaw and pineapple. Further production and marketing of a group of less common species in both the lowlands and highlands also has potential.

**Fruit with significant commercial potential**

**Mandarin (Citrus reticulata)**

Mandarin is grown in the lowlands, the intermediate altitude zone and in the highlands up to 1800 m (Table 4). It is commonly grown by only 4% of the rural population (Table 6), although many more people grow the occasional tree. The sweetest fruit is produced in the intermediate altitude zone in the range 800–1400 m (Bourke and Tarepe 1982). Mandarin is a significant cash crop in some locations in this zone, for example, in the Arona Valley in Kainantu District, in the Bulolo–Wau area and parts of the Huon Peninsula in Morobe Province, and the Kokoda Track area of Central Province. Fruit grown in the intermediate altitude zone is popular with consumers in highland and lowland urban markets during the producing season (May–August). Sellers from lower altitude locations readily sell their fruit in highland markets and consumers clearly prefer these to those grown at higher altitudes (1400–1800 m). Many mandarin trees in PNG are old and new plantings are limited.

A number of issues need to be addressed to increase production of mandarin for sale, including:

1. Propagation and distribution of selected cultivars. I am not aware of the introduction of any selected cultivars, but trees with superior fruit could be located in PNG. Propagation could be done by a commercial nursery.
2. Distribution of selected cultivar seedlings in locations in the intermediate altitude zone. It is a higher priority to promote commercial mandarin production in the intermediate altitude zone than in either the lowlands or the main highland valleys, as the fruit is sweeter in the intermediate zone and is more attractive to consumers.

3. Addressing soil fertility problems, including widespread zinc deficiency.

Agriculturalists commonly group mandarin with orange and view mandarin as a minor citrus species. My experience is that mandarin is used differently from orange, with consumers eating mandarin as a snack food, as it is less messy to eat and the skin can be easily removed. I suggest that the potential market for mandarin in PNG is much greater than it is for orange or for the minor citrus species, and that mandarin should be a higher priority than orange as a commercial fruit. Rogers and Movis (1991) also note that mandarin is the most popular type of citrus in local markets.

**Mango (Mangifera indica)**

Mango is one of the most widely grown fruits in the lowlands (Figure 1) with an estimated 44% of the rural population living in households where mango is grown and eaten (Table 6). It grows best in locations with a marked dryer period each year.2 Significant quantities are moved from the Markham and Ramu valleys into the highlands during the production season. Even more fruit could be sold if superior cultivars were widely distributed. Virtually all trees in PNG are derived from seedlings rather than from selected clones. Fifteen selected cultivars have been introduced to PNG and are located at Lanakaulana, Pacific Adventist University and NARI Laloki in Central Province, near Cleanwater Plantation in the Markham Valley and at LAES Keravat (Brian Watson, pers. comm. 2005).

Evaluation and distribution of superior cultivars to growers in the Markham and Ramu valleys and coastal locations in Central Province is a high priority for further development of commercial mango production.

**Mangosteen (Garcinia mangostana)**

Mangosteen is a lowland fruit that does best in locations with a high rainfall. It is uncommon in PNG and until a few years ago was limited to experimental plantings at LAES Keravat, Aropa Plantation on Bougainville Island, some agricultural stations, some plantings in towns and a handful of villages on the Gazelle Peninsula. It is difficult to propagate and this explains its limited distribution, despite seed and seedlings being distributed from Keravat over the past 35 years. Some fruit is now being sold in markets on the Gazelle Peninsula in the producing season (November to March). Fruit is very popular with consumers and Tio Nevenimo in his presentation at this workshop described it as ‘the hottest fruit in town during the season’. Mangosteen is popular in its South-East Asian homeland, and production is steadily expanding elsewhere, for example, in far north Queensland. I suggest that a large number of fruit could be sold in PNG urban centres, especially Port Moresby and Lae, and in the highlands.

The priority for development of commercial mangosteen production is propagation of a large number of seedlings and distribution of these in lowland locations where rainfall is even throughout the year, especially those places with reasonably good access to the Highlands Highway and to Port Moresby.

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2 See the paper ‘Production patterns for fruit and nut species in Papua New Guinea and some implications for marketing’ in this volume for a description of locations where mango is most productive in PNG. Two indigenous species, *Mangifera minor* and *M. foetida*, are also grown and eaten. They seem to be more common in locations where *M. indica* does not bear because there is no dryer period each year, such as on the south coast and interior of New Britain.
**Rambutan (Nephelium lappaceum)**

Rambutan grows well in some lowland locations where rainfall is well distributed throughout the year. In South-East Asia it is grown at medium elevations, that is, up to about 800 m altitude. It is a minor crop in the north-east lowlands of the Gazelle Peninsula of East New Britain and on Bougainville and Buka islands in Bougainville Province. It is only sold in markets on the Gazelle Peninsula and in Bougainville, where it is a popular fruit during the producing season in February to May.

There is considerable potential for expansion of rambutan production. It could be sold in all urban markets, and is likely to be especially popular in the highlands where there are few types of sweet fruit. The intense colour of the fruit is an additional feature. A number of selected clones have been introduced into PNG and three clones have been released by NARI (Tio Nevenimo ‘Exotic fruits with potential in the lowlands’, this volume). These should be evaluated in different environments, particularly in locations near the main markets, and distributed to growers. They should be distributed throughout the lowlands, but the highest priority locations are those with reasonable access to the Highlands Highway and to Port Moresby.

**Well-established species with potential for expanded commercial production**

Five fruit species – avocado, banana, orange, pawpaw and pineapple – are already well established in PNG, but have potential for expanded commercial production. These five species grow in all altitude zones to the highlands, although the most favourable locations vary between species.

**Avocado (Persea americana)**

Avocado grows from sea level to 2050 m (Table 4). It is a relatively minor fruit in PNG and is grown by an estimated 6% of the rural population. It is most commonly grown in Simbu and Eastern Highlands, as well as mountainous parts of Central and Morobe provinces (Tables 6, 7). The main producing season is January to April. Avocado has increased in importance over the past 40 years, especially in the highlands. People tend to use it as a spread on bread, as they might use butter or margarine. Avocado has an important contribution to human nutrition in PNG as it is rich in energy. The staple food diet of rural people tends to have low energy density and energy-rich foods, such as avocado, are often lacking in the diets of rural people, especially children (Marks 1992). For this reason, avocado deserves to be promoted widely as a subsistence and marketed crop.

There is potential for further sales, especially in the Port Moresby market. The main limiting factor is poor handling as fruit is easily damaged. The priority for further commercial production is more plantings in locations near Port Moresby and training of growers and middlemen in handling and packing of fruit.

**Banana (Musa cvs)**

Banana is not an introduced crop in PNG, but it is covered here because the more common types sold in PNG are introduced cultivars, such as the various Cavendish types and Yawa. Recent research at Kuk in Western Highlands Province has confirmed earlier suggestions that banana was domesticated in New Guinea (as well as in South-East Asia). Denham et al. (2003) found that banana was being intensively cultivated from about 7000 years ago in the Kuk area, well before migration of the Austronesian speakers from Asia to the New Guinea region. Kennedy and Clarke (2004) provide a useful overview of banana in PNG and its role in prehistory.

Banana is widely grown throughout PNG with most rural households growing it, up to its usual altitudinal limit of 2150 m. Production was estimated in 2000 as
436,000 tonnes per year. Banana provides an estimated 7% of food energy from locally grown staple foods, making it the second most important of the staple foods, just ahead of sago and cassava, although very much less than sweet potato, which provides 66% of the food energy from staple crops (Bourke and Vlassak 2004). Cultivars are grown for cooking and for fresh fruit. Dual-purpose types are also grown.

The market for sweeter fruit, including Cavendish types, in the urban areas is probably not saturated, particularly in Port Moresby. The Pacific Adventist University supplies significant volumes of banana (as well as watermelon and pawpaw) to retailers in Port Moresby (McGregor 2003). A detailed study of demand for banana and other fruit for the Port Moresby market would assist planning.3 The main issue, as with much fruit sold in urban markets, is poor handling and consequent poor quality of the marketed product.

Orange (Citrus sinensis)

Orange grows from sea level to 1800 m (Table 4). It is grown by an estimated 13% of the rural population, with trees most common in intermediate altitude locations in the mountains of Morobe, Oro, Gulf and Central provinces (Table 6). As with mandarin, the best quality fruit is grown in the 800–1400 m altitude zone, although good quality fruit can also be produced at slightly higher altitudes in the main highland valleys (Bourke and Tarepe 1982). The main producing season is April to August, but the pattern is quite variable from year to year. Large plots were established in Eastern Highlands and Western Highlands provinces from the early 1980s onwards. The Department of Agriculture and Livestock promoted orange and mandarin production in the highlands in the late 1980s and early 1990s (Rogers and Movis 1991).

There is a limited demand for orange in both rural and urban locations, much less than for mandarin. As with mandarin, the main issues that need to be addressed to promote greater production are planting in the optimum altitude zone; use of selected cultivars on appropriate rootstock; and attention to soil nutrition, including application of zinc and possibly other micronutrients such as manganese and boron.

Pawpaw (Carica papaya)

Pawpaw (papaya) is widely grown from sea level to 1700 m (Table 4), although the quality of fruit is poorer above 1200 m altitude. After banana, it is the most commonly grown fruit in PNG, with an estimated 64% of the rural population living in households where pawpaw is grown and eaten (Table 6). Many trees are self-sown and villagers commonly eat fruit when they are working in food gardens or moving around. Production is not seasonal in the lowlands, so it is available year round. It is somewhat seasonal in the highlands, with fruit more plentiful in August–October. Pawpaw is commonly sold in urban markets. The main issue to improve marketing is greater attention to handling and transport.

Pineapple (Ananas comosus)

Pineapple is grown from sea level to 1800 m (Table 4). The smooth leaf type is more common in the highlands above 1500 m. The sweetest fruit is grown over the altitudinal range 400–1200 m. It is widely grown, with over half of the rural population living in households where pineapple is grown and eaten (Table 6). Production is greatest in East Sepik, Morobe, Western Highlands and Madang provinces, although those statistics reflect the fact that these are populous provinces.

Production is seasonal, with the best supply usually between October and March, although the period of peak production varies somewhat from year to year. It is easy to induce flowering and fruiting throughout

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3 McGregor’s 2003 study gives a valuable overview of marketed horticultural produce in PNG. A more detailed study of market demand is suggested here.
the year and this is standard practice in countries where there is significant commercial production, such as Australia, Malaysia and the Philippines. Ethephon is the chemical used for flower initiation and it is available under a range of brand names in Australia, including Promote 480, Ethrel, Ethephon and Bounty.

The main issue that needs to be addressed to expand production and consumption in PNG is the use of chemicals to induce flowering and hence make fruit available throughout the year. Any producer who can grow fruit in periods when supply is low will be able to readily sell fruit at a high price. Poor handling is less an issue for pineapple than for most other fruit.

Less common fruit species with limited potential for further commercial production

Lowland species

Carambola (Five corner) (*Averrhoa carambola*) This species is a minor fruit in the lowlands and is occasionally grown into the lower highland valleys up to 1300 m (Table 4). It is a popular fruit in some lowland markets. Production is irregular, but non-seasonal in the lowlands and appears to be seasonal near its upper altitudinal limit. Most trees arise from seedlings, not from selected clones, and the fruit is somewhat sour. Eight clones with sweeter fruit are grown at LAES Keravat (Tio Nevenimo, ‘Exotic fruit with potential in the lowlands’, this volume). It would be useful to evaluate these clones in different environments, especially in locations with access to the Highlands Highway and to Port Moresby, and to propagate and distribute cultivars with sweet fruit that perform well in those locations.

Durian (*Durio zibethinus*). Durian trees in PNG are mainly confined to LAES Keravat, Vunakanau Plantation on the Gazelle Peninsula and Aropa Plantation on Bougainville Island. The main producing period is between November and April. Fruit from LAES and Vunakanau can be readily sold to people from South-East Asia in the Rabaul area. Durian is a very popular fruit in much of South-East Asia and has become more popular with Papua New Guineans. Fruit at LAES in the 1970s was rarely eaten, but now security guards are required to watch over ripening fruit at LAES to prevent its theft (Tio Nevenimo, pers. comm.). Five clones were introduced into PNG in 2000 and their evaluation should be done at sites drier than Keravat or on better-drained sites (Brian Watson, pers. comm.). Eight clones have been released from LAES Keravat (Tio Nevenimo, this volume).

My feeling is that durian could be sold to people from South-East Asia living in Port Moresby, Lae and other urban centres. It is also possible that it could become popular with rural and urban Papua New Guineans. Certainly three of the presenters at this workshop (Tio Nevenimo, Brian Watson and Steve Woodhouse) see durian as having considerable potential in PNG. The highest priority is to get planting material of a range of clones to growers in various lowland locations, including sites with reasonably good access to the Highlands Highway, such as coastal areas near Lae and Madang, and sites near Port Moresby.

Guava (*Psidium guajava*) Guava is a minor fruit in many lowland locations and grows into the highlands up to 1850 m. An estimated 18% of the rural population live in households where guava is commonly grown, with production greatest in Bougainville, East New Britain, Morobe, Madang and West New Britain provinces (Table 6). Production is not seasonal in the lowlands, but is seasonal in the highlands (Bourke et al. 2004). The so-called Vietnamese guava was introduced to PNG, probably in the 1980s, and it is now commonly grown in some lowland locations.

Guava is a nutritious fruit with a particularly high content of vitamin A. It is not clear how much unsatisfied demand exists, but it
is likely that more fruit could be sold if fruit with a good flavour and of good quality was available. The main limiting issues are poor handling and the high incidence of fruit fly.

**Langsat (Lansium domesticum)** This is a minor species. It is grown at LAES Keravat and planting material has been distributed in the past. The producing season is March–April. It is not sold in markets as far as I know. Langsat is quite popular in parts of South-East Asia and deserves to be grown and eaten more widely in PNG. In the Philippines it is very popular and is usually planted under coconuts (Coronel 1983). I suggest that planting material should be widely distributed in the lowlands.

**Longan (Euphoria longan)** This species from southern China and India does not appear to be present in PNG, as neither French (1986) nor Woodhouse (1991) mention it. It has become popular in far north Queensland (Brian Watson, this volume) and fruit is commonly sold in supermarkets in southern Australia. Watson (this volume) ranks longan as having high potential for PNG and this is supported by the experience in north Queensland over the past 30 years (Menzel et al. 1995). It would be useful to introduce a number of clones from north Queensland and evaluate them in several lowland locations.

**Pomelo (Citrus maxima)** This minor citrus species grows up to 1300 m (Table 4). It is more common in New Britain and New Ireland than on the New Guinea mainland (Table 6). It is sold in some lowland markets, especially in the Islands Region. Production is non-seasonal. The fruit is sweet and has potential to be sold in the highlands and in Port Moresby if more fruit was available near those locations.

**Pulasan (Nephelium mutabile)** Both the fruit and tree is similar to rambutan (Chin and Yong 1980). There is a small experimental planting at LAES Keravat. I have seen beautiful pulasan fruit sold in Buka market in Bougainville Province. Presumably the village trees on Buka or Bougainville came from the collection at Aropa Plantation near Kieta airport. At Keravat, fruit ripens between November and March, but the pattern varies considerably from year to year. The fruit is visually attractive and has a sweet taste. It is likely that fruit could be readily sold in urban lowland and highland markets. Seedlings should be grown in locations with a well-distributed rainfall pattern, including near Lae and Madang.

**Rockmelon (cantaloupe) (Cucumis melo)** This is a very minor fruit, occasionally grown for sale. It only produces well in locations with a distinct dry season, such as the Markham Valley and coastal locations in Central Province. It is subject to fungal disease and the recommended planting period is April–May (Antonio 1986). Fruit is sometimes available in August–November. It could be promoted as a cash crop for sale to hotels and supermarkets in the Markham Valley and coastal Central Province.

**Sweetsop (custard apple) (Annona squamosa)** Sweetsop or custard apple is a very minor fruit in PNG. It is more common in lowland locations that experience a distinct dry season, such as near Port Moresby. Fruit is occasionally sold in markets during the season, which seems to be December to February. It may be useful to introduce superior cultivars, including the horticultural custard apple varieties from Australia, which are a cross between sweetsop (Annona squamosa) and cherimoya (A. cherimolia) (Alexander et al. 1982).

**Watermelon (Citrullus lanatus)** This is a popular fruit in many lowland locations and is grown up to 1700 m, although it is uncommon above 1200 m. An estimated 28% of the rural population live in households where watermelon is grown and eaten, with it being most common in Milne Bay, Bougainville, Central, East New Britain and Oro provinces (Table 6). It is a significant cash crop in the Markham and Ramu valleys and much fruit is sold to highlanders. Production is seasonal, with the
best supply occurring in November to March. There is probably potential to sell more watermelon, at least in the highlands. Sale or distribution of seed of suitable varieties is the key to increasing production, especially in the Markham and Ramu valleys and near Port Moresby.

**Highland species**

**Banana passionfruit** (*Passiflora mollissima*) This species occurs as self-sown plants at high to very high altitudes (1850–2800 m). Small quantities are sold in highland markets and, in recent years, it is being sold to hotels in Madang. It is a pleasant fruit and has potential to be sold to hotels and supermarkets in Port Moresby and other lowland towns.

**Cape gooseberry** (*Physalis peruviana*) This is a very minor fruit in the highlands, growing over an altitudinal range of 950–2800 m. Production appears to be non-seasonal. Small quantities are sold in the market at Ukarumpa near Kainantu. The fruit makes very good jam and small quantities could probably be sold to expatriates in lowland urban centres, particularly in Port Moresby.

**Cherimoya** (*Annona cherimolia*) There are a few bearing trees in the Kainantu area, and in the Wapenamanda and Laiagam areas of Enga Province (Bourke et al. 2004:23). These few trees seem to bear reasonably well and the species may have potential for further production in the highlands.

**Naranjilla** (*Solanum quitoense*) This fruit was introduced into PNG in the early 1960s. It grows wild in the Kainantu area where it grows well and produces continuously. Fruit has been sold to expatriates (Tarepe 1982). I have also seen plants in south Bougainville Island. Naranjilla has potential as a minor cash crop for the highlands with sales targeted at expatriates in urban areas.

**Purple passionfruit** (*Passiflora edulis f. edulis*) This species grows over an altitudinal range of 800–2300 m (Table 4). It was a significant cash crop for the export market in the 1960s, but production has steadily declined over the past 30 years. An estimated 11% of rural villagers live in households where the various passionfruit species (purple, suga prut and banana passionfruit) are grown and eaten (Table 6). Production of purple passionfruit is markedly seasonal, with most fruit available in January to April. As with the other passionfruit species, there is potential for sale of fruit in lowland urban centres, especially to Port Moresby. This species is more likely to appeal to expatriate tastes, with the sweeter suga prut more popular with Papua New Guineans.

**Raspberry, black** (*Rubus lasiocarpus*) There are a number of indigenous raspberries in PNG, none of which has a strong flavour nor is particularly sweet. Black raspberry, an introduced species, grows over an altitudinal range of 950–2250 m. It produces the best fruit at about 1000–1400 m, especially in the Arona Valley in Eastern Highlands Province, where there is a regular dry period each year. Production is non-seasonal. Small quantities are sold in Ukarumpa market in the Kainantu area. It can be used to make wine and liquor. There is potential for sale of this species in lowland urban centres, especially Port Moresby. As with all raspberries, fruit is delicate and spoils easily. If fruit could be packed and transported to Port Moresby so that it arrived undamaged, some could probably be sold there.

**Strawberry** (*Fragaria sp.*) Strawberry grows over an altitudinal range of 800–2450 m. Minor quantities are grown and sold to expatriates in the highlands and some is transported to lowland towns, including Lae and Madang. There is potential for sales to hotels and supermarkets in Port Moresby during the producing period (June–September). Strawberry is a delicate fruit and must be handled gently and consumed within a few days of being picked. This is the major limitation at the moment. Producing strawberries and marketing them in Port Moresby could be a lucrative small
business for growers and middlemen who were prepared to handle the fruit properly and get it to market quickly.

**Suga prut (Highland yellow passionfruit) (Passiflora ligularis)** Suga prut grows over an altitudinal range of 800–2350 m. It was formerly a minor species in the highlands, but has become much more common over the past 30 years. The sweet flesh is appreciated by highlanders. Production is non-seasonal. It is occasionally sold in lowland towns, including Madang. As with the other passionfruit species, there is probably potential for further sales in Port Moresby and other lowland urban centres.

**Tamarillo (Tree tomato) (Cyphomandra betacea)** This species grows over an altitudinal range of 1050–2300 m (Table 4). It is grown in the highlands and in mountainous locations in Morobe and Central provinces (Table 6). Minor quantities are sold in some highland and lowland markets, including Madang. There may be potential for further sales, especially in Port Moresby.

**Discussion**

Significant potential exists for greater sales of a number of introduced fruits, especially mandarin, mango, mangosteen and rambutan in the highlands and in Port Moresby. There is also potential for more sales of some well-established species, in particular, avocado, banana, orange, pawpaw and pineapple. Potential is limited for sales of species that grow best in the highlands, such as strawberry and tamarillo, as these mainly appeal to expatriate tastes. More highlands fruit could probably be sold in Port Moresby and other urban areas. A number of poorly known species, including rambutan, mangosteen, durian, guava and longan, could be sold in large quantities, especially into the highlands where there is a small amount of sweet fruit.

A number of issues are common for many of the species reviewed here. The first is the need for improved handling, particularly for more delicate fruit such as avocado, banana, pawpaw, raspberries and strawberries. The second is the need to evaluate improved varieties at locations nearer the main markets on the mainland rather than at Keravat, where the demand for fresh food is less because of the limited population and shipping to the New Guinea mainland is expensive.

Some effort was made by the PNG Government to develop the domestic fruit industry, especially in the 1980s and early 1990s, but there has been little input since then. Greater effort by the government, supported by donors, is likely to result in greater production, sales and income to rural villagers. There are many benefits, including diversification of the income base for villagers. A few of the fruits are rich in energy, especially avocado, and deserve to be widely promoted for that benefit.

PNG is blessed with environments that have contrasting rainfall and temperature regimes. This means that different species can be grown in different locations and traded. However, this is unlikely to happen without further research and development by the PNG Government. A modest increase in effort could result in significant increases in production and sale of fruit on the domestic market.

**Acknowledgements**

The papers by Tio Nevenimo, Brian Watson and Steve Woodhouse at this workshop have been helpful to me in suggesting which lowlands fruit which should be given priority for research and development.

**References**


Tropical Fruit Development in Papua New Guinea
“The Hard Yards”

B.J. Watson

Abstract

This paper addresses the potential and constraints of fruit development in Papua New Guinea. Although there are some references to nuts, it is essentially concerned with fruits but also omits specific reference to bananas, citrus and deciduous fruits which are covered by other authors at the workshop.

Papua New Guinea has had a long history of fruit production in wide ranging climatic zones, although the diversity of species available and the quality of clonal cultivars is not as yet sufficient for both domestic and potential export markets. With the exception of banana, mango and some citrus, there has been a paucity of superior cultivars introduced and developed commercially.

Much news is often made politically for export potential for fruits and nuts but the “Hard Yards” are in fact yet to be achieved – that is the proving of productivity and fruit quality in the most appropriate climatic zones for each species. The “Hard Yards” are essentially an appreciation of the long term planning, policy implementation, and dedicated long term effort from researchers to achieve objectives. The author suggests it is chicken before the egg scenario – where future efforts should centre on proving the production capacity for the acceptance of the domestic market and then to develop export as the opportunities arise. This of course may not necessarily apply to all products (nuts etc) since some have only substantial export capacity for sales.

There is a strong case for ‘seeding’ selected growers with a superior gene pool to engage maximum evaluation of species and cultivars over appropriate climatic zones rather than rely solely on costly research on government facilities. This also avoids sequestration of neglected gene pools which often are not properly evaluated and also have no propagation capacity for ‘seeding’ cooperators.

This ‘seeding’ has worked well in northern Australia – albeit with cooperators who have usually been financially better off than their PNG counterparts and thus can usually better afford the costs of evaluation.

The constantly changing scenario as to fruit export opportunities and constraints is provided with examples as to what has happened in north Queensland in recent years. Of particular note the relaxation of import quarantine requirements, improvements in post harvest insect/disease infestation procedures for both export and import and the changing tastes of consumers.

There is offered a prioritisation of fruit species for possible domestic markets (with later opportunities for export) but the consultant makes no claim as having the crystal ball prophecy correct by any means. NARI and other relevant organisations need to be cognisant of improved cultivar potential and not base evaluation of fruit species/cultivar potential on evidence from existing seedling production – so common in local markets where consumers are not exposed to the best products.

Some recommendations are offered as to the future path for NARI and like organisations to develop tropical fruit industries in Papua New Guinea.

Constraints to tropical fruit production in Papua New Guinea

The key feature to future successful fruit development may arise from a competent evaluation of the existing gene pool
(seedlings versus clonal imports and local selection as appreciated in domestic markets) and a best reasoned programme for further introductions and evaluation for both the domestic and export markets.

If and when productivity and market potential for both domestic and export is established for the various species, and, the best climatic zones are delineated for recommendation to growers the market progress may occur. As an example - the definition of best climatic zones for vanilla production before promotion of the crop at a national level may have saved heartache for many producers.

The principle is to define the zones and what stress requirements to maximise flowering and successful fruit set are required. It may be that a specific crop is planted in the correct climatic zone (temperature, precipitation and radiation levels) but the actual site is in a high sub soil moisture situation which negates the original premise about stress requirements for substantial flowering.

Reliance on the promotion of seedling populations rather than selected clones (with some exceptions) for market development has also been detrimental to a number of appreciations for fruit species in local markets (e.g. rambutan and durian).

The lack of competent nurserymen/businesses capable of reproducing quality clonal material and government organisations/entrepreneurs promoting seedlings has also done substantial damage to species reputations on the farms and in the marketplaces.

The lack of ‘seeding’ competent cooperating growers with good clonal material and sequestration of gene pools on government stations without further adequate evaluation and multiplication for grower assessment.

**History of clonal fruit introductions in far North Queensland**

In 1975 there was a significant mango industry in the Bowen/Townsville area and also on the lower Atherton Tablelands – but based on the one cultivar – Kensington Pride (Bowen). There was also a small lychee industry. There were no avocado, rambutan, durian, longan, macadamia nut, custard apple, chempedak, jack fruit, pitaya and carambola industries.

At that time and for the next decade the Queensland Department of Primary Industries (QDPI) was very compliant as to the initiatives of local staff endeavours to introduce new cultivars of existing species and also new species. Fortunately the quarantine charges at that time were waived for QDPI imports as an arrangement with the Commonwealth Government in lieu of QDPI management of quarantine facilities. Considerable expertise was developed for best survival of clonal material in the quarantine and reproduction (multiplication) process. The consultant brought in a great number of fruit cultivars – principally from Asia but also from Pacific countries and Hawaii. In some cases accessions were brought in as a result as the consultant’s private trips to Asia with only purchase costs and freight transport refunded by QDPI.

In the period 1975 to 1989 some 32 mango, 21 lychee, 12 longan, 17 rambutan, 8 langsat/duku, 10 carambola, 18 durian, 6 pummelo, 4 salak, 3 abiu, 8 breadfruit, 5 caimito, 3 canistel, 3 guava, 5 chempedak, 6 jackfruit, 9 sapodilla, 3 Indian jujube and a few other minor crop clonal accessions were successfully brought in and released from quarantine.

There were of course some private importations by nurserymen/growers during that period. However after 1989 new introductions were largely by private growers who had committed themselves to the R&D process and at considerable financial cost.
Fortunately from the outset and particularly as from circa 1980 there developed a number of nurserymen with significant clonal reproduction expertise. They and individual growers did however always have access to new QDPI introductions as soon as there was available sufficient propagation material. The material was released without a recommendation as to authenticity and production/quality attributes guarantee. There was a local QDPI policy as to from the outset of introduction to make propagation material available without cost (i.e. for scion material and not grafted plants and thus of no real cost to the organisation). In a few cases grafted trees were made available to cooperators but this was the exception and not the rule. This free access policy was not mandated by QDPI administration but rather left as a decision by local staff. Because release was also general (many cooperators) there was no risk that one grower could hold others to ransom if he proved substantial benefits for a particular clone.

Choice of cooperators for formal trials/demonstrations was always a problem (as discussed later) but all actions have led to the ‘seeding’ policy which in retrospect appears to have been quite successful in developing a number of industries.

Research on introductions in FNQ was not entirely with cooperators and QDPI operated gene pool reserves and some cultivar screening at appropriate research stations.

However, the extent of these was generally economical in terms of costs, including the trials duration.

There was also a programme of acquiring new accessions from QDPI introductions in southern Queensland and also relevant material from other states. In no instance was a request denied. A number of those accessions proved quite beneficial to a number of fruit and nut industries.

Lessons learned reintroductions

Production/Marketing/Post Harvest in FNQ

The scenarios with production, markets (internal and export) and fruit imports into Australia are forever changing. Successful industries may be threatened very quickly when technology changes (e.g. altering the seasonality of production or improving post harvest disinfestations procedures) within the exporting countries occur.

PNG would have the same constraints and thus it is very difficult to plan for a substantial and long term viable export situation for PNG fruits. This is not to say however that opportunities will not arise due to superior productivity/products or quirks in seasonality. The point being to need to have a sophisticated domestic consumption scenario with superior clones for the export opportunity window – if it does occur!

All is not as it sometimes seems however – a group comprising QDPI and Australian Federal Marketing experts went to Singapore circa 1983 for consultations with fruit importers regarding the potential for marketing Australian produced tropical fruits in that country and further a-field to Hong Kong and Japan. Amongst other comments for various fruits the fruit importers without exception said locals would not buy Australian lychees and longans (out of season for Asia) since consumers were tired of the product after their own season.

Logic of course is that when any product is in short supply then it only takes a small percentage of the Asian consumers to establish significant demand important enough for Australian producers.

Such has been the case – FNQ coastal rambutan exports to Japan have not been spectacular – but averaging A$1.3 m for the past few years. Also since Tableland longan post harvest life has been increased as due to sulphur post harvest treatment for export gaining approximately $5 m per year to
Asia. However again in the changing research/marketing scenario the longan exports are now under threat due to the Thai discovery of potassium chlorate tree application (stimulation for flowering at any period of the year) which can give virtual year round production.

Of note however, the coastal FNQ rambutan production (domestic and export) is valued at circa A$5m from 600 t and the Tableland longan at 1,700 t worth A$10m.

These are of course small industries – but valuable contributors to the region’s whole.

Research Staff and Cooperator Needs for PNG and Anecdotes from FNQ

NARI and other organisations involved in tropical fruit production, research and promotion have limited funds. Cooperator research is a logical cost reduction scenario.

Papua New Guinea (PNG) Local and Federal Governments are always wanting to look for possible success stories for production of various products – particularly for export. These expectations sometimes place undue stress on researchers – particularly for those who are prepared to seek reasonable finality in their research – rather than seek short term glory through offering unsubstantiated opinions.

Promotions of specific crops by any organisations often exceed realisations. Usually there is a lack of political appreciation that success stories are not instantaneous and there is a need to suffer the ‘hard yards’ – which may take years to get an industry established, proven and a profitable result.

There is a basic need for NARI and other relevant organisations to more often use cooperative research/development. Research purists may suggest that suitable papers do not arise from cooperative work. In fact there is a place for all of, - pure research, cooperative research and research/development scenarios. All can contribute to a researcher’s beneficial CV and for the best value for the country.

Researchers are also concerned about their personal kudos when suspecting that a cooperator may usurp beneficial publicity for a success story. This doubtful scenario can be obviated by the researcher/his organisation publicising each step of the cooperative research in a manner that asserts the lead role for the researcher. A detailed contract with the cooperator is an appropriate step in the procedure.

The problem may be that there is great difficulty in selecting suitable cooperators – particularly when there are few well funded (richer) growers in PNG. North Queensland experience suggests that contact with established and long term production growers is best – irrespective of whether they have grown the particular crop before. Often the most enthusiastic potential cooperators have little history base in growing and their attention span to the long task ahead is very limited. There are however always some exceptions.

Cooperator success stories from FNQ

1 In the period 1977 – 1985 the author and local QDPI staff engaged in an avocado selection process primarily concerned with finding an early season cultivar (harvesting January/March) to replace Fuerte which had significant post harvest problems. Requests to the south Queensland QDPI to examine previous introductions provided amongst others, the Californian cultivar Shepard – which was discounted in the south because of lack of productivity in that environment. Results from the FNQ screening (productivity, seasonality and post harvest attributes) proved inconclusive as to early season potential. The cultivar was not directly recommended but 20 trees were given to a cooperating grower – Bruce Watkins in a slightly different environment at Walkamin (approx 590 m asl) in 1979. The first marketing was successful and the cultivar was
subsequently adopted by many growers in the Tablelands 300 to 600 m asl. elevation zone. The crop has largely displaced import of late season Hass from New Zealand throughout Australian markets. Today the Shepard industry is some 2,750 tonnes on the Tableland valued at approx $7.5 m.

There are additional plantings in a narrow coastal zone in the Bundaberg/Childers area. Had not those few trees been given to the cooperator then it is very unlikely we would have a Shepard industry today – the exercise also points to the specifics for appropriate productivity of some fruit cultivars in narrow climatic zones.

2 In 1975 the mango industry on the lower Atherton Tablelands was well established albeit all plantings as seedlings of the polyembryonic cultivar – Kensington Pride (KP/Bowen). The region relied on a marketing slot late December/ early January for which it little competition. The substantial new cultivar introductions by QDPI - FNQ from 1976 to 1986 were both DPI station screened and with cooperators. A number were late season but growers initially commented that they did not want to grow late season cultivars because of wet season complications (disease and transport disruptions). Today by their own initiatives growers have 85% Kensington Pride, 10% Kiet, 2.5% Palmer and 2.5% Brooks – the last three are late season cultivars. The proportion of late season cultivars is increasing due to the continuing post harvest problems with KP and the tree size (growth rates / pruning / biennial bearing complications). The late season cultivars are generally less vigorous and less tending to biennial bearing.

Because also the planting of mangoes has been more widespread throughout the more southern Australian areas, the Lower Tablelands have increasingly lost their Kensington Pride end of year marketing advantage. Today the Tablelands mango industry averages 18,000 tonnes, worth A$26m

Tropical fruit species with potential for Papua New Guinea

Potential is a mystery until proven

The author does not presume to offer concrete advice as to future priorities for fruit species research in PNG, - particularly when domestic consumer preference is often influenced by what quality of the gene pool is offered to them – i.e. the consumers decide on taste and value. Export is definitely a possible follow on from successful production from excellent cultivars offered to the domestic market. It is not however something which can be driven without the basic ‘hard yards’ research/cooperator development.

Species potential comments

xxxxx Banana Some of the QDPI introductions(world gene pool selections/ hybrids) for trial at Laloki in 1998/1999 have proven to have substantial benefits for productivity and leaf disease resistance. These should be released to cooperators as soon as possible for them to establish preferences and, consumer acceptance for flavour/use. Continuing problems with pests and diseases (including nematodes) are troubling most banana growers - for the local cultivars in particular.

xxxxx Mango The 15 clones imported through ACNARS contribution were released to Laloki and Keravat research stations as well as cooperators at Lanakaulana and Clearwater (Markham) in 2000. These plantings should be comprehensively monitored (unified approach to criteria) by NARI staff over the next 2-3 years to establish potential for the various climatic zones and, consumer preferences. Those at Keravat need to repropagate to supply
cooperators in the drier zones and islands in East New Britain.

PNG now has a significant representation of world wide mango clones and there are really only a few top potential clones not represented – however some are now under Plant Variety Rights restrictions re access and use.

Note that even polyembryonic varieties (e.g. Kensington Pride) need to be selected and propagated asexually since there is always a percentage of zygotic seedlings (different inherited/cross characteristics) within the polyembryonic seed.

xxxxx Rambutan and Pulasan No rambutans should be provided to the public or cooperators as seedlings since there is a 50/50 chance of being male trees (no fruit) or hermaphrodite and the seedlings may have poorer or better characteristics than the parents.

Further, the clones imported from Malaysia and Thailand via Australia are a result of thousands of selections in a diverse gene pool and thus chances of bettering those selections is remote.

The few imported clones of rambutan have lacked repropagation and distribution to cooperators and thus the PNG public still has little comprehension of quality fruit. There are few pulasan selections available in Asia. However trees at Buka are reputed to have good quality fruit (M.Bourke pers com). These probably came as seed from the Arawa estate.

A moisture stress period in spring is favourable for rambutan flowering – but again even in favourable climatic zones high water table sites should be avoided.

xxxxx Durian There is need for substantial superior clonal cultivar range importation. The few superior Thai/Malaysian cultivars already imported have not been distributed to cooperators. These would undoubtedly create a market demand much superior to the seedling population currently available.

Is consumer demand increasing even from the largely seedling population/production?

The crop is similar to rambutan for stress requirement for flowering. Keravat has problems in many years due to lack of moisture stress for flowering. NARI needs to look at opportunities in slightly drier zones.

xxxxx Avocado Due to an existing widely heterozygous population, local selection is important for climatic zone specifics. This has occurred in the Highlands – at village level. It is also possible that importations of overseas cultivars and rescue of neglected previous importations at Wapenamanda would provide a market for more sophisticated PNG consumers who want named predictable quality.

However, seedlings are more disease resistant (Phytophthora spp. root rot). This crop could rate a 7x if considering health benefits at the village level – particularly in the Highlands.

Guatemalan and Mexican hybrids/selections for 800 to 2,000 m asl and West Indian selections at lower altitudes to sea level.

xxxxx Mangosteen In reversal to general policy – only seedlings are recommended for this polyembryonic species – grafted trees are relatively unproductive and with repeated rootstock suckering problems. Range 0 to 800 m asl suggested and with some dry stress period. Early flowering (precocity) is greatly enhanced by good nursery practices and
nutrition/mulching/ weed control for trees establishing in the field.

xxxxx Longan This is a very excellent fruit which has not previously been recommended for PNG. However now with the seemingly infallible Thai researched (as also proven in Queensland) potassium chlorate stimulation for flowering and fruit development the fruit has definite potential for probably the 300 to 1,000 m asl climatic zone. Prime clones such as Kohala and Biew Kiew are available. NB that the chemical provides no similar response in lychee and rambutan (same family Sapindaceae) but is unknown as for taun. Custard Apple It is suggested that there be rescue of previous importations (Wapenamanda) for appropriate climatic zone development. New clonal importations could have significant benefits. Suggestions are that there is a paucity of sweet fruits in the Highlands to fit the locals’ tastes but certainly custard apple would fit the bill. Probably 800 to 1,600 m range best.

xxxxx Chempedak What is this you may ask? Really unknown in PNG and similar but superior to jackfruit and only by sampling superior clones will the market be impressed. Superior clones available in Australia. Probably 0 to 800 m asl range best.

xxxxx Jackfruit Market perceptions for this fruit are influenced by the very heterozygous seedling population and the majority of poor quality. Only with selected clones will there be an industry where consumers are subject to quality and repeatable quality. Good clones are available in Australia. 0 to 1,200 m asl range suggested.

xxxxx Breadfruit Why as the centre of Artocarpus altillis genetic diversity in the world PNG has so few seedless breadfruit selections available? It is underrated in the marketplace as seeded materials most common. Good clones of seedless available. This does not however underrate the importance of seeded breadfruits (breadnut) in many rural provinces in PNG as a basic staple. Range for seedless 0 to 1,500 m.

xxxxx Langsat/Duku/Longkong These are lumped under one species - Lansium domesticum. There are virtually no clones in PNG but they are most desirable fruits. Unfortunately there is long gestation to first harvest even for grafted clones. Superior clones available. Probable range 0 to 800 m asl.

xxxxx Pummelo This is the only citrus commented on in this text. However cultivars have lowlands wide application and are neglected as to good clone potential as opposed to common inferior seedling production. Clones available. Probable range 0 to 800 m asl.

xxxxx Pineapple The industry has few although the sweeter “Rough Leaf” does not perform well above 1000 m asl and at higher levels is replaced by “Smooth Cayenne”. It would be possible to introduce smooth Cayenne selections and hybrids with sweeter fruit for the higher altitude range up to 1,800 m asl.

xxxxx Taun It is not clear how Taun has been developed by researchers/cooperators but clonal selection in the native gene pool may still provide substantial rewards.

xxxxx Golden Apple Spondias cytherea is a popular fruit in the east of Papua. There are several clones available in Asia/Pacific which may or may not be superior to the existing gene pool in PNG.

xxxx Abiu Popular but underexploited in FNQ and problems with post harvest bruising. Seedling population exists in
PNG but no clones developed. However, clones with better post harvest handling attributes available in Australia. Probable range 0 to 1,700 m. asl.

**xxx Salak** This species never became developed in FNQ due to climatic unsuitability but in Indonesia/ Malaysia clones are very popular. Probable range 0 to 600 m.asl.

**xxx Carambola** Excellent clones available in PNG but not a fruit for everybody’s tastes. There has been little exposure by PNG consumers to the best cultivars. Probable range 0 to 800 m.asl.

**xxx Sapodilla** This fruit is very sweet to European tastes and is now a flying fox (bat) favourite delicacy. Not think tested for PNG population tastes. Probable 0 to 600 m. asl

**xxx Passionfruit** ‘Sweet fruit’ – Passiflora ligularis has taken over in the Highlands from the former processing purple passionfruit (Passiflora edulis) and is reputed to be popular because of consistent sweetness even at high altitude. Banana passionfruit (Passiflora mollissima) still grows wild at high altitudes and is worthy of selection. Yellow passionfruit (Passiflora edulis f. flavicarpa) could also be selected – but for the lowlands to 800m asl?

**xxx Tamarind** This refers to the Thai sweet tamarind used as a fresh fruit as opposed to the normal sour seedlings available for processing. Seedlings are reputedly true to type but no introduced clones in Australia. Should well suit lowland dry zones – Central and Markham.

**xxx Jaboticaba** Polyembryonic member of the Myrtaceae family from Brazil. Would have good value for children’s vitamin potential and general popular acceptance. Has remarkable short fruit gestation – 27 to 30 days ripe from flowering.

**xxx Pitaya** Colombian tropical cactus fruit with now great popularity in Asia and high prices in Australia. Often called dragon fruit. Both white and red fleshed. No clones but cuttings easy. Probable range 0 to 1,000 m asl.

**xx Cx Caimito** Mainly called Star Apple. Some clones available.

**xx Canistel** This fruit appeals differently to different people. No clones available.

**xx Indian Jujube** As for the above but has easy grow attributes even in very dry zones. Some clones in Australia – but lost?

**xx Rollinia** Cousin of the custard apple with good productivity even from seedlings- however different fruit texture.

The status and market position of all previous introductions as held on research stations and also those provided to cooperators.

To solicit local market information throughout PNG as to preference for selected clones as compared with run of the mill seedlings.

Depending on market demand and potential, to detail potential for species/cultivars whilst being cognisant that superior clones not being available in the market place may sway consumer perceptions of products.

To access information regarding possible accession of overseas clones for potentially market acceptable fruits not yet available in PNG. This in most instances referring to additional cultivars.

- NARI to commission a review of the capacity of the organisation to research and prove clonal propagation capacity for introduced and locally selected fruits and
nuts where in fact there is no existing capacity for various species.

This is to allow sufficient propagation for training for private industry nurserymen and also to allow for sufficient propagation to provide grower cooperators with relevant clonal material.

- NARI after the above reviews and in consultation with various local and international tropical fruit experts, to develop a list of desirable clones for the major potential fruits and to seek donor assistance for relevant importation and costs.

This proposal however dependent on the ability of NARI to ensure that they have the research capacity to handle importations through quarantine and to be able to multiply accessions sufficient for on station screening and supply to competent grower cooperators and nurserymen.
Suitability for Commercial Macadamia Production in PNG

Dr R A Stephenson

Development of a commercial macadamia industry

Commercial macadamia production depends on favourable returns to capital investment and operating costs. These returns are more significant if achieved as early in the life of the orchard as possible and maintained for 30 or more years. This depends on good tree survival and on consistently high yields of high quality kernel. These factors need to be considered when seeking the environmental range in which commercial production is viable.

Producing trees may be found in Australia from Sydney in the south, to Cairns in the north. In California, they extend from Santa Barbara just north of Los Angeles to the Mexican border. Commercial plantings have also been established in South Africa, Malawi and to a lesser extent in Kenya in Africa and in the Central American countries of Guatemala and Costa Rica and in Brazil. The conditions in these countries may give an indication of the environmental range but not optimum production.

The environment of native macadamia stands in Australia

The environment in which macadamias grow is not necessarily a good indication of optimum conditions. In the wild, macadamias grow as understorey trees in coastal and subtropical rainforests. Macadamia integrifolia is found on the eastern slope of the Great Dividing Range to an altitude of 300-400 metres. Distribution is from Mt Bauple in Queensland on the lower Mary River, near Maryborough, south to lower Beachmont or the Numinbah Valley, a distance of about 440 km; latitudinal range approximately 25° to 28°S. M. tetraphylla is found in similar country but extending further south from the Coomera River near Mt Wongawallen, and the Nerang River near Advance Town in Queensland to the Richmond River near Casino and Lismore in N.E. New South Wales, a distance of 120 km; latitudinal range approximately 28° to 29°S. At a point where these species meet, natural hybrids between the two species occur.

The macadamia tree has several features suggesting adaptation to relatively harsh environments, including sclerophyllous leaves and dense clusters of fine, proteoid roots which develop to enhance nutrient uptake from poor soils, particularly those low in phosphorus. The conditions required for optimum production, however, are quite different from those for survival.

Soils

Macadamia is adapted to a wide range of soils but heavy, impermeable clays and saline or calcareous soils are unsuitable. The trees are most suited to deep, well-drained soils with good organic matter content (3-4% carbon), medium cation exchange capacity (10-15%), and pH of 5.0 to 5.5. Macadamias may in fact be adapted to pH as low as 4.5. They do not perform well on alkaline or calcareous soil. Common nutrient deficiencies that limit growth, yield and quality are nitrogen, potassium, phosphorus, magnesium, calcium, zinc, copper, and boron. High levels of soil P, high Ca and high pH may all induce Fe deficiency and impede the uptake of other nutrients.

Temperature

Temperature has the major influence on macadamia performance and kernel quality. The mature macadamia tree is able to withstand frost for short periods to as low as -6°C, and slightly lower for M. tetraphylla. In practice, however, commercial trees should not be planted in frost prone areas as young trees and flowers may be killed and the trunks of mature trees may also be
damaged. The incidence of frost is likely to jeopardise the commercial viability of macadamia orchards.

Glasshouse experiments have shown that the threshold temperature for macadamia growth is between 10-15°C, the greatest growth occurring at 26°C. At a constant 30°C macadamia leaves become chlorotic and distorted, indicating sensitivity of macadamias to high temperatures. The young flush growth of one variety, 781, becomes chlorotic under summer temperatures in SE Queensland.

Mean temperatures do not give the full story as the temperature extremes often have a strong influence on macadamias. At Kona in Hawaii, which is considered an ideal climate for M. integrifolia production, the normal minimum diurnal range is 10°C and the maximum temperature recorded is 31°C and the minimum 9°C. At Nambour in Queensland, where macadamias are grown, temperatures may reach 40.5°C and frosts occur in lower exposed sites.

Allen (1972) concluded that mean summer temperatures of around 26°C with minimum temperatures not exceeding 38°C and the absence of frosts would give good production. The best production areas in Hawaii are those where the temperatures rarely exceed 32°C. In Australia many commercial orchards consistently experience some 35°C-35°C days and still produce reasonable crops, although high temperatures probably limit yield or quality. Some varieties develop leaf chlorosis and necrosis on the northern side of the canopy during summer.

The actual temperature occurring at vital phenological stages of the plant's annual cycle can be critical. In Hawaii, Nakata showed that night temperature influences floral development in M. integrifolia. Floral initiation occurred at 12, 15, 18 and 21°C, while 18°C resulted in the production of most racemes. Initiation in Queensland occurs in April when night temperatures fall well below this and consequently flowering is often excessive compared with that observed in Hawaii, possibly being wasteful of stored tree reserves, potentially limiting nut development.

In South Africa, extensive plantings have been established south of the Tropic of Capricorn in the hot Lowvelt at an altitude of approximately 200 metres. This area has a strong continental climate and often experiences high temperatures, and drying winds.

**Altitude**

In the tropics (15°N, 15°S), the required temperature range for macadamias can be achieved at higher altitudes, eg 1,600 m in Kenya, 1,300 m in Malawi, 800 m in Guatemala and 700 m in Costa Rica. Productivity, however, has been low at the sites below 1,000 m. In Hawaii, macadamia orchards occur from just above sea level up to about 800 m but production is lower at the higher altitudes. Apart from the temperature effect, heavy cloud cover and frequent rain is believed to restrict photosynthesis and hence slow down tree development and reduce productivity at high altitudes.

**Rainfall**

The high productivity of nuts in Hawaii is correlated with well-distributed rainfall exceeding 2,000 mm. Storey (1969) estimated that the minimum water requirements for macadamia is about 1,000 mm well distributed annually. Under Australian conditions, precipitation is low in late Winter/Spring (July-November) when flowering, nut set and early nut development occurs. These conditions are not considered ideal for macadamia production, another reason why the environment of origin should not be accepted as an ideal for a crop.

In both Australia and Hawaii, yield responses to irrigation have been achieved in some years but not in others. Yield increases were related to number of nuts whereas Radspinner (1971) showed a correlation.
between rainfall and nut size. Thus, irrigation is desirable in some years in localities with less than 2000 mm annual rainfall which is unequally distributed.

Lysimeter work showed differences in sensitivity of phenological stages to mild stress. Stress during the dormant, vegetative stage when floral induction occurs is relatively tolerant of mild stress whereas nut development stages, and particularly the later stages of oil accumulation, are very sensitive to even mild water stress which restricts oil accumulation and results in low yields of very low quality kernel. Irrigation can be applied to alleviate stress at this critical stage of nut development.

Macadamia produces dense clusters of proteoid roots which are adapted to poor soils. They effectively increase root surface area for maximum absorption of water and nutrients. These contribute to enhanced tree survival during extended dry periods.

Salinity

Adverse effects due to high salinity have been noted in the field. Symptoms include chlorosis of foliage and marginal necrotic areas and a lack of vigorous growth particularly at the tips. Irrigation of macadamias with brackish water (2400 ppm total soluble salts) in Hawaii over an 8-year period had no apparent adverse effects on tree growth, yield, or production efficiency (yield per unit tree trunk area). An increase in the percentage of immature kernels, however, appeared to have been correlated with saline irrigation water (5% immature kernels compared with 1-3% irrigated with fresh, non-saline water). This level of immaturity is still considerably less than the 12% produced by unirrigated trees, but is still economically significant. Nevertheless, the impact on oil production during the final stages of kernel development may be an early indication of salinity stress.

Wind

Macadamias are very susceptible to wind damage. Growth rate in young plants is significantly reduced by damage to new vegetative flushes, potentially delaying commercial cropping by 1-2 years. Mature trees suffer loss of large limbs and in shallow soils or soils which restrict root penetration, the whole tree may be lost. Such losses significantly reduce yields but where large limbs are lost, they usually recover in 1-3 years. Locating orchards in areas subject to cyclonic and other violent wind storms is risky. In exposed trees, flowering and nut set may be affected by strong winds but once the orchard canopy develops, only external trees are at risk. Windbreaks are an effective measure to overcome the problem during the early establishment years.

Tree training may reduce susceptibility to limb breakage. Branches with to narrow crotch angles are most susceptible to splitting as are nodes with multiple branches. Tree training to a central leader should commence in the nursery to avoid later problems in the field. Pruning can only be economically carried out in the first 2-3 years of establishment to remove poorly developed limbs. Excessive pruning reduces growth rate and may increase time to commercial production. It is desirable to select varieties that have better tree structure and wide crotch angles which reduce the need for tree training to a minimum.

Humidity

Although humidity was not considered to be important for macadamias in Hawaii, it can be important in harsher environments such as those in Australia and South Africa. Excessive evapotranspiration under dry conditions will exacerbate stress. Excessive rain at flowering reduces pollen viability and hence pollination. High humidity at this critical stage can promote the development of flower blight (Botrytis) which also destroys flowers resulting in little or no nut set, and anthracnose (Colletotrichum) and
husk spot (Pseudocercospora) which can reduce both yield and quality. Thus, areas with misty, foggy conditions during the flowering-early nut development stages should be avoided.

**Light**

Radspinner (1971) also found that rainfall in the two month period prior to flowering in Hawaii resulted in smaller nuts, presumably due to reduced light inception under cloudy conditions, and hence reduced photosynthesis and reduced production of carbohydrate.

Although the photoperiodicity of the macadamia is not confirmed, it is probably a short day (or long night) plant initiating flowers in autumn. However, temperature also has an influence.

The normal pattern is for initiation of inflorescences to occur in autumn and the floral buds to stay dormant until early spring when they all develop rapidly. In some areas such as Cairns (19°S) (or in warm autumn conditions) many floral buds, although initiated in autumn, develop soon after, producing an ‘out-of-season’ flowering. Mean monthly temperatures from June to August in Cairns are about 22°C. Temperature conditions are similar in Hawaii where flowering is spread over many months. Extended and poor flowering is reported from tropical areas but this is generally undesirable as the spread of the cropping season makes insect and disease control more difficult and increases harvesting costs. The spread of maturity also increases the chances of quality deterioration.

Since temperature has a bigger influence on flowering than light, as long as altitude can provide the required temperature range, cropping may be possible well into the tropics, irrespective of day length.

**Extending the climatic adaptation of macadamias**

Commercial production based on processing, relies on a uniform product of high quality. The world wide market for macadamias draws on product from various countries so it is essential that varieties have acceptable processing and quality characteristics. For consistency, particularly for the processed product, it is important to use the accepted M. integrifolia and only those interspecific crosses that satisfy commercial requirements. M. tetraphylla is an excellent tasting nut but contains residual sugars that are not present in M. integrifolia. On roasting, these sugars caramelise, giving the kernel a burnt, unattractive brown colour. This is the reason tetraphylla kernels are not commercially acceptable. They are widely grown in California, however, largely for the fresh table market. This species is adapted to cooler climates and can therefore help extend the production area (subject to market/processing requirements). There may also be opportunities to select varieties (including hybrids) that are tolerant to either hot or cold conditions.

**Summary of Environmental Requirements**

It is apparent that an equitable climate is more desirable than one of extremes, with a practical range of 0-38°C and a desirable range of 10-30°C C. The most desirable level for flower initiation in April coincides with 15°C nights and nut development, with a mean daily temperature of ca. 25°C. Areas with prolonged high humidity, excessive rain or mist at flowering should be avoided. Water requirements are fulfilled by 2,000 mm equitably distributed throughout the year, although this is not important after the nuts are mature in March, particularly the dormant period 2-3 months prior to flowering (June-August). This dormancy is also under control of temperature and mean monthly temperatures of 22°C and higher at this time can result in erratic, out of season flowering. Sites at altitude may be suitable where the temperature range is satisfactory. However, they should be avoided where prolonged overcast or misty conditions occur during flowering. Windy or exposed sites should be avoided and windbreaks provided to give protection during
establishment. With the exception of heavy, impermeable clays, macadamia is adaptable to a wide range of soils provided water and nutritional requirements are supplied.

Conclusions for PNG

Macadamias would be restricted to intermediate altitude locations in PNG. The highly sophisticated production systems used for commercial development in Australia and elsewhere are probably not appropriate in PNG.

Insects limit commercial production in many parts of the world so good management of pests and diseases is important for ‘commercial’ production to be reliable. Rats are also frequently a problem.

There is a considerable amount of information available, based on commercial experience and research, and this could be applied to growing macadamias in PNG.

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Hilo temperatures represent the high and Mountain View the lower temperature range for macadamia production on the island of Hawaii.
MONTHLY MEAN RAINFALL DATA FOR AUSTRALIAN, HAWAIIAN AND CALIFORNIAN SITES

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*Months have been offset by 6 months for Hawaii and California to allow direct comparison of temperature and rainfall figures on a seasonal basis.
Indigenous Edible Nuts in Papua New Guinea

R. Michael Bourke

Abstract

This paper describes some of the indigenous edible nut species of Papua New Guinea (PNG), that is, species which were grown and eaten prior to settlement by other Pacific Islanders, Europeans and Asians from about 1870 AD onwards. More than 40 species of indigenous nuts are eaten in PNG. Information is given here on 13 of the most commonly eaten indigenous nuts, which are grown by two percent or more of the rural population, and three other indigenous nut species. The following attributes are covered for each species: how the nut is consumed; global distribution; distribution within PNG; altitudinal range in PNG; production pattern (crop seasonality); the number of rural people who live in locations where the species is commonly consumed; marketing; and potential for further development.

The species covered are breadfruit (Artocarpus altilis), candle nut (Aleurites moluccana), castanopsis (Castanopsis acuminatissima), dausia (Terminalia megalocarpa), finschia (Finschia chloroxantha), galip (Canarium indicum), karuka (Pandanus julianettii), wild karuka (Pandanus antaresensis and P. brosimos), okari (Terminalia impediens and T. kaernbachii), pao (Barringtonia procerca), Polynesian chestnut (aila) (Inocarpus fagifer), sea almond (talis) (Terminalia catappa), sis or solomon (Pangium edule) and tulip (Gnetum gnemon). Notes are given on three minor introduced species – macadamia, cashew and pecan.

Introduction

Indigenous edible nuts are defined here as species that were grown and eaten by Papua New Guineans prior to settlement by other Pacific Islanders, Europeans and Asians from about 1870 AD onwards. The species include nuts that are endemic, native, or introductions from other locations prior to 1870 AD. The term nut is used in a popular sense, not a botanical one. A list of more than 40 species of indigenous nuts that are eaten in PNG is given in Bourke (1996). Other papers that cover more than one species include Powell (1976: Table 3.1), Henty (1982), French (1986), Evans (1996a, 1996b), Yen (1996), and Walter and Sam (2002) (Table 1).

Information is given here on 13 of the most commonly eaten indigenous nuts in PNG, and three other indigenous species. Those 13 species were selected as they are grown by two percent or more of the rural population (Table 3). The other three species (candle nut, finschia and Pandanus antaresensis) were included as they are minor foods in a few locations. Two important nut species, coconut and peanut (an introduced species), are not considered here.

All of the commonly grown edible nuts are indigenous (Table 3). A number of edible nut species have been introduced to PNG over the past 130 years but have failed to bear or bear poorly and have not been adopted by villagers. These species include almond, chestnut, hazelnut, pecan and walnut (French 1986). Macadamia (Macadamia integrifolia and M. tetraphylla) has been introduced from Australia. There are plantings on research stations or agricultural colleges, for example, at Aiyura, Karimui, Kuk, Laloki and Popondetta. Macadamia has never been adopted by villagers as a food in PNG. I have only seen trees in villages on two locations; on Karkar Island, Madang Province (where they did not bear) and in a village in the Lai Valley in Enga Province. Macadamia bears from sea level to a mean altitude of 1,750 m, and occasionally up to 1,810 m (Table 5). The best trees are at Karimui station (1,140 m), where both species bear reasonably well.

1 References to tables and figures in this paper are to those in the paper ‘An overview of edible fruit and nuts in Papua New Guinea’ in this volume.
Another introduced nut species that is sometimes grown is cashew. There are a few trees on agricultural stations, other government stations and in villages in the lowlands, including near Aitape, Amanab and Lumi in Sandaun Province, the Gazelle Peninsula in East New Britain Province, the Ramu Valley in Madang Province, and at Bulolo and Wau in Morobe Province. The highest bearing trees were at 1,400 m in the Benabena Valley in Eastern Highlands Province. There was a plot on Numa Numa Plantation in north-east Bougainville (Allen 1991). There are larger plantings at Lanakaulana Plantation in Central Province, intended for the export market. Trees seem to bear quite well both at locations that experience a dryer period each year, but also at locations where rainfall is fairly even throughout the year. At the PNG Fruits and Nuts 2005 Workshop, it was reported that some villagers have been roasting nuts for local sale. Pecan nut (*Carya illinoensis*) has been introduced to PNG and several bearing trees have been noted growing at 1,400–1,600 m on a plantation and a research station (Aiyura) in Eastern Highlands Province.

Where available, information is given on the following attributes for each species: how the nut is consumed; global distribution; distribution within PNG; altitudinal range in PNG; production pattern (crop seasonality); the number of rural people who live in locations where the species is commonly consumed, 2 marketing; and potential for further development. The distribution data is from the Mapping Agricultural Systems of PNG (MASP) database (Bourke et al. 1998) and the author’s field observations. Data on crop altitudinal range is from Bourke (1989) (Table 5), and that on production patterns is from Bourke et al. (2004). The figures for the number of people who grow each species is from the MASP database (Table 3). I use the term New Guinea to refer to the island and Papua New Guinea (PNG) to the state.

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**Sixteen indigenous nut species**

**Breadfruit (*Artocarpus altilis*)**

Breadfruit has a number of economic products, with the flesh of the fruit and the nuts eaten. Other uses include medicine, timber, fuelwood, canoe construction, clothing, rope, wrapping and adhesive (Ragone 2005). Both the flesh and nuts are eaten on the smaller islands off the north coast of New Guinea, on the Admiralty Islands, the Bismarck Archipelago, the Solomon chain, and throughout Milne Bay Province. In contrast, only the nuts are eaten on the mainland of New Guinea, with some exceptions, such as the mainland of Milne Bay Province and some coastal locations on the south of Central Province. As well, types of breadfruit with few or no seeds have been introduced into PNG from Polynesia over the past century, but these types remain uncommon. The fruit is cooked, commonly in a stone oven, but there are numerous ways of cooking and preparing breadfruit (Walter and Sam 2002:109). On Nissan Island, villagers preserve the flesh by roasting it to form a biscuit and this is said to remain unspoilt for several years (Bourke and Betitis 2003:65).

Breadfruit was domesticated by people in New Guinea (Yen 1996:37), probably thousands of years ago. From New Guinea, people spread the species in pre-European times throughout the Pacific islands, as far east as the Society Islands, north to the Marianas and north-east to Hawaii (Walter and Sam 2004:109). It was introduced into the Philippines in ancient times from Guam. Breadfruit has been introduced throughout the tropical world in recent centuries.

In PNG, breadfruit grows from sea level up to a mean of 1250 m, occasionally as high as 1450 m (Table 5), and is widespread throughout the Momase, Islands and Southern regions. It is also grown at lower altitudes in the highland provinces, up to about 1200 m. On the islands of New Britain, it was ranked by villagers as their

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2 Population figures are derived from the 2000 census data, with a total rural village population of 4.2 million people.
most important fruit and nut bearing tree (Table 2).

Breadfruit does not produce fruit in a regular manner in most of PNG and the production period varies from year to year, despite many statements about its ‘seasonality’. The exception is in Milne Bay Province at 8–11° south where villagers give the producing period as commencing in October or November. Production is likely to be seasonal at locations south of about 8° latitude, but is irregular at most locations in PNG, which are nearer the equator. Such a pattern would arise from the changes in day length during the year with increasing distance from the equator (Bourke et al. 2004:36–37).

An estimated 2.4 million rural people grow breadfruit, which represents 57% of the rural population (Table 3). Breadfruit nuts are widely eaten throughout the lowlands, especially in Momase Region. The flesh is eaten on most islands in PNG and in a limited number of locations on the New Guinea mainland. Nuts are commonly sold in markets in Momase Region. It is possibly now a less important food item than before the widespread adoption of sweet potato, cassava and Xanthosoma taro in the lowlands. It is not clear whether there is potential for further commercial sale of fruit and nuts within PNG. Fresh breadfruit is exported from Fiji to New Zealand and volumes grew rapidly over the period 2001–2005 (NWC 2005). There is little prospect of exporting breadfruit from PNG because of fruit fly infestation, but there may be a market for some fresh fruit in Port Moresby at least.

**Candle nut (Aleurites moluccana)**

This species has been described as ‘… one of the great domesticated multipurpose trees of the worlds’ (Elevitch and Manner 2005:2). The seed can be eaten after being roasted. Consumption of raw seeds results in nausea and vomiting (as I found out in an early venture into gastronomy exploration on New Ireland in the early 1970s!). Candle nut is native to the Indo-Malaysia region and was introduced in ancient times throughout the Pacific islands (Elevitch and Manner 2005). Its pre-European distribution was from India in the west to the Marquesas Islands in the east; and from Australia in the south to Guam and China in the north, including New Guinea and associated islands (Walter and Sam 2002:88). It has now been introduced to much of the tropical world.

It is widely distributed throughout PNG, where it grows from sea level up to a mean of 1800 m and occasionally as high as 2160 m (Table 5). The limited information on the production pattern from Simbu Province, the Goroka area, New Ireland and New Britain indicate that fruit ripens seasonally between August and December (Bourke et al. 2004:37).

While the tree is widespread in PNG, the nuts are rarely eaten. It is most commonly used as a food in Simbu Province, where it is a very minor food item. It is occasionally eaten elsewhere, for example, in the Goroka area of Eastern Highlands Province and in the Morehead area of Western Province. The MASP database indicates that it is eaten by only about 8000 people. Nuts are occasionally sold in food markets in Simbu Province and in Goroka market.

Candle nut provides many economic products, including oil. This has a number of uses including for the cosmetics industry where it is used in products to soothe skin maladies (Elevitch and Manner 2005:13). It is also used as folk medicine, for animal fodder and as a dye. It is unlikely to be adopted as a food in PNG, but candle nut oil may have commercial potential for export.

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3 In our publication on production patterns (Bourke et al. 2004), we treat breadfruit as two species (A. altilis and A. camansi, the former termed ‘breadfruit’ and the latter termed ‘breadnut’). In fact, the information on distribution and production patterns presented there is for breadfruit only (A. altilis).
Castanopsis (*Castanopsis acuminatissima*)

Castanopsis kernels are eaten either raw or cooked and are gathered from self-sown or planted trees. Henty (1982:80) reports that, in the Pomio area of inland New Britain, seeds were commonly eaten after boiling and that some children, against the advice of their elders, persistently ate raw kernels. Millar and Dodd (1982:201) compare the flavour to a walnut. The global distribution includes parts of India, China, Burma, Taiwan, Thailand, Vietnam, Laos, Indonesia and New Guinea (Walter and Sam 2002:137). Within PNG, the species is widespread on the New Guinea mainland, especially in the highlands and nearby locations, including in the Wau area of Morobe Province. It grows in the interior of New Britain and on some of the islands of Milne Bay Province. Castanopsis grows from a mean of 700–2350 m, and occasionally over the range 570–2440 m (Table 5).

The nuts are available seasonally, with a producing period of about two months that commences at some time between July and December. The limited available data suggest that the producing season commences earlier (July–September) at lower altitudes (800–1200 m) than at higher altitudes (1600–2000 m), where it commences in November–December (Bourke et al. 2004:38).

Castanopsis is eaten in parts of the highlands, the highland fringe and in the interior of New Britain. The MASP database indicates that about 293,000 people live in locations where the crop is commonly eaten (7% of the rural population) (Table 3). Most of those people (75%) live in Southern Highlands Province. Generally it is a minor food in PNG and is not seen as having much commercial potential.

Dausia (*Terminalia megalocarpa*)

Dausia is a minor species where the nut is eaten only after elaborate processing, which usually involves the fruit being soaked in water for some days. French (1986:172) reports that the outer flesh of the fruit is eaten and that a selected yellow-fleshed form is eaten in the Solomon Islands. The species is moderately common in the islands of Milne Bay, including Misima, Rossel, Sudest, Engineer Group, Calvados Islands, Trobriand Group, Iwa and other nearby islands. Dausia is a lowland species, and its upper altitudinal limit is not known. Nuts are available seasonally in the period December to February (Bourke et al. 2004:38). The MASP database indicates that 88,000 people live in locations where the species is commonly eaten. This is 2% of the rural population and all are located in Milne Bay Province. As far as I know, it is not sold in food markets.

Finschia (*Finschia chloroxantha*)

Finschia is a minor species. Nuts are gathered from self-sown trees and eaten raw. Henty (1982:81) notes that trees are sometimes planted near villages. The species is related to macadamia. Finschia is distributed through New Guinea, Solomon Islands, Aru Islands, Vanuatu and Palau Island (Micronesia) (Henty 1982). Within PNG, it has been recorded in Morobe, Eastern Highlands, Southern Highlands, Western, Gulf and Milne Bay provinces. It no doubt occurs elsewhere in PNG. Finschia grows from sea level up to a mean of 1850 m, and occasionally as high as 2000 m in PNG (Table 5). Production is reported to be seasonal, but there is insufficient data to generalise about the pattern. While the species is widely distributed in PNG, it is a very minor food, the nuts of which are eaten by some people occasionally. I have never seen nuts sold in food markets. It is not clear whether this species has any potential for further domestication or commercialisation.

Galip (*Canarium indicum*)

There are a number of domesticated Canarium species with edible nuts in PNG, including *Canarium indicum*, *C. decumanum*, *C. lamii* and *C. salomonense* (Kennedy and Clarke 2004;
Yen 1996). There are other wild species, which are also eaten. Canarium indicum is the most widespread and important of the PNG species, and most of the rest of this section refers to that species. Yen (1996:41) states that *C. indicum* is the oldest domestic species in Melanesia, and plant remains appear in the archaeological record as early as 14,000 years ago, several thousand years before the start of arable agriculture in New Guinea. Thus the species was used in the late Pleistocene in the transition from a hunting-gathering economy to a horticultural-based economy. Yen (1996:41) also notes that the distribution of this species in the archaeological record implies the transportation at an early date of forms of the species that were already highly selected.

The kernel of galip is generally eaten raw, and sometimes roasted. Trees are grown from protected self-sown seedlings or planted seedlings. The species is present from northern Sulawesi in East Indonesia through New Guinea, the Solomon Islands and Vanuatu (Walter and Sam 2002:133; Kennedy and Clarke 2004:16). Yen (1996:38) presents a distribution map of seven edible Canarium species, including *C. indicum*. Within PNG, galip is widely grown below 500 m altitude along the north coast and inland areas of the New Guinea mainland and in the Islands Region (Figure 3). Galip grows from sea level up to a mean of 700 m, and occasionally as high as 930 m in PNG (Table 5). It is uncommon above 500 m altitude in PNG.

Nuts are produced seasonally with the producing period typically about three months long. Latitude has a strong influence on the start of the harvesting season, with the harvest commencing progressively later at locations further from the equator. At locations near the equator at 3–4° south, the producing season appears to be less well defined. There is no relationship between harvesting season and rainfall seasonality (Bourke et al. 2004:39).

About 1.347 million people live in locations where galip is commonly eaten in PNG (32% of the rural population) (Table 3). It is most common in Madang, East Sepik, East New Britain, Bougainville, Sandaun, Morobe, West New Britain, New Ireland, Oro and Manus provinces. Villagers on New Britain have ranked galip as one of the most important fruit and nut species on the island (Table 2). Galip nuts are widely eaten during the producing season. There are indications that consumption is somewhat less than in past generations. For example, puddings were made from galip and taro in some locations such as Bougainville, and this is rarely done now. Nuts are traded in some locations, for example, from Boisa Island to villages near the mouth of the Ramu River in Madang Province; on Vokeo (Woge) Island north-east of Wewak; and Siassi Islands in Morobe Province (Kennedy and Clarke 2004:17). Again there are indications that this trade has diminished in recent decades.

There is considerable potential for commercialisation of galip nut. Yen (1996:37) considered that ‘Of all the food-producing trees in Melanesia, Canarium’s almond-like nut probably has the greatest potential for commercialisation’. Thomson and Evans (2005a:2) similarly state that ‘The species has a great, as yet largely untapped, economic potential for commercial development and export, mainly because of its abundance and non-perishable nut-in-shell’. They further note that the size of the international market for Canarium nut is very large. There has been one unsuccessful attempt to commercialise galip in PNG. This was in the Kandrian area on the south coast of New Britain (Evans 1994; Wissink 1996). This was done as part of the AusAID-funded Kandrian Gloucester Rural Development Project and the operation failed as soon as donor support ceased. This is a particularly difficult location in which to base a commercial galip industry, as the producing season (about May to August) coincides with the wettest period of the year where rainfall is often about 1000 mm per
month. Sea transport links from the Kandrian area are also poor.

Evans (1996a) has estimated that there are about one million edible Canarium trees in PNG, with kernel production of 7200 tonnes per year. The yield from a plot of mature 10–15-year-old trees is estimated as 4–7 tonnes of kernel per hectare per year at a planting density of 100–250 trees per hectare (Thomson and Evans 2005a:11). One of the most important limiting factors for commercialisation is the high oil content of the kernel, as it becomes rancid unless processed adequately. The shell is very hard and considerable effort is required to break it to extract the kernel. Traditionally, this was done using stone tools, and is still the main technique used in PNG. However, this is not suitable for commercial use. Evans (1996b:69) lists research and development requirements to facilitate commercial production of Canarium nut.

**Karuka (Pandanus julianettii)**

There are a number of Pandanus species that produce edible nuts in PNG, all of which grow above 1000 m. Pandanus julianettii and P. brosimos are the most important. Stone (1982:412) suggests that P. julianettii is the cultivated form of P. brosimos. The former is planted by people, while the latter is spread by animals. P. julianettii grows at a lower altitudinal range than P. brosimos, although the ranges overlap (Table 5). Kennedy and Clarke (2004) review the Pandanus species used as edible food in the south-west Pacific.

Nuts of karuka pandanus are an important dietary item during the producing season for those living at high altitudes in the highlands of New Guinea. The kernel is eaten raw or cooked by roasting in an open fire, baking in hot ashes or steaming in a stone oven (Rose 1982:162). Sometimes the complete cephalium (head-like ball) is immersed in mud or water for temporary storage. The nuts (kernels) can be preserved by drying and smoking on a bark platform above the household fire. For longer storage, the kernels are extracted and stored in baskets hung in the rafters of houses (Rose 1982). Smoke from the house fires imparts a characteristic flavour to the nuts.

Pandanus julianettii is endemic to New Guinea and is not grown elsewhere (Henty 1982:79; Stone 1982). Within PNG, it is confined to a narrow altitudinal band in the central and fringe highlands and on the Huon Peninsula (Figure 4). Karuka grows from a mean of 1800 m up to 2600 m, and occasionally as low as 1450 m and as high as 2800 m (Table 5).

Production is irregular in the western part of the highlands, where rainfall seasonality is slight or absent. In the eastern part of the highlands, where rainfall is seasonally distributed, production approximates an annual seasonal pattern, but there is still large year-to-year variation in the harvest size. In any year, the producing period also varies between locations. The nuts are most likely to mature during January–March, but nuts may mature during any month of the year. After periods of soil moisture stress or drought, the producing periods coincide at all or most locations. The biggest harvests tend to follow major droughts, such as those in 1965, 1972 and 1982, although there were no reports of especially large harvests after the major drought in 1997. Water stress is the likely cause of flowering rather than frost (Bourke 1996:49; Bourke et al. 2004:40).

Karuka is one of the most widely grown edible nuts in PNG, with almost half the national population living in locations where it is grown. The MASP database indicates that 1.975 million people live in locations where the crop is commonly eaten (47% of the rural population) (Table 3). It can be found in all mainland provinces, except East Sepik. Most (95%) of the people who grow karuka live in the five Highlands Region provinces and in Morobe Province. The nuts are an important food source during and after the producing period. When the nuts are in season, entire households, and their domestic pigs, commonly migrate from
villages to high-altitude bush camps for some weeks to harvest and eat the nuts. Karuka nuts are commonly sold in highland markets. When sweet potato is scarce because of frost damage or other causes, villagers commonly survive on karuka. The nuts are highly nutritious and provide both protein and oil, the two components that tend to be deficient in highlanders’ diets. Rose (1982:166) recorded crude protein of 13–15% (dry weight basis).

A survey in two highlands villages in 1984 recorded 176 and 12 karuka nut pandanus trees per household respectively (Table 7). In the same year, Bruce Carrad (pers. comm. 1988) conducted a census of karuka nut pandanus trees in Kamus village, Asaro Valley, Eastern Highlands Province, at 1900–2000 m altitude. The mean number of karuka trees there (765 trees per household or 225 per person) was much higher than the numbers recorded at Asiranka village (1600–1800 m) or Upa village (1700–2000 m). This is not unexpected, as Asiranka and Upa villages are at the lower limit of karuka’s altitudinal range. In Kamus village, 42% of the trees were mature, somewhat more than in Asiranka village (28%), a reflection of the high planting rate in the years prior to the surveys. Hyndman (1984:295) recorded that each Wopkaimin man, who live in the mountains of north-west Western Province, maintains approximately 10 karuka trees and 10 marita trees.

Villagers commonly distinguish a number of cultivars of karuka. For example, people living near the Wage River west of Nipa in Southern Highlands Province distinguish at least 45 cultivars (Sillitoe 1983:105). In one area of the north Tari Basin, also in Southern Highlands Province, Rose (1982) recorded data on 17 named cultivars.

Karuka nut is highly sought after by highlanders and is popular with non-highlanders who live in the region. It has potential as a cash crop within PNG and perhaps as an exotic export crop.

Wild karuka (Pandanus antaresensis)

Nuts of a number of wild pandanus species are eaten occasionally, including P. antaresensis. This species is endemic to New Guinea (Stone 1982). Within PNG, it grows in an altitudinal band of 1000–2350 m on mainland provinces. It occasionally grows as low as 850 m (Pindiu, Huon Peninsula) and as high as 2460 m (Gumine, Simbu Province) (Table 5). I have recorded wild karuka in the Highlands Region and in Western, Madang and Morobe provinces, but it probably grows in all provinces on the New Guinea mainland. The only information on the production pattern is a comment by Hyndman (1984:296) that it bears continuously throughout the year.

Some people in the highlands and highland fringe eat the nut of this species, but in many locations it is not known as a food. Even where it is eaten, it is a minor food and is only used by a limited number of people. The shell is thick and hence it is difficult to extract the kernel. Hyndman (1984:297) notes that prominent aerial stilt roots with large spines make this species too difficult to climb and, in the Wopkaimin area, the fallen ripe cephalia are collected from the ground. Nuts are not sold in food markets. It probably has no potential for commercial development as a food crop.

Wild karuka (Pandanus brosimos)

This species is similar to the cultivated karuka nut (Pandanus julianettii) and the expert on the botany of the genus, Ben Stone (1982:412), believes that the cultivated form is a cultivar of P. brosimos. As with cultivated karuka, P. brosimos is an important food for those living at high altitudes in New Guinea, although it is not quite as important as P. julianettii. Wild karuka is endemic to New Guinea and is not found elsewhere (Stone 1982). Within PNG, it is widespread in a high altitudinal band (2400–3100 m) in the central and fringe highlands and on the Huon Peninsula. It occasionally grows as low as 1800 m and as
high as 3300 m (Table 5). Thus it is found at the top of the range of food gardening in PNG (up to 2850 m) and some hundred of metres higher.

Production is discontinuous and non-seasonal. Nuts are most likely to mature in January–February, but may mature in any month. The producing period may coincide with that of P. julianettii at lower altitudes in the same region, but this does not always occur (Bourke et al. 2004:41).

The MASP database indicates that 1.322 million people live in locations where the crop is commonly eaten (32% of the rural population) (Table 3). It can be found in all mainland provinces, except East Sepik. Most (91%) of the people who grow wild karuka live in the five provinces of the Highlands Region and in Morobe Province. Nuts have not been noted in highland markets, but it is possible that they are sold in high-altitude locations.

P. julianettii is likely to have greater potential for commercialisation than P. brosimos because the shell of the cultivated karuka is usually easier to break. Nevertheless, the wild species may be an important source of breeding material if improved types are to be bred in the future.

Okari (**Terminalia impediens**)

The name okari is used in Motu (and now English) in the Southern Region for *Terminalia kaernbachii*, but it has been adopted in Tok Pisin as the term for the related *T. impediens*.

The kernel of *T. impediens* is eaten raw. Trees are not planted, but are preserved when land is cleared for gardening. It is endemic to New Guinea (Henty 1982:83). Within PNG, it is most common in East Sepik, Madang, Sandaun and Morobe provinces. Henty notes that a few botanical collections have been made in Central and Gulf provinces. I have also seen it on the Managalas Plateau in Oro Province. *T. impediens* grows from sea level up to a mean of 1000 m, and occasionally as high as 1100 m (Table 5). There is no clear indication of the production pattern.

The MASP database indicates that about 340,000 people live in locations where the crop is commonly eaten (8% of the rural population) (Table 3), but this probably overestimates the importance of the species as it is a very minor food item in the locations where it grows. Most of those people live in East Sepik, Madang and Sandaun provinces. I have not noted it in fresh food markets, but it may be sold sometimes. This species has much less potential than the closely related *T. kaernbachii*, although it could possibly be developed as a commercial crop.

Okari (**Terminalia kaernbachii**)

Okari nuts are eaten raw. The nuts are greatly appreciated by Papua New Guineans and non-Papua New Guineans alike. Evans (1996a:22) notes that ‘Many would consider okari nut to be the best tasting indigenous nut in the Pacific’. Trees are preserved in garden land or planted. Villagers either harvest nuts from trees or, more commonly, collect the fallen fruit. The species is endemic to New Guinea and is also found on the Aru Islands (south-west of New Guinea). Okari has been introduced to the Solomon Islands, Australia and Sri Lanka (Evans 1996a:22; Henty 1982:83; Walter and Sam 2002:260). Within PNG, okari is mainly distributed in the Southern Region in Central, Oro, Gulf, Western, and Milne Bay provinces. It also occurs in adjacent locations in Southern Highlands and Simbu provinces, in the Mumeng-Wau-Menyamya area of Morobe Province, and in West New Britain from the Aria River west to Cape Gloucester (Bourke 1996:50). Over the past 50 years, the tree has been taken from its area of natural distribution to other locations in PNG, including East New Britain, New Ireland and as far east as Makira in Solomon Islands.

Okari grows from sea level up to a mean of 1100 m, and occasionally as high as 1260 m
(Table 5). The species is uncommon near the ocean in its natural range in southern New Guinea, although it does seem to produce well near the ocean, for example at Keravat on New Britain or at Kavieng on New Ireland. It may be that the best production occurs where the diurnal temperature range is greater (day to night variation), or perhaps people did not plant it near the sea where coconuts and sea almond were available. Fruit produces seasonally (Bourke et al. 2004:41–42). Experimental recordings at Keravat suggest that the start of the producing period is fairly constant from year to year, although the size of the harvest varies each year. The harvesting period is two to four months long. There is a clear relationship between latitude and the start of the harvesting period, with the producing period commencing later at locations further south from the equator (Bourke et al. 2002:42, 156). This is presumably caused by differences in day length, although it could also be related to seasonal temperature changes.

About 528,000 people live in locations where okari is commonly eaten in PNG (13% of the rural population) (Table 3). Most of those people (80%) live in the Southern Region, and the rest in adjacent locations on the southern fringe of the central highlands and in Morobe, Manus and West New Britain provinces. During the producing season, okari nuts are commonly eaten in the producing region and some are sold in local and regional markets, including in Port Moresby.

Okari nut has considerable potential for sales within PNG and overseas. It is a high quality nut and is highly regarded by those who have tasted it. There is much that is poorly understood about the agronomy, processing and marketing of the nut. On the Managalas Plateau in Oro Province, a 1985 census recorded 6300 mature okari trees in a 5000 ha area. Yields were recorded as 480 nuts per tree, with an estimated average yield of 4.8 kg of kernel per tree (Anon. 1985). Using these figures it was estimated that 30 tonnes of kernel was potentially available from this area each year. Average consumption was recorded as 25 kg per person in 1985, or 2.5% of the potential harvest (Anon. 1985). Production of about 5 kg of kernel per tree is in the range of 0.5–10 kg kernel per tree per year estimated by Evans (1996a) who provided an overview of some characteristics of the species. In another paper, Evans (1996b:72) summarises some of the research and development issues that need to be addressed for the species to be commercialised.

A local NGO called Okari Ecoenterprises attempted to commercialise okari nut on the Managalas Plateau in Oro Province in the early to mid 1990s (Ase 1996; Houghton 1996; Olsson 1996). Nuts were collected from planted and self-sown trees and transported to Port Moresby where they were sold through Associated Distributors (Andersons). The operation folded a few years after it started, possibly because of an insufficient and irregular supply of nuts, rather than constraints at the retail level in Port Moresby, where the processed nuts were in high demand.

**Pao (Barringtonia procera)**

There are three main species of Barringtonia with edible nuts in the western Pacific: Barringtonia procera, B. edulis and B. novae-iberniae (Jebb 1992:165; Evans 1996a; Walter and Sam 2002; Pauku 2005a). The last-named is found mainly in the wild form in forests, is largely undomesticated and is less abundant around villages. The distinction between B. procera and B. edulis is not easy because of the great variation within each of the two species, which means that morphological characteristics can overlap (Pauku 2005a). B. procera is the most important of the species in PNG. However, B. edulis is important in some locations. For example, Millar and Dodd (1982:201) note that the Russian botanist Miklouho-Maclay recorded B. edulis as being a very common tree in villages on the Rai Coast in Madang Province in the 1880s.
The kernel is eaten either raw or roasted. B. procera is always planted. The three species of edible Barringtonia are distributed from New Guinea through the islands as far east as Fiji (Evans 1996a:20; Walter and Sam 2002). Distribution of B. procera was restricted to parts of the Islands Region of PNG, the Solomon Islands and north and central Vanuatu. Within PNG, it was limited to Bougainville, Buka, New Ireland and Manus islands and the Gazelle Peninsula of New Britain (Bourke 1996:48). Since about 1960, the species has been planted at other locations on New Britain and the New Guinea mainland, including coastal and island locations in Morobe, Madang, East Sepik, Sandaun and Milne Bay provinces.

Jebb (1992:177) suggests that B. procera originated in the Solomon Islands as collections have been made in the forest only in the Solomon Islands. This suggestion is consistent with the limited distribution in PNG. I suggest that the species was brought by people from the northern Solomon chain (Bougainville and Buka) to New Ireland and the Admiralty group. Later it was taken by migrants from southern New Ireland to the Gazelle Peninsula of New Britain. Thus the species may have been present in what is now PNG for a relatively short time, perhaps less than 1000 years.

B. procera is very much a lowland crop and grows from sea level up to a mean of 500 m, and occasionally as high as 620 m in PNG (Table 5). Pao fruits intermittently in a non-seasonal manner in PNG (Bourke et al. 2004:42). The MASP database indicates that about 561,000 people live in locations where the crop is commonly eaten (13% of the rural population) (Table 3). It is most common in East New Britain, Bougainville, New Ireland, West New Britain and Manus provinces. This species is still a minor food on the New Guinea mainland, although it is increasing in importance. Pao nut is an important food in the Islands Region and is commonly sold in food markets.

Edible Barringtonia species have been commercialised in Vanuatu where there is high demand for the nuts (Long Wah 1996). B. procera in particular has considerable potential as a cash crop for both the domestic and export markets, given the small area required per tree, a relatively short time to maturity and the possibility of growing it as a horticultural crop rather than relying on naturally occurring forest trees. As with other South Pacific indigenous nuts, processing issues need to be improved to facilitate commercialisation (Evans 1996b). However, there are probably fewer issues that need to be addressed than for okari or galip, given that the kernel is not oily and the ‘nutty’ flavour of pao is readily accepted by Western consumers.

**Polynesian chestnut (aila) (Inocarpus fagifer)**

The seed of Polynesian chestnut is cooked prior to consumption. It is cooked by baking the entire fruit or boiling or roasting the nut. Polynesian chestnut is found near villages, rivers and in or near food gardens at low altitudes. It is distributed from Java and Borneo in the west through New Guinea and the island chains as far south as New Caledonia and as far east as east Polynesia (Walter and Sam 2002:184). Within PNG, it is grown in the lowlands of the mainland and island provinces. It is not common on the New Guinea mainland, except in Milne Bay Province, where it is important on both the mainland and on all larger islands. Polynesian chestnut is also commonly grown on New Britain and New Ireland. Polynesian chestnut grows from sea level up to a mean of 400 m, and occasionally as high as 870 m in PNG (Table 5).

Production in PNG is discontinuous and non-seasonal at locations closer to the equator. In Milne Bay Province (8–12° south), fruit ripens seasonally over a two to three month period, especially in November–February (Bourke et al. 2004:43).
The MASP database indicates that 637,000 people live in locations where the crop is commonly eaten (15% of the rural population) (Table 3). Most (83%) of those people live in Milne Bay, East New Britain, West New Britain and New Ireland provinces, with the rest in the other lowland provinces. In most locations, Polynesian chestnut is only a moderately important food. It is most important in Milne Bay Province, where it is available on a predictable seasonable basis during the period when garden food is scarce. However, since the widespread adoption of sweet potato and cassava, it seems to have become a less important food there, as the tuber vegetables are available throughout the year. The decline in the importance of the nut as a food is a Pacific-wide phenomenon (Pauku 2005b:3–4). Cooked nuts are sold occasionally in markets in the islands in PNG.

Polynesian chestnut is not a popular food with those who did not grow up eating it. For that reason, it is unlikely to have great potential for commercial production within PNG or overseas. Evans (1996b:72) notes that standard techniques for the removal of the toxins need to be developed for commercial production.

**Sea almond (talis) (Terminalia catappa)**

The small kernel of sea almond (talis in Tok Pisin) is eaten raw or roasted. Sea almond is widely distributed in PNG along the seashore. It is sometimes planted in coastal villages and inland villages. It has also been planted as a street tree in a number of PNG towns (Henty 1982:82). Sea almond has a widespread natural distribution in near-coastal areas of the Indian Ocean, through tropical Asia and into the Pacific Ocean (Thomson and Evans 2005b:2). Its range extends from India and Sri Lanka in the west to the Marianas Islands in the north to eastern Polynesia and northern Australia (Walter and Sam 2002:256).

Within PNG, the species can be found on the coast of all lowland provinces (Bourke 1996:50). It is most common in Milne Bay Province and the Islands Region provinces. Sea almond grows from sea level up to a mean of 300 m, and occasionally as high as 460 m in PNG (Table 5). It fruits sporadically throughout the year nearer the equator, but has heavier crops toward the end of the year at locations further from the equator (Evans 1996a:22). The available and limited information on its production pattern in PNG indicates that production is seasonal, with fruit ripening sometime between November and May. In Milne Bay Province, where sea almond is a more common food, the producing period is reported by villagers as 2–3 months long, with December–February as the most commonly reported time of fruiting (Bourke et al. 2004:44).

The MASP database indicates that about 568,000 people live in locations where the crop is commonly eaten (14% of the rural population) (Table 3). This overestimates the importance of the species as it is a very minor food item in most locations where it grows and it is mostly only eaten by people who live near the seashore. It is most widely used as a food in Milne Bay Province, and also in East New Britain, New Ireland and West New Britain provinces. My observation in Milne Bay and the Islands Region is that sea almond is not a commonly eaten food, and then the kernels are mostly eaten by children. Lepofsky (1992) notes that, on Mussau Island north of New Ireland, there were once strict laws concerning who was able to harvest trees, but today the nuts are eaten mostly by children. Sea almond is, however, more important on some islands. For example, on Iwa Island in the Marshall Bennett Group in Milne Bay Province, soft-shelled nuts occur. They are preserved by smoking and exported to nearby islands such as Woodlark (Bourke 1996:53). On Mussau Island, there is also reported to be a variety with a soft external skin which can be easily broken with the teeth (Lepofsky 1992:195). I have not seen kernels sold in PNG markets, such as occurs in the fresh food market in Port Vila in Vanuatu, but they may be sold sometimes. The species has potential for commercialisation for sale.
within PNG and overseas as it is a tasty nut. Processed sea almond kernels are sold in stores in Port Vila (Long Wah 1996). Evans (1996a) and Thomson and Evans (2005b) summarise information on estimated tree yields and other characteristics, while Evans (1996b:72) notes some issues that need to be addressed to facilitate commercial exploitation. One of the most important limiting factors is the small size of the kernel, and it would be desirable for any commercial production to be based on cultivars with larger kernels.

**Sis or Solomon (Pangium edule)**

The seed of Pangium edule is widely eaten in PNG, despite it requiring extensive processing to remove a toxic substance, a cyanogenic glycoside (French 1986:193; Henty 1982:80–81). The seed is only eaten after being washed in water, then roasted and fermented. P. edule is known by the common name sis in some locations in Momase Region and solomon in parts of New Britain. It is distributed from Malaysia in the west to Vanuatu in the east (Walter and Sam 2002:220). Within PNG, it is grown in all provinces and the seed is eaten in most provinces. Sis grows from sea level up to a mean of 1050 m, and occasionally as high as 1380 m (Table 5).

Production is seasonal, commonly starting around May or June and lasting 2–4 months (Bourke et al. 2004:44).

The MASP database indicates that about 336,000 people live in locations where the crop is commonly eaten (8% of the rural population) (Table 3). It is reported as being eaten in most provinces, and is most common in Milne Bay, West New Britain, Madang, Southern Highlands, Sandaun and Morobe provinces. It was ranked by villagers on New Britain as a moderately important nut species (Table 2). Nuts being are occasionally sold in food markets.

Because of the extensive processing required to make the nuts safe for human consumption, it is unlikely that this species has any commercial potential. However, there may be non-food uses for products from the tree.

**Tulip (Gnetum gnemon)**

Tulip is an important food crop in many locations in New Guinea, especially in East Sepik and Sandaun provinces, where the young leaves are an important green vegetable. The young flowers, young fruit and ripe fruit are also eaten (French 1986:57). The ripe fruit containing the seeds (‘nuts’) is eaten cooked, either boiled or roasted. The species is distributed from Assam (India) through Indo-China, Malaysia, Indonesia, New Guinea, Solomon Islands, Vanuatu and Fiji (Walter and Sam 2002:181). Within PNG, it is very widely grown on the island of New Guinea. It is present in the Islands Region, but is a less common crop. Trees are planted and self-sown. Tulip grows from sea level up to a mean of 1100 m, and occasionally as high as 1330 m (Table 5). The limited information on fruit availability indicates that it ripens in December–February (Bourke et al. 2004:14).

The MASP database indicates that tulip fruit and ripe seed are eaten by about 68,000 people, or less than 2% of the rural population (Table 3). However, this figure underestimates the number of people who eat the fruit and ripe seed occasionally. The fruit is sometimes eaten in lowland locations in all mainland provinces. Overall, tulip seed is a minor food, with the main food product from the tulip tree being the young leaves. It is not clear whether this species has any potential for further domestication or commercialisation.

**Discussion**

Five of the species discussed here are considered as having significant potential for commercial development. These are galip, karuka, okari, pao and sea almond (Bourke 1996). Nuts of three of these are sold as processed nuts in modern packaging in Vanuatu, although the actual Vanuatu species differ from the PNG ones. These are
Canarium species (nangai in Bislama), Barringtonia species (navele) and sea almond (natapoa) (Long Wah 1996). The operation in Port Vila has been sustained for the past 15 years. In the Solomon Islands, processed Canarium nuts were being sold in retail outlets in Honiara in 2005.

There have been two unsuccessful attempts to commercialise two of PNG’s indigenous nuts: galip in the Kandrian area on the south coast of New Britain and okari on the Managalas Plateau in Oro Province. These failed projects in PNG in the early to mid 1990s indicate that establishing a viable domestic or export industry for processed indigenous nuts is not easy. Nevertheless, the successes in nearby Vanuatu and Solomon Islands show that it is possible, provided that the operation is run by the private sector or a local non-governmental organisation and not by a donor-funded project or government.

A number of factors are limiting the commercial development of edible indigenous nuts in PNG. These include the lack of suitable mechanical crackers to extract the kernel from the shell, especially for galip which has a particularly hard shell. Currently, this is done by hand using stone tools, but this is laborious and potentially risky for the fingers of the operator. For some species, mature trees are very large, including galip, okari and Polynesian chestnut. Smaller trees would be easier to manage and harvest.

Basic information is lacking for all species on yield potential, yield patterns over the life of trees, the productive life of plantings and variation within populations. Such data are basic for investing in plantations and commercialisation. Evans (1996b) gives a valuable summary of aspects of indigenous nuts that are poorly understood, but which need to be known to facilitate development. He notes that most research and development requirements are to do with either resource sustainability or quality assurance during processing.

There is significant commercial potential for at least five of the forty-plus indigenous edible nuts in PNG. In the medium to long term, the indigenous edible nuts could be worth many hundreds of millions of kina to the PNG economy, and worth more than the existing major export cash crops. Much remains to be learnt about the trees and the markets. The best way to deal with these unknowns is to begin the commercialisation process and to address the constraints as they are identified.

References


Geography, The Australian National University, Canberra.


PNG Galip Consumer Survey
Tio Nevenimo, Clifton Gwabu, Jesse Anjen, Mark Johnston and Jeffrey Binifa

Introduction
During 2004 and 2005, a study was conducted to assess the feasibility of developing a strategy and methods for the parallel improvement of the food/nutritional security, and income generating opportunities of smallholder farmers through the domestication and commercialisation of galip nut (*Canarium indicum*). One component of this feasibility study was a consumer survey, which was conducted in selected urban markets and supermarkets in three major towns, namely Rabaul, Lae and Port Moresby.

The objectives of the survey were to:

- Determine the potential market demand at the consumer level for galip nuts in a range of urban centres in PNG
- Determine the consumer opinions and perceptions about accessibility and domestic consumption of galip nut.
- Identify the potential opportunities and constraints for Galip marketing and consumption

This report presents the survey findings, which are discussed in relation to the survey’s objectives listed above.

Methods
The social and economic importance and market potential of galip at consumer level was evaluated by conducting a consumer survey. The survey was conducted in selected urban markets (fresh produce) and supermarkets in three major centres of Rabaul, Lae and Port Moresby. The selected markets in Rabaul included those in Kokopo.

The survey target was to interview a cross section of people as given in Table 1. The target was to interview approximately 40 consumers in each supermarket with equal proportion of expatriates (20) and nationals with equal proportions of males (10) and females (10). The target at the urban market was to interview 20 nations at each market in Lae and Port Moresby and 40 nationals at Rabaul urban markets with equal proportion of male and female (Table 1).

<table>
<thead>
<tr>
<th></th>
<th>Supermarkets</th>
<th>Fresh produce markets</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(♂ and ♀)</td>
<td></td>
</tr>
<tr>
<td>Port Moresby</td>
<td>Andersons and/or Boroko Food Store</td>
<td>Expatriates – 10/10 Nationals – 10/10</td>
<td>Central market</td>
</tr>
<tr>
<td></td>
<td>RH Hypermarket and/or Stop and Shop Stores</td>
<td>Expatriates – 10/10 Nationals – 10/10</td>
<td></td>
</tr>
<tr>
<td>Lae</td>
<td>Andersons and/or Food Mart</td>
<td>Expatriate – 10/10 Nationals – 10/10</td>
<td>Central market</td>
</tr>
<tr>
<td></td>
<td>Papindo and/or Best Buy</td>
<td>Expatriate – 10/10 Nationals – 10/10</td>
<td></td>
</tr>
<tr>
<td>Kokopo</td>
<td>Andersons and/or Tropicana</td>
<td>Expatriate – 10/10 Nationals – 10/10</td>
<td>Central market</td>
</tr>
<tr>
<td>Rabaul</td>
<td>-</td>
<td>-</td>
<td>Central market</td>
</tr>
</tbody>
</table>
The consumers were interviewed using a structured questionnaire. Interviewees were selected as the next person entering the shop or approached at the market following the completion of the interview of the previous respondent who was willing to be interviewed.

The survey was conducted from September to November 2004. In Rabaul, the survey team consisted of a multi-disciplinary team from LAES Keravat, an economist from NARI Head Office, while the two economists based at NARI Head Office in Lae conducted the Lae and Port Moresby surveys.

Table 2. Stratification of the respondents based on the market location, market type, nationality and gender

<table>
<thead>
<tr>
<th>Location</th>
<th>Market type</th>
<th>Nationality</th>
<th>Gender</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Rabaul</td>
<td>Supermarket</td>
<td>Papua New Guinea</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Expatriate</td>
<td>13</td>
<td>7</td>
</tr>
<tr>
<td>Urban market</td>
<td></td>
<td>Papua New Guinea</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Expatriate</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Rabaul Total</td>
<td></td>
<td></td>
<td>46</td>
<td>34</td>
</tr>
<tr>
<td>Lae</td>
<td>Supermarket</td>
<td>Papua New Guinea</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Expatriate</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Urban market</td>
<td></td>
<td>Papua New Guinea</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Expatriate</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Lae Total</td>
<td></td>
<td></td>
<td>40</td>
<td>27</td>
</tr>
<tr>
<td>Port Moresby</td>
<td>Supermarket</td>
<td>Papua New Guinea</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Expatriate</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Urban market</td>
<td></td>
<td>Papua New Guinea</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Expatriate</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Port Moresby Total</td>
<td></td>
<td></td>
<td>22</td>
<td>5</td>
</tr>
<tr>
<td>Total Respondents</td>
<td></td>
<td></td>
<td>108</td>
<td>66</td>
</tr>
</tbody>
</table>

**Data analysis**

Data was analysed using the Statistical Package for Social Sciences (SPSS) program. The respondents gave multiple responses for a number of questions. If this was the case the data was grouped for analysis. For questions with multiple responses the percentages presented for the valid cases are greater than 100% as it is expressed as a percent of the number of respondents who gave an answer to the question. This made the interpretation a little confusing, however it should be remembered that some respondents may have three or four responses. A good example of this is the response given when the consumers were asked how they preferred to eat galip nuts, overall 80% of them also said they liked eating the nuts raw, 24% said they liked eating them as dried nuts, 28% said they liked them roasted and 27% also said they liked galip prepared with other foods.

**Results and Discussion**

A total of 174 consumers were interviewed in three urban centres, 80 in Rabaul, 67 in Lae and 27 in Port Moresby. The respondents were stratified as shown in Table 2. Despite the plan to interview approximately equal numbers of respondents with a good gender balance at the different markets (Table 1), this did not always happen. The number of expatriates interviewed in Lae and Port Moresby was less than targeted as many declined to be interviewed. One criterion for completing the interview was that the interviewee must have eaten galip nuts. This was to ensure that the respondents were familiar with galip nut and that information collected was based on experiences with galip. A record was kept on the number who said they had not eaten galip nuts.
The majority of the respondents thought that galip nuts was a healthy food while a number were not sure only 2% thought galip was not a healthy food (Figure 2).

Uses of Galip

A farmer survey conducted during the same period and reported separately showed that galip is a multi purpose tree with many parts and products from the trees still being used by some villagers. However it is the kernels that are used for both food and income that are the most important product followed by the wood which is extensively used for firewood and timber.
In this survey consumers were asked how they use galip nuts and all of the respondents said they used it for food, while 14% also said they use it for special or traditional occasions, 8% used it for oil, 6% for medicinal purposes and 5% for bartering (Figure 1). There was not much difference in the uses of galip between PNG nationals and expatriates except no expatriates said they used galip for oil or bartering and only one (2.6%) used galip for medicinal purposes and two (5.3%) used it for special occasions.

**Consumption and preference of galip nut**

Galip is often eaten as 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 the shell is sun dried, 

![Figure 4. The form the respondents preferred to consume galip nuts (n= 80, 66, 27 and 173 for Rabaul, Lae, Port Moresby and all locations respectively)](image)

**Figure 4. The form the respondents preferred to consume galip nuts (n= 80, 66, 27 and 173 for Rabaul, Lae, Port Moresby and all locations respectively)**

![Figure 5. Preferred form of Galip for eating between PNG Nationals and Expatriates (n= 134 and 38 for PNG Nationals and Expatriates respectively)](image)

**Figure 5. Preferred form of Galip for eating between PNG Nationals and Expatriates (n= 134 and 38 for PNG Nationals and Expatriates respectively)**
stored and shells cracked), or kernels extracted from the shells (fresh or dry) and roasted, or kernels (fresh or dry) are used as ingredients with other food preparation. To determine what form of galip was preferred, consumers were asked how they preferred galip nuts.

The bulk of the galip nuts bought by the consumers are consumed as fresh raw nuts. As shown in Figure 4, the majority (80%) of the respondents preferred to eat fresh raw galip nuts, 23% said they liked eating dried galip nuts, 28% said they eat roasted nuts while 27% liked galip prepared in combination with other foods. A lower percentage of the respondents in Lae (10%) said they liked eating dried galip nuts than the respondents in Rabaul (35%) or Port Moresby (22%). While there was no real difference between respondents preference for roasted galip nuts or galip prepared with other foods, a slightly higher percentage of the respondents in Rabaul said they liked galip roasted or prepared with other foods compared to Port Moresby and Lae. This also demonstrates the versatility of the product with a large number of people using galip nuts in the preparation of other foods.

![Figure 6. Respondents reasons for liking galip nut](image1)

The bulk of the galip nuts bought by the consumers are consumed as fresh raw nuts.

![Figure 7. Reasons given for eating galip nut by PNG nationals and expatriates](image2)
Galip nuts sold in local markets are mainly sold in nuts in shells or raw kernels in testa. Very little is sold as dried kernel or roasted kernels in both the local and the supermarkets so responses by the consumers may have been limited by the form the galip nuts were available to them.

Looking at the type of galip preferred between expatriates and PNG nationals, the majority of respondents in both groups like the nuts raw although there were a higher proportion of PNG nationals who preferred raw nuts than expatriates (Figure 5).

Considerably more expatriates said they preferred roasted nuts than the PNG nationals. This probably reflects the way expatriates normally buy nuts for snacks. Fewer expatriates said they preferred galip dried or incorporated with other food. This may be because many have probably not tried galip prepared in these ways.

Galip is bought and eaten mainly because of its nutty taste as indicated by the majority (88%) of the people interviewed. Twenty eight percent like galip because they perceive it to a healthy food, 19% said they like it as a handy snack while 19% liked galip because it is good when prepared with other food (Figure 6). Expatriates liked galip because of its nutty taste, about 27% of each group liked galip because they thought it was a healthy food. Twice as many expatriates (32%) said they eat galip as a handy snack than PNG nationals (Figure 7).

**Comparison of galip with other nuts**

Consumers were asked to compare galip nut...
Figure 9. The rating of galip nuts in relation to other major lowland indigenous nut tree species by respondents familiar with these nuts, a. Pao, b. Talis, c. Okari and d. Aila (n= 115, 152, 122 and 82 for pao, talis, okari and aila nuts respectively)

Figure 10. The rating of galip nuts in relation to other major lowland indigenous nut tree species by PNG nationals and expatriates familiar with the indigenous nuts a. Pao, b. Talis, c. Okari and d. Aila (n= 100 & 14 for pao, 125 & 26 for talis, 107 & 14 for okari and 70 & 12 for aila for PNG nationals & expatriates respectively)

with other popular local nuts and introduced commercial nuts such as cashew and macadamia nut. Respondents were able to compare the various nuts with galip, however a large percentage of respondents were not familiar with a number of
indigenous and introduced nuts (except for peanut). This was not surprising because the individual indigenous nut species are not grown in all parts of PNG. For example pao and aila is mainly grown in the New Guinea Islands region and okari in Oro and few parts of the Southern and the New Guinea Islands region. This is clearly shown in Figure 8 where high percentage of respondents in Lae and Moresby said they were not familiar with pao and aila while most of the people who were not familiar with okari were in Lae and Rabaul.

Overall the respondents generally rated galip as being better than the other indigenous nuts with only a small proportion (10% or less) of the respondents rating indigenous nut species better than galip (Figure 8 and 9).

The respondents rating of galip in relation to pao and aila was significantly different (Chi-Square \( p<0.001 \)) between the three locations. More respondents in Rabaul thought galip was better than pao and aila than the other locations where more respondents said they were not familiar with pao and aila nuts.

The respondents rating of galip in relation to okari was also significantly different (Chi-Square \( p<0.05 \)) between the locations. Fewer respondents in Lae thought galip was better than okari than the other locations. More respondents in Rabaul and Lae said they were not familiar with okari nuts. There was no difference in the ranking of galip in relation talis in the different location.

A clearer picture of the ranking of galip in relation to the other major lowland indigenous nuts can be seen when the respondents who were not familiar with the indigenous nut are removed from the analysis (Figure 9). The majority of respondents ranked galip as being better than pao, talis and aila. A similar number of respondents thought galip was better than okari as though it was similar to okari indicating that okari is also a highly preferred nut by the respondents.

The rating of galip in relation to the other major lowland indigenous nuts by the PNG national and expatriate respondents who were familiar with the indigenous nuts were in general quite similar (Figure 10). However, the expatriates tended to rate galip as being similar to okari and the PNG nationals rated pao and aila slightly better than galip.

These results could be a result of the familiarity of the different groups to the nuts. Many of the PNG nationals would have been brought up with the nuts whereas the expatriates may only have limited experiences with the other indigenous nuts.

When comparing galip to the introduced nuts, the majority of the respondents were not familiar with most of the introduced nuts apart from peanuts. Fifty seven percent of the respondents were not familiar with cashew, 70% with macadamia, 69% with hazel nut, 73% with Brazil nut and 75% with pistachio nuts (Figure 11).

Most introduced nuts are sold at high prices in supermarkets and are often not affordable by most average wage earners. There was no significant difference in the ranking of galip in relation to the introduced nuts between the different locations.

Galip was ranked as good as or better than the most popular introduced nut, peanuts. Thirty nine percent of the respondents said galip was better than peanut and 51% said galip was the same as peanut while only 10% said galip nut was not as good as peanut (Figure 12a). Although the number of respondents familiar with the other introduced nuts was low, galip was rated as being better than Brazil and hazel nuts by the majority of respondents. Galip was rated similar to cashews and macadamias with roughly equal numbers of respondents saying galip was better than, the same as and not as good as these nuts (Figure 12b & c). Pistachio was the only nut which was rated as being better than galip by more respondents (Figure 12f).
How PNG nationals and expatriates rated galip in relation to the introduced nuts varied (Figure 13). Both groups have similar rating of galip in relation to peanuts, hazel and Brazil nuts although there were more expatriates who thought galip is not as good as hazel nuts and Brazil nuts than PNG nationals. However PNG nationals tended to rate galip better than cashews, macadamias, and pistachios whereas the expatriates tended to rate cashews, macadamias, and pistachios better than galip (Figure 13 b, c & f). This would tend to suggest that there may be some slight differences in preference of nut types by different ethnic groups and is probably based on their familiarity of eating nuts due to their availability when growing.

Figure 11. Comparisons of the respondents ranking of galip nut with the main introduced nuts, a. Peanuts, b. Cashew nuts, c. Macadamia nuts, d. Hazel nuts, e. Brazil nuts, and f. Pistachio nuts (n=77-79, 62-63, 24-27 and 165-167 for Rabaul, Lae, Port Moresby and all locations respectively for the
Figure 12. The rating of galip nuts in relation to the main introduced nuts, a. peanuts, b. cashew nuts, c. Macadamia nuts, d. Hazel nuts, e. Brazil nuts, and f. Pistachio nuts by the respondents who were familiar with these indigenous nuts (n = 167, 71, 49, 52, 40 and 41 for peanut, cashew, macadamia, hazel, brazil and pistachio nuts respectively)
Figure 13. The rating of galip nuts in relation to the popular introduced nuts by PNG nationals and expatriates who were familiar with these nuts, a. peanuts, b. cashew nuts, c. Macadamia nuts, d. Hazel nuts, e. Brazil nuts, and f. Pistachio nuts (n= 131 & 31 for peanut, 34 & 37 for cashew, 16 & 33 for Macadamia, 19 &33 for Hazel, 10 & 30 for Brazil, 9 & 32 for Pistachio nuts for PNG nationals & expatriates respectively)

Quality issues

Over half of the respondents said they have encountered quality problems with the galip nuts they buy (Figure 14).

A wide range of problems that affect quality were reported (Figure 15). While nobody said it directly, most of these problems are related to post harvest handling, processing, packaging and storage. The most commonly mentioned problems were rotten, old or stale, discoloured and/or over dried kernels, which indicated the nuts have been stored too long under poor storage conditions. Immature nuts, soft kernels and poor tasting kernels were also common quality problems.
Figure 14. The number of respondents who have encountered quality problems with galip nuts they have purchased in the past (n = 161)

Although no measure of the frequency the of quality problems was made, this data indicates there are issues with quality of marketed galip related to post harvest handling, processing and storage that need to be addressed.

Figure 15: Quality problems respondents have encountered with purchased galip nuts (n = 81)

Market, marketing and prices of galip

The village people generally regard galip nuts as a seasonal food rather than marketable crop. However, observations in the past indicated that people do sell fresh kernels, dried nut in shell (NIS) or dried kernel in testa (KIT) at the local and roadside markets in East and West New Britain and Lae (Evans, 1994). It was found earlier that dry KIT was being sold for K7 per kilogram in the town markets (Carlos & Dawes, 1990). However, recent (2001), personal observations in the Gazelle shows that prices are now much higher and range from K17 to K50/kg KIT in the Rabaul, Kokopo and roadside markets.

The survey results show that galip nut is mainly sold in the local markets in all the centres surveyed. Ninety six percent of the respondents buy their galip from local town markets while 28% buy from roadside markets, only one percent buy galip nut from supermarkets which is not surprising as galip is only very rarely available in supermarkets (Figure 16). Slightly more people (35%) in Rabaul buy their nut from roadside markets compared to Lae (23%) and Port Moresby (13%). This is also expected for Port Moresby because not much galip is grown around Port Moresby. Most of the galip sold has to be brought in from other provinces and is therefore more likely to be sold in local markets than along the roadside. There was no difference in the type of markets that the PNG nationals or expatriates bought their galip. 41% of the
respondents in all locations said that they have difficulty in buying galip during the main production season while 59% said they have no trouble buying it (Table 3). It is interesting to note that more people (51%) out of 65 respondents in Lae where galip should be reasonably plentiful during main production season said they did not have access to galip during the season, which was higher than the 44% in Port Moresby who said they had difficulty getting galip during the season. Only 33% of the respondents in Rabaul said they did not have access to galip during the season, which would reflect a good supply as galip is widely grown by farmers in the Gazelle.

The main reason the respondents gave (94% previous question may be affected by price of galip at the market during the season rather then availability. It is not surprising that consumers perceive galip price to be high in Rabaul because observation (Nevenimo pers. comm.) at both Rabaul and Kokopo markets show that most of the galip nuts are sold bundled in leaves, which may contain between 20 and 50 kernels, with each parcel sold at K1 or K2. The prices are often pushed higher or the quantity reduced,

Table 3. Consumers access to galip during the main galip season and the reasons given for not being able to access galip if they had experienced difficulty in buying galip

<table>
<thead>
<tr>
<th>Difficulty of buying galip</th>
<th>% of responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumers who find it difficult to buy galip when in season</td>
<td>Rabaul N=80</td>
</tr>
<tr>
<td>33</td>
<td>51</td>
</tr>
<tr>
<td>Consumers who do not find it difficult to buy galip when in season</td>
<td>67</td>
</tr>
<tr>
<td>Reasons for the difficulty in being able to buy galip when in season</td>
<td>Rabaul N=25</td>
</tr>
<tr>
<td>Galip not available to purchase</td>
<td>84</td>
</tr>
<tr>
<td>Galip too expensive to purchase</td>
<td>16</td>
</tr>
</tbody>
</table>

Figure 16. The type of markets where consumers purchase galip in the three locations (n= 74, 52, 16 and 142 for Rabaul, Lae, Port Moresby and all locations respectively)
when farmers sell nuts to retailers at K1 per parcel. Retailers then resell the same bundle at K2 or they may repack so that each bundle has a reduced fixed number of (10-15) kernels per bundle and sell at K1 or even K2.

When asked how frequently they buy galip nuts when they are in season, 20% said they buy them daily, 47% weekly and 19% monthly, 3% in 3-4 month intervals and 1% said they buy once a year (Figure 17). The pattern was similar between the different locations. This indicated that consumers are willing to regularly purchase galip when it is in season and available in the markets.

**Figure 17.** The frequency respondents at the different locations said they currently purchase galip when it is in season (n= 75, 62, 17 and 154 for Rabaul, Lae, Port Moresby and all locations respectively)

When farmers sell nuts to retailers at K1 per parcel. Retailers then resell the same bundle at K2 or they may repack so that each bundle has a reduced fixed number of (10-15) kernels per bundle and sell at K1 or even K2.

When asked how frequently they buy galip nuts when they are in season, 20% said they buy them daily, 47% weekly and 19% monthly, 3% in 3-4 month intervals and 1% said they buy once a year (Figure 17). The pattern was similar between the different locations. This indicated that consumers are willing to regularly purchase galip when it is in season and available in the markets.

**Figure 18.** The form that the consumers from the different locations said they would prefer to purchase galip (n= 77, 61, 20 and 158 for Rabaul, Lae, Port Moresby and all locations respectively)
The main forms in which galip nuts are traded are: raw galip kernels packaged, raw unpackaged kernels and dried nuts in shell unpackaged (Figure 18). The majority of the respondents (81%) in Rabaul buy raw kernels packaged, 10% raw kernels unpackaged and 13% dried nuts in shell unpackaged. In Lae, 54% buy raw unpackaged kernel, 25% buy raw kernels packaged and 25% dried nuts in shell unpackaged. In Port Moresby the trend was similar to Lae as 35% purchased raw unpackaged kernel, 30% buy raw kernels packaged and 30% dried nuts in shell unpackaged (Figure 18). The packaging refers to local packaging, which includes being wrapped in leaves or put in baskets woven from coconut fronds.

It can be seen from Figure 19 that the majority of galip is sold as raw kernels. It is also sold as nut in shell (25% of responses)

Table 4. The price the consumers said they normally pay for a bundle or heap of nuts at the different locations

<table>
<thead>
<tr>
<th>Market sale price (K per karamap or heap)</th>
<th>Rabaul</th>
<th>Lae</th>
<th>Port Moresby</th>
<th>All locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>K 0.10</td>
<td>0</td>
<td>27</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>K 0.20</td>
<td>0</td>
<td>46</td>
<td>43</td>
<td>22</td>
</tr>
<tr>
<td>K 0.30</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>K 0.40</td>
<td>1</td>
<td>0</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>K 0.50</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>K 0.80</td>
<td>0</td>
<td>8</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>K 1.00</td>
<td>85</td>
<td>13</td>
<td>36</td>
<td>53</td>
</tr>
<tr>
<td>K 1.50</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>K 2.00</td>
<td>4</td>
<td>6</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>K 10.00</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>1</td>
</tr>
</tbody>
</table>

(n= 73, 52, 14 and 138 for Rabaul, Lae, Port Moresby and all locations respectively)
and a little is sold as dried kernels (10% of responses). More was sold as nut in shell in Port Moresby than in Rabaul and Lae which is probably because of the distance the nuts are transported to Port Moresby and the kernels would go bad during transit whereas the nuts in shell are not as perishable. It is the farmers who normally crack the nuts and the sellers would be less likely to take the effort to crack large numbers of nuts.

The respondents pay anything from 10 toea to K10 for a heap of nuts, however the price range is K0.10 to K2 per heap or packet of nuts. Only one person said they buy galip in bags at K10 each. The normal price for galip in Rabaul is K1 (table 4). In Lae and Port Moresby there were two price ranges; one around 10 or 20 toea and the other at K1. This reflects the different number of nuts sold per parcel. The 10 or 20 toea will only be for a few nuts whereas the K1 will be for a bigger parcel with a larger number of nuts.

The amount of galip bought by individuals at any one time varied from 1 to 6 heaps. Over 80% of the respondents bought more than one packet or unit every time they bought galip nuts.

The amount of money the respondents currently spend on galip when it is available was calculated from the information provided on the amount of galip they buy and the cost of galip at the markets. There were 113 valid responses of the 174 respondents questioned. On average the respondents spent K2.77 on galip. Each time they purchased some at the market, the data was skewed by a few respondents, who said they purchase large amounts of galip (Table 5). Because the data is skewed, the median value of K2 is probably a better estimate of how much the average consumer spends on galip each time they buy some. Although the data was limited and the conclusion is only indicative, there was no significant difference between the amounts the respondents currently spend on galip between the different locations or between PNG nationals or expatriates.

Future potential of galip

When asked if they would like to be able to buy more galip nuts than they currently do 64% of the 145 respondents to the question said they would like to be able to purchase more. The majority of the respondents (96%) said they are willing to buy galip nuts all year round if nuts were available (Figure 20). This demonstrates that there is a big market demand for galip nuts outside their normal production season. This could be addressed by a coordinated market system sourcing nuts from the areas with different seasonality and/or the selection and cultivation of out of season varieties.

Table 5. The amount respondents currently spend on galip each time they purchased some

<table>
<thead>
<tr>
<th>Measure</th>
<th>Amount in kina</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>2.77</td>
</tr>
<tr>
<td>Median</td>
<td>2.00</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>2.92</td>
</tr>
<tr>
<td>Maximum</td>
<td>1</td>
</tr>
<tr>
<td>Minimum</td>
<td>20</td>
</tr>
</tbody>
</table>

Figure 20. The respondents’ willingness to purchase galip nuts year round if they were available. (n = 156)
Figure 21  The form in which the respondents at the different locations said they would like to purchase galip (n= 48, 31, 8 and 87 for Rabaul, Lae, Port Moresby and all locations respectively)

Figure 22  The form of galip nut that the respondents at the different locations said they would prefer to purchase (n= 48, 31, 8 and 87 for Rabaul, Lae, Port Moresby and all locations respectively)
Figure 23. The form of galip nut that PNG nationals and expatriates said they would prefer to purchase (n= 73 and 14 for PNG nationals and expatriates respectively)

Figure 24. The market types that the respondents at the different locations said they would prefer to purchase galip (n= 49, 31, 9 and 89 for Rabaul, Lae, Port Moresby and all locations respectively)
The majority of the respondents said they would still prefer to purchase galip in the local markets (Figure 24). However, some said they would prefer to buy it in supermarkets or from other traders if it was available. A higher proportion of expatriates said they would prefer to purchase galip in supermarkets and traders than the PNG nationals (Figure 25). This probably reflects the shopping habits of the two groups.

Only about half the consumers gave an indication of the amount of galip they were likely to buy in the future if it was readily available.

Based on the price currently paid for galip and the amount of galip respondents said they would buy each time, the average amount the respondents would like to spend on galip was estimated to be about K4 to K5 each time they bought it (Table 6).

Table 6. The value of galip the respondents would like to purchase each time they bought some if it was readily available in the future

<table>
<thead>
<tr>
<th>Measure</th>
<th>Amount in Kina</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>4.86</td>
</tr>
<tr>
<td>Median</td>
<td>4.00</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>4.85</td>
</tr>
<tr>
<td>Maximum</td>
<td>21</td>
</tr>
<tr>
<td>Minimum</td>
<td>1</td>
</tr>
</tbody>
</table>

Although only 38 (out of 174) respondents answered the question on how regularly they would purchase galip if it was available 35% said they would purchase galip daily, 57% would buy it weekly and 8% would purchase it monthly.

Again although the data was limited and the conclusion is only indicative, there was no significant difference between the amounts the respondents were prepared to purchase in the future between the different locations or whether the respondents were PNG nationals or expatriates.
Table 7. The price the respondents at the different market locations said they would pay for a 50 g packet of galip

<table>
<thead>
<tr>
<th></th>
<th>Rabaul</th>
<th>Lae</th>
<th>Port Moresby</th>
<th>All Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average price</td>
<td>2.33 (0.16)</td>
<td>3.14 (0.23)</td>
<td>3.13 (0.30)</td>
<td>2.73 (0.120</td>
</tr>
<tr>
<td>Median price</td>
<td>2.00</td>
<td>3.00</td>
<td>3.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Minimum price</td>
<td>0.20</td>
<td>1.00</td>
<td>1.00</td>
<td>0.20</td>
</tr>
<tr>
<td>Maximum price</td>
<td>5.0</td>
<td>10.00</td>
<td>5.00</td>
<td>10.00</td>
</tr>
</tbody>
</table>

(The figures in brackets are the SEM, n= 80, 56, 22 and 158 for Rabaul, Lae, Port Moresby and all locations respectively)

The interviewees were shown 50g of galip kernels in a clear plastic package and asked how much they were prepared to pay for the pack. The prices the respondents said they were willing to pay for the 50g package of galip ranged from 20 toea to 10 kina with an average of K2.73 (which equates to about K55 per kg of nuts) across the three locations (Table 7). There appears to be two price ranges the respondents were willing to pay for the 50g pack of galip, one around K1 to K3 range and another around K5 (Figure 26). The price the respondents in Rabaul said they were willing to pay for the packet of galip was significantly less (p<0.05 ANOVA) than those in Lae or Port Moresby. There was no difference in the average price the respondents in Lae and Port Moresby said they would pay for 50g of galip nuts. The price distribution of what the respondents at the different market locations said they would pay is shown in Figure 27.

Although the difference was not great there was also a significant difference (p<0.05 ANOVA) in the average price the respondents interviewed at supermarkets said they would pay for the 50g package than those at the open markets. Those at the supermarkets were willing to pay around K3 and those at the open markets were willing to pay K2 (Table 8). The price distribution of what the respondents at the different market types said they would pay is shown in Figure 28.

As could be expected, there was also a significant difference (p<0.01 ANOVA) in the price the expatriates said they would pay for the packet of galip PNG nationals. The average PNG nationals said they would pay...
Table 8. The price the respondents at the different markets said they would pay for a 50g packet of galip

<table>
<thead>
<tr>
<th></th>
<th>Supermarket</th>
<th>Open market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average price</td>
<td>K2.99 (0.16)</td>
<td>K2.35 (0.18)</td>
</tr>
<tr>
<td>Median price</td>
<td>K3.00</td>
<td>K2.00</td>
</tr>
<tr>
<td>Minimum price</td>
<td>K0.20</td>
<td>K0.50</td>
</tr>
<tr>
<td>Maximum price</td>
<td>K10.00</td>
<td>K5.00</td>
</tr>
</tbody>
</table>

(The figures in brackets are the SEM, n= 94 and 64 for supermarkets and open markets respectively)

Table 9. The price the PNG nationals and expatriates interviewed said they would pay for a 50g packet of galip

<table>
<thead>
<tr>
<th></th>
<th>PNG nationals</th>
<th>Expatriates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average price</td>
<td>K2.51 (0.15)</td>
<td>K3.45 (0.21)</td>
</tr>
<tr>
<td>Median price</td>
<td>K2.00</td>
<td>K3.50</td>
</tr>
<tr>
<td>Minimum price</td>
<td>K0.20</td>
<td>K1.50</td>
</tr>
<tr>
<td>Maximum price</td>
<td>K10.00</td>
<td>K5.00</td>
</tr>
</tbody>
</table>

(The figures in brackets are the SEM, n= 120 and 37 for PNG nationals and expatriates respectively)

was K2.51 while the expatriates on average said they would pay K3.45 for the pack of galip (Table 9). The price ranges the PNG nationals and expatriate respondents said they would pay for a 50g pack of galip is shown in Figure 29 which clearly shows that PNG nationals tended to say they would pay less for the galip than the expatriates. There was a trend in the relationship between the amount the respondents said they were willing to pay for a 50g pack of galip and their fortnightly income range. As expected the respondents with a low income tended to say they would pay less for the galip than those in the higher income range (Figure 30).

Figure 27. The price distribution of what the respondents at the different locations said they would pay for a 50g packet of Galip (n= 80, 56, 22 and 158 for Rabaul, Lae, Port Moresby and All locations respectively)
Figure 28. The price distribution of what the respondents at the different market types said they would pay for a 50 g packet of galip (n = 94 and 64 for supermarkets and open markets respectively)

Figure 29. The price distribution of what PNG nationals and expatriates said they would pay for a 50 g packet of galip (n = 120 for PNG nationals and 37 for expatriates)
These results demonstrate that consumers would be willing to pay an average from K40 to K70 per kg for packaged galip kernels depending on their location, socio-economic situation and ethnic background.

When asked if they would like to buy commercially processed and commercially packaged galip kernels, the majority of the respondents said they were willing to buy commercially processed and commercially packaged galip nuts (Figure 31) indicating there would not be any consumer resistance against the acceptance of commercially processed and packaged galip nut industry in PNG.

Figure 30. Price consumers willing to pay when comparing their family income (n = 40, 50 and 50 for the less than K100, K100-500 and more than K500 categories respectively)

![Chart showing price consumers willing to pay when comparing their family income.](chart)

Figure 31. The respondents willingness to purchase a. commercially processed and b. commercially packaged galip nuts if they were available (n = 163 for a. and 164 for b.)

![Pie chart showing consumers willingness to purchase.](pie_chart_a)

- **Consumers who would like to buy commercially processed galip nuts:** 87%
- **Consumers who do not want to buy commercially processed galip nuts:** 13%

![Pie chart showing consumers willingness to purchase.](pie_chart_b)

- **Consumers who would like to buy packaged galip nuts:** 88%
- **Consumers who do not want to buy packaged galip nuts:** 12%
Summary

A total of 174 consumers were interviewed in urban markets and supermarkets in three urban centres, Rabaul, Lae and Port Moresby in PNG. The results confirmed that everyone in the household eat the nuts and that the vast majority of consumers thought the nuts were a healthy food. Most consumers prefer to consume the kernels raw while some also like dried or roasted kernels and the nuts prepared with other foods. This also demonstrates the versatility of the product with a large number of people using galip nuts in the preparation of other foods. Galip is bought mainly because of its nutty taste but also because some perceive it to be a healthy food, or because it is a handy snack or because it is good when prepared with other food.

Most of the consumers interviewed rated galip as being better than the other common indigenous and imported nuts. It was rated as being better than the indigenous nuts, pao, talis an aila by the majority of respondents and an equal number rated it as being better than okari while others rated it as being the same as okari. In relation to the introduced nuts, galip was rated as being better than peanuts, hazel nuts and Brazil nuts and similar to cashews and macadamia nuts. However pistachio nuts were rated as being better than galip by more respondents than those that thought galip was better than pistachios. There was a difference in the rating of some of the imported nuts in relation to whether the respondent was PNG national or expatriate with the expatriates tending to prefer some of the imported nuts over galip and vice versa for the PNG nationals. Despite these small differences galip was generally rated better than or as good as the imported high value nuts.

Over half of the respondents said they have encountered quality problems with the galip nuts they buy. Although no measure of the frequency the consumers encounter quality problems was made, the data indicates there are issues with quality of marketed galip related to post harvest handling, processing and storage that need to be addressed.

Currently galip is mainly purchased by consumers from the local markets in the form of raw kernels. Some is also sold as nut in shell or as dried kernels. Only one or two respondents said they buy galip from the supermarkets, which probably reflects the fact, that galip is only very rarely available in the supermarkets. The price consumers pay for galip varied depending on the number of kernels or nuts but were 10 to 20 toea for a few nuts in Lae and Port Moresby to K1 for larger parcels of nuts or kernels. Consumers spend on average of around K2 on galip nuts each time they buy some.

41% of the respondents in all locations said that they have difficulty in buying galip during the main production season. The main reason the respondents gave for not being able to access galip during the main production season was that galip is just not available to buy.

The frequency the respondents said they purchase galip if it is available was, 20% buy it daily, 47% weekly and 19% monthly. This indicates that consumers regularly purchase galip when it is in season and available in the markets.

64% of the respondents said they would like to be able to purchase more galip than they currently do. 96% also said they would like to be able to buy galip nuts all year round. This demonstrates that there is a big market demand for galip nuts both during and out of season. This could be addressed by a coordinated market system sourcing nuts from the areas with different seasonality and the selection and cultivation of out of season varieties.

Based on the price currently paid for galip and the amount of galip respondents said they would buy, the average amount the respondents would spend on galip each time they bought galip was estimated to be about K4 to K5. If available, 35% said they would...
purchase galip daily, 57% would buy it weekly and 8% would purchase it monthly.

The prices the respondents said they were willing to pay for a 50g package of galip kernels ranged from 20 toea to 10 kina with an average of 2.73 (which equates to about K55 per kg of nuts). There was a slight difference in the average price the respondents interviewed at supermarkets said they would pay for the 50g pack of galip. The respondents interviewed at the supermarkets were willing to pay around K3 and those at the open markets were willing to pay K2 for the 50g pack of galip kernels. As expected there was also a difference in the price the expatriates said they would pay for the 50g packet of galip than the PNG nationals who were interviewed. On average PNG nationals said they would pay was K2.51 while the expatriates said they would pay K3.45 for the pack of galip. There was also a trend in the amount the respondents said they were willing to pay for a 50g pack of galip and their fortnightly income range. As expected the respondents with low income tended to say they would pay less for the galip than those in the higher income range.

The results demonstrate that consumers would be willing to pay an average from K40 to K70 per kg for packaged galip kernels depending on their location, socio-economic situation and ethnic background.

The majority of the respondents said they were willing to buy commercially processed and commercially packaged galip nuts indicating there would not be any consumer resistance against the acceptance of commercially processed and packaged galip nut industry in PNG.

This survey demonstrates there is a large consumer demand and acceptance of galip nuts and highlights the potential for the industry to grow both as fresh kernel sales in local markets and as a commercially processed and packaged product.

References

Evens, 1994
Carlos & Dawes, 1990
Fruit and Nut Domestication Experiences

Roger Leaky

Abstract

Participatory domestication has been developed in Cameroon in central Africa as a technique to bring traditionally-important indigenous food producing species, especially fruit and nut trees, in agroforestry systems. This approach is based on strengthening and enriching traditional mixed-cropping farming systems so that farmers are able to take advantage of market opportunities and so to enhance their income and livelihoods. Through its participatory approach, the system also aims to empower subsistence farmers by creating the opportunity for them to develop cultivars of local trees species and to be the beneficiaries of their own efforts. The approach involves: working with farmers so that they can create village nurseries for the vegetative propagation of indigenous trees; to select elite individual trees present in their own area and to develop cultivars from them. The approach was developed using two indigenous fruit trees from West Africa (Irvingia gabonensis and Dacryodes edulis). Studies of the tree-to-tree variation in fruit and nut morphology, quality attributes such as taste and oil content, food thickening properties, led to the identification of elite trees for development as cultivars at the village level, based on market-oriented ideotypes. An investigation of the socio-economic and biophysical constraints to indigenous tree cultivation found that indigenous fruits could play a major role in the rural economy of subsistence households in west and central Africa. A similar approach has been taken to the domestication of Barringtonia procera and Inocarpus fagifer in the Solomon Islands and is being developed for Canarium indicum in Papua New Guinea. Together these projects provided insights into the value of domesticating indigenous fruit trees, which are of strategic importance to poverty alleviation and sustainable development worldwide.

Introduction

Throughout the tropics there are indigenous tree species that produce locally important fruits and other non-timber forest products, and that have the potential to be domesticated to provide economic and livelihood benefits to subsistence farmers (Leakey and Simons, 1998; Simons and Leakey, 2004). Many of these species are valuable sources of nutrition (Leakey, 1999a) with important health benefits against malnutrition and possible nutritional benefits conferring enhanced resilience to epidemics such as AIDS/HIV (Barany et al., 2001). The integration of these species as novel crops within existing farming systems can also provide environmental benefits (Leakey and Tchoundjeu, 2001). The need for greater emphasis on the cultivation and domestication of these overlooked ‘Cinderella’ species in ‘development’ programmes, poses important policy questions which need to be addressed (Leakey and Tomich, 1999).

The purpose of this paper is to draw attention to a participatory approach to agroforestry tree domestication, which has been developed in west and central Africa and that may have application in the Pacific. This is done in the knowledge that there is considerable current interest in tree domestication in Latin America (Clement and Villachica, 1994; Prance, 1994; Sotelo Montes and Weber, 1997; Jaenicke et al., 2000; Weber et al., 2001), southern Africa (Maghembe et al., 1998), East Africa (Simons, 1996) and South-east Asia (Roshetko et al., 1999) and that similar interest was expressed at the ‘Regional Workshop on the Value of Traditional Mixed Cropping Farming Systems and Agroforestry in Ensuring Food Security in
the Pacific Region’ (Mohammed et al., 2005; Leakey, in press).

**Participatory domestication**

To determine the relevance of agroforestry tree domestication to subsistence farmers in west and central Africa, a socio-economic study to examine both the constraints and potential benefits of bringing indigenous trees into cultivation was carried out in Cameroon and Nigeria (Schreckenberg et al., 2002). The overall conclusions of this study, obtained through participatory community-level research, household surveys and whole-farm fruit tree inventories were that farmers in the study area are very interested in the cultivation of indigenous fruits (Schreckenberg et al., 2006).

In contrast to the widely cultivated agricultural and horticultural crops of the world that have been domesticated for millennia, the initiatives to domesticate some of the indigenous fruit trees of different eco-regions of the tropics (Leakey and Simons, 1998) are starting now with wild, or virtually wild, gene pools. This imposes responsibilities on the scientists involved to ensure that domestication proceeds wisely, efficiently and within the constraints imposed by the Convention on Biological Diversity, and to maintain and protect the diversity of the genetic resource.

Tree improvement and breeding has usually been the prerogative of national and international research institutes, because of its long-term nature and the emphasis on timber production by government forestry departments. In agroforestry, however, with the much greater emphasis on the social, cultural and economic needs of resource-poor subsistence farmers, there has been a recent shift towards domesticating trees producing valuable non-timber forest products with the people and for the people (Sanchez et al., 1997; Tchoundjeu et al., 1998; Tchoundjeu et al., 2006). This requires a very different approach to tree improvement, one based more on horticultural than forestry techniques (Leakey and Jaenicke, 1995); and one situated on the farm rather than in a research station.

The model, which has been developed in Cameroon and Nigeria by ICRAF and partners (Tchoundjeu et al., 1998; Kengue et al., 2002), is based on involving the farmers in all stages of the process. This starts with asking the farmers about which of the trees from the natural forest they would like to cultivate on their farms (Franzel et al., 1996), and progresses to the development of simple, low-technology plant propagators (Leakey et al., 1990) in the villages. These inexpensive and effective propagators, made from readily available products (wood, sand and polythene) for the rooting of stem cuttings, do not require running water or electricity. This simple and appropriate technology has many benefits for rural development projects over more complex propagation systems, especially micro-propagation, as with the involvement of NGOs, villagers are trained in the basic principles of vegetative propagation so that they can themselves produce and bulk up ‘cultivars’ from the trees that they know and like best in their area. This emphasis on the empowerment of the community and its use of indigenous knowledge about superior phenotypes in the forest allows rapid progress to be made, as it overcomes the need to do expensive and time-consuming mass propagation and selection from populations of seedlings with unknown potential. This is particularly important, when there are a number of different fruit characteristics that together form a ‘plus-tree’ (Atangana et al., 2002), as the more traits for which selection is desired, the larger is the number of trees that would need to be screened. With a participatory approach, local people use their knowledge about the characteristics of the individual trees in their area to select those for domestication, while in a research station approach to tree improvement it is necessary to grow and screen very large numbers of trees of unproven potential. The latter is expensive and time consuming.
Participatory domestication also allows farmers to be the beneficiaries and guardians of the use of their indigenous knowledge about inter- and intra-specific variation in the population, and germplasm derived from it. This approach conforms to the aims of the Convention on Biological Diversity, which seeks to protect the rights of local people to their indigenous knowledge and germplasm. It is, thus, in stark contrast to the ‘research station model’ of tree domestication. It does, however, require that national legal instruments exist for farmers to protect their rights and that the farmers understand these rights and know how to maintain and protect them. Currently, this is not the case in the Pacific.

**Characterisation of intraspecific variation in fruit and kernel characteristics**

The purpose of this component of the programme was to identify combinations of fruit traits that could be brought together through ‘plus-tree’ selection and then captured as a ‘cultivar’ by vegetative propagation.

(i) The levels of diversity available to farmers within their community

This study found highly significant and continuous variation between individual trees for each trait, and as expected, trees with superiority in one trait (e.g. fruit size) are not necessarily superior in other traits (e.g. fruit taste). Consequently, the chance of finding trees with superiority in two or more traits is considerably lower than for a single trait. Nevertheless, it is highly desirable to identify combinations of traits, which should be brought together for cultivar development. To pursue this objective of defining combinations of desirable traits, an ‘ideotype’ approach has been developed (Leakey and Page, 2006).

In *Irvingia gabonensis*, an examination of all the data indicated that there are some trees with high values for fruit traits (fruit length, fruit width, flesh weight, flesh depth and taste) that are close to the ‘fruit ideotype’, and thus superior as fruit for eating fresh. In the same way, there are other trees with kernel traits (kernel weight, shell brittleness) close to the kernel ideotype. Interestingly, however, the study of the physical and chemical properties of the kernels (Leakey et al., 2005a) found that none of the trees assessed had high values for both of the food thickening traits (viscosity and drawability). Furthermore, the viscosity and ‘drawability’ of the polysaccharide extract were poorly related traits and thus probably kernels from different trees have different uses in food preparation. Consequently, depending on the use of the kernels, the kernel ideotype should be sub-divided into two food-thickening sub-ideotypes, one with good properties for viscosity, and the other for drawability (Leakey et al., 2005a).

Fat determination and fatty acid profiling of kernels confirmed previous studies (see review by Leakey, 1999a) that fat content ranges from 50-70% between samples, although the range in individual tree samples in the present study was greater than this (37.5 - 75.5%). As also found elsewhere, the study identified myristic acid and lauric acid as the major fatty acid components of the extracted fat. Thus, it appears that kernels for vegetable oil production may have to conform to a third ideotype, depending on the yield and desirable properties of the oils.

To date, the range of nutritional values of *I. gabonensis* kernels has not been reported to vary between samples, although reported protein content of different samples has ranged from 14.3 – 24.1% (Leakey, 1999a). However, it is clear from a protein analysis of de-fatted kernel samples from six trees, selected for their diverse viscosity properties, that they were similar to the published range. Thus study of more trees may determine opportunities to further select individual trees for their nutritional value. Electrophoretic analysis of total protein extracts according to molecular weight, demonstrated that all six samples had similar protein patterns.
In *Dacryodes edulis*, the fruits for eating as a nutritious cooked vegetable would appear to fit a single ideotype characterised by large size, thick flesh and a small kernel. Further refinement of this ideotype may follow once the organoleptic properties of these fruits are better understood. A preliminary study by a trained tasting panel has found that there is variation in acidity, astringency, bitterness, sourness, as well as in fibrosity, (Kengni et al., 2000, Leakey et al., 2002). Thus, taking all these traits together, the morphological and organoleptic studies to date suggest that there are opportunities, through ideotype selection, for the development of cultivars that combine large size with good quality attributes for the fresh fruit trade. However, there are also potential industrial uses of these fruits for vegetable oils (Kapseu and Tchiegang, 1996; Silou et al., in press), which may require further refinement of the fruit ideotype, depending on the oil properties required.

For both species, the above definition of ideotypes feeds into the on-farm domestication process, by helping researchers to explain to NGOs and farmers what traits, or combinations of traits (ideotypes) are available for selection and thus their opportunities for cultivar development. The inclusion of this information into the community domestication programmes could have very rapid impacts on the level of genetic gains achieved by farmers in the next 10 years. For example, fruit size could probably be increased two to three fold by creating cultivars that conform to the ‘fruit ideotypes’. Since different villages will create different sets of cultivars for each species they wish to cultivate, intra- and inter-specific diversity will be maintained at the farm level, at least in the short-to-medium term.

The study has also identified some variation in the fruiting phenology of different trees, illustrating opportunities for selection for the seasonality of production. Seasonality is not a problem in the case of *I. gabonensis* as the storage of dika nuts allows a year-round market, but the fruits of *D. edulis* have a very short shelf life and thus there is a need to extend the productive season, as for example with the recently created ‘Nöel’ cultivar that fruits at Christmas. Alternatively, research is needed to develop storage and/or processing techniques for the fruits that can be used in the villages or local towns.

An additional advantage of the ideotype approach is that the cultivars may have a broad genetic base in many other characteristics, especially if the cultivars come from unrelated populations. This could make them less susceptible to pest and disease outbreaks (Leakey, 1991). To minimise the risks of narrowing the genetic base and associated disease and pest problems, it would also be wise to ensure that there is a turnover of recommended cultivars arising from an on-going and continuous programme of selection.

(ii) The levels of selection intensity being applied by farmers

In an attempt to determine the levels of tree selection by farmers, the frequency distributions of the data for each measured trait were plotted and examined. The results did not provide an answer. However, an assessment of the genetic gain made by farmers through their own selection efforts was achieved.

Typically, trees are out-breeding and genetically very diverse due to the contribution of large numbers of individuals to a shared gene pool and the free segregation of alleles during meiosis (Zobel and Talbert, 1984), typically resulting in normally-distributed variation of quantitatively-inherited polygenic traits. These patterns of intraspecific variation mean that for any one trait there are relatively rare genotypes which display the desired set of characteristics; so called ‘plus-trees’. In addition, it is well known that tree populations from geographically different locations (provenances) can have different mean values. Leakey et al. (2004) have
postulated that when data from different wild populations for a given trait are combined, the overall population will also be normally distributed. In plant breeding, cycles of selecting and crossing between only the best individuals in the population (truncated selection), result in new progenies, which outperform their parents in the selected trait (Futuyma, 1998). The degree of improvement depends on the narrow sense heritability (Stearns and Hockstra, 2000). The domestication of a species must therefore result in changes in the frequency distribution of the values of the selected trait among the members of the population (and typically an increasing reduction in diversity within the selected population, due to an increasing intensity of selection). During the course of several generations of truncated selection, the frequency distribution of the trait can thus be expected to change through a progression of stages that ultimately lead to the formation of a variety.

To determine the stage of farmer-selected domestication reached in different populations of *I. gabonensis* and *D. edulis*, it has been hypothesised that it is possible to use changes in the pattern of the frequency distribution of data relating to specific selected traits to assess which of five stages of domestication have been reached (Leakey et al., 2004). Evidence from this study indicates that this is indeed the case and that in some villages in Cameroon the farmers have achieved Stages 2-3 in *D. edulis*, with about a 66% increase in flesh depth. This fact emphasises the importance that subsistence households attribute to indigenous fruits, both for their own consumption and for trade. The recognition that subsistence farmers have initiated the domestication of two of their indigenous fruit trees emphasises the importance of the current Participatory Domestication activities to further improve the indigenous trees that provide marketable non-timber forest products of importance to local people for food security and income generation. The need now is to go to the next stage of domestication in which cultivars are developed, using vegetative propagation techniques (Leakey et al., 1990; Shiembo et al., 1996), from the very best trees available in each village. This is starting in the west African participatory tree domestication programme (Tchoundjeu et al., 1998) with the intention of using these cultivars in cocoa and other agroforests to diversify the agroecosystem. In this way, it is envisioned that it may be possible to create landuse systems that enhance the livelihoods of poor subsistence farmers (Leakey, 1999b). In addition, the domestication of these species may lead to the creation of export commodities to diversify both the farmers and national economies. These benefits, together with the international public goods and services (carbon sequestration, biodiversity, etc.) that can be derived from increasing the numbers of trees in agroecosystems, are outcomes that could benefit the global community (Leakey, 2001).

(iii) Market recognition of variability in fruit or kernel traits

To be successfully adopted by farmers, domestication must create new or enhanced market opportunities. In West Africa market studies have indicated that, for example with *D. edulis*, wholesale traders in Gabon travel to markets like Makenene to buy fruits for importation into Gabon. Similar evidence of regional trade has recently also been documented for *I. gabonensis* and *Ricinodendron heudelotii* kernels, and the nuts of Cola spp. (Ndoye et al., 1998; Ruiz Pérez et al., 1999).

To determine if these markets reward farmers for producing fruits with desirable characteristics, fruit samples were purchased and characterised at the peak of the season (3-17 August 2000) from urban and rural markets in Cameroon (Atangana et al., 2002; Leakey et al., 2002). The area around Makenene has a reputation for producing and selling *D. edulis* fruits, leading to the existence of a retail market as well as one of the largest wholesale markets in the country. Statistically significant differences in each
fruit trait were found between samples for each market, but the relationships between fruit traits and prices were found to be weak in wholesale markets. However, in retail markets, fruit mass, length and width were all positively correlated with price per fruit, indicating that small-scale traders can benefit from consumers’ preferences for large fruits. Interestingly, the relationship between fruit mass and price was stronger in the urban retail market suggesting that urban consumers will pay more for large, tasty fruits than they will pay for small or less tasty fruits.

It seems therefore that at present farmers who typically sell their produce in rural wholesale markets are not currently being rewarded for producing superior fruits, although big fruits, which have the most pulp, fetch the highest prices in retail markets. This indicates that retailers, who are in closest contact with consumer demands, take into account phenotypic variation in fruit size when fixing market prices. There is also some evidence that some other qualitative traits (e.g. flavour) are also recognised by urban retailers as Leakey and Ladipo (1996) found that while big fruits tended to have high market prices, some small fruits were also highly priced. Similarly, Waruhiu et al (2004) found that a relatively uncommon white skinned fruit type was more expensive than similar sized fruits of the common purple colour. Wholesalers on the other hand, do not appear to take the characteristics of individual fruit types into account when pricing fruits. It is to be hoped that in the future, farmers producing large quantities of fruits from named cultivars will be rewarded with higher prices.

Improved market access is required to enhance communities’ opportunities to cultivate and sell indigenous fruits of all species. Similarly, improved market information systems would improve the opportunities to generate income. These systems should be targeted first and foremost at women, for whom the *D. edulis* trade, for example, is particularly important (Awono et al., 2002).

**Impact and strategic importance**

The domestication of trees to produce Agroforestry Tree Products (AFTPs), such as indigenous fruits and nuts, is aimed at strengthening and enriching traditional mixed-cropping farming systems so that farmers are able to take advantage of market opportunities and so to enhance their income and livelihoods. Through its participatory approach, the system also aims to empower subsistence farmers by creating the opportunity for them to develop cultivars of local trees species and to be the beneficiaries of their own efforts. The approach involves: working with farmers so that they can create village nurseries for the vegetative propagation of indigenous trees; to select elite individual trees present in their own area and to develop cultivars from them (Leakey et al., 2005b). In these and other indigenous fruits (e.g. *Sclerocarya birrea* in southern Africa – Leakey et al., 2005c/d; Leakey, 2005), intra-specific variation is typically found to be greatest at the village level, thus there seems to be several strategic advantages of tree domestication at this level. This village-level, self-help approach to domestication also helps to maintain a broad genetic base within the species being domesticated, as each village will develop a different collection of cultivars. Furthermore, it allows the farmers to practice their new skills on any other species of interest to them, and so does not restrict the domestication process to the priority species. In the long-term, this will promote the species diversity of their farming systems. In terms of ensuring impact from development assistance, this approach of working directly with farmers has the advantage that the project outputs are immediately disseminated into the target population (Tchoundjeu et al., 2006), thus overcoming the delays that often arise from a research station stage in the domestication process.
Potential for wider application of participatory domestication

The domestication of new species is a major undertaking, one that is a continuous process of improvement and one that has to be justified by the benefits that accrue to the producers and consumers of the products. There is currently some debate among development organisations focused on poverty alleviation, sustainable livelihoods and food security, about the direction for future research: some favour biotechnology and an expansion of the Green Revolution (McCalla and Brown, 1999; Lipton, 1999), while others see potential for broadening the basket of crops (Mc Neely and Scherr, 2001) – a Really Green Revolution (Leakey, 2001). In the case of a number of agroforestry trees, including Irvingia gabonensis (Aubry Lecomte ex O’Rorke) Baillon, and Dacryodes edulis (G.Don) H.J. Lam, it has been argued that their domestication will enhance farmer livelihoods, reduce poverty, and promote economic development (Leakey, 2001; Leakey et al., 1990), as was the marcotting of mature B. procera. Results from the characterisation of tree-to-tree morphological variation found similar patterns of continuous intra-specific variation as found in the west African species. The molecular characterisation of the same trees found that the elite individuals were typically unrelated, confirming that it is possible to develop a set of cultivars which would span the range of inherent genetic variation (Pauku, 2005).

In the 1990’s several projects were implemented to market the kernels and kernel oil of Canarium indicum in Papua New Guinea and the Solomon Islands (Nevenimo et al., in preparation a), but after initial success supply side issues such as the lack of regular stocks, variable quality and storage difficulties resulted in failures; although a private sector initiative in Vanuatu was successful. A feasibility study of the potential for the domestication and commercialisation of Canarium indicum kernels involving producer and consumer surveys (Nevenimo et al., in preparation b) and market chain analysis (Bunt and Leakey, in preparation), found that the demand for C. indicum products is high in both national and expatriate communities. Characterisation studies found similar patterns of fruit/nut/kernel morphological variation, some variation in nutritional qualities of the edible kernels and substantial tree-to-tree variation in medicinal properties of kernel oil (Leakey et al., in preparation). A programme to initiate the domestication of C. indicum will hopefully be implemented in Papua New Guinea in 2006, through studies at the National Agricultural...
Research Institute’s Lowlands Agriculture Experiment Station at Keravat.

Conclusion

This experience with the domestication of indigenous fruit tree species in west Africa is probably relevant to many other regions of the tropics, including the Pacific, because throughout the tropics:

- There are many tree species producing edible fruits and other products, which are grown and marketed on a small scale and which are potential candidates for domestication. The range of available species, allows for the choice of those that meet labour availability, different markets, systems of tenure, variations in soils and climate, etc.
- There is a decline in the availability of traditionally important forest products from wild sources, especially near urban markets.
- There is great interest in agroforestry as a low input, low-risk, sustainable farming system, which supports rural livelihoods.
- There are many small-scale subsistence farmers who are poor and need opportunities to generate income.
- There are risks arising from falling cash crop prices, pests and diseases, increasing environmental pressures, which could be averted by economic and ecological diversification.
- It could build on and enhances the local social and cultural traditions.
- It could promote small-scale local processing and entrepreneurial activity at the community level
- It could benefit and empower women who are often involved in the labour intensive harvesting, processing and marketing of forest fruits, and who play a strong role in managing home gardens and village nurseries.
- It could enhance the health of the rural and urban communities, as indigenous fruits are rich in minerals, vitamins, protein, oils and carbohydrates and so can also meet the needs of poor people for food and nutritional security.
- Finally, the participatory approach to domestication is a relatively rapid and low cost option to development, which given the need to domesticate a wide array of species, can not be achieved by the “Green Revolution” approach to agricultural development.

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References


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The macadamia is considered as one of the world’s finest gourmet nuts because of its unique, delicate flavour, its fine crunchy texture, and rich creamy colour. Nuts from wild macadamia trees provided a source of food for the aboriginals in the Australian subcontinent, but Australian farmers were slow to appreciate the commercial potential of this fine nut.

**Origin**

The macadamia nut is the only commercial food crop indigenous to Australia, originating along the fringes of rainforests in coastal southeast Queensland and northeast New South Wales (25 to 32°S latitude). The tree has several features suggesting adaptation to harsh environments, including sclerophyllous leaves and dense clusters of fine, proteoid roots that develop to enhance nutrient uptake from poor soils, particularly those low in phosphorus.

Of the four southern species of macadamia, only two are edible, the smooth-shelled *Macadamia integrifolia* and the rough-shelled *M. tetraphylla*. Only the former has been developed commercially. The latter, grown on a moderate scale in California and New Zealand, produces a raw kernel of excellent eating quality but contains a higher percentage of sugars that may caramelise on roasting, thus detracting from its appearance and reducing its effective shelf life. The wild *M. ternifolia* produces a small, unpalatable, bitter kernel. *M. jansenii* was first discovered in 1982 and there are less than 100 known individuals surviving in the wild. It has small inedible fruit.

**Botany**

The evergreen macadamia tree is medium to large, attaining a height of up to 20 m and a spread of up to 15 m. In *M. integrifolia*, the leaves are arranged in whorls of three and often have spiny, dentate margins, and short (5-15 mm) petioles. Multiple branches (or inflorescences) may be produced from each node. The pendulous racemes, up to 15 cm long and bearing approximately 200 creamy, white flowers, are borne on hardened wood. Less than 5% of flowers set fruit and the nuts take six months to mature, after which they abscise naturally.

The fruit is a globose follicle in which only one of two ovules develop. As the husk dries, it splits along a single suture to release the nut, consisting of a hard, thick, stony, light-tan shell (the seed coat) that encloses the kernel.

The leaves of *M. tetraphylla* are sessile and are arranged in whorls of four. The margins are more serrated, with up to 40 spines on each side and, whereas new leaf growth of *M. integrifolia* is pale green in color, young *M. tetraphylla* leaves are an attractive pink to red color. Racemes are longer (up to 30 cm) and bear up to 500 reddish-pink flowers.

**History**

A German explorer, Ludwig Leichhardt was the first person to collect macadamia. Some time later, in 1857, Ferdinand von Mueller, the Director of the Royal Botanical Gardens in Melbourne, and Walter Hill, the superintendent of the Brisbane Botanical Gardens, discovered a macadamia tree on the banks of the Pine River, 30 km north of Brisbane. Von Mueller described the specimen and named it after his good friend, Dr. John Macadam.

One of the earliest macadamia orchards in Australia was established at Rous Mill, near Lismore in the early 1880s and it is still producing nuts today. Other small blocks.
were planted throughout New South Wales and Southeast Queensland but the total area prior to 1960 was less than 100 ha with annual production of less than 50 tonnes (t) of nut-in-shell. Although the macadamia is native to Australia, large-scale commercial development first occurred in Hawaii after trees were imported by William Purvis, also in the early 1880s. It was not, however, until the early 1920s that the first developmental macadamia orchards were established in Hawaii. A major breakthrough to commercialisation was the development of efficient cracking machines. The first truly commercial orchards were established by Castle and Cooke at Keauhou on the island of Hawaii in 1948.

Research in Hawaii

The development of the macadamia industry was supported by research at the Hawaii Agricultural Experiment Station of the University of Hawaii. An early achievement was the discovery of the importance of starch accumulation above girdled branches for successful grafting; resulting in true-to-type trees that commenced bearing earlier, and produced much higher yields than seedling trees. J.H. Beaumont and R.H. Moltzau initiated a cultivar selection program in 1936 and William Storey released the first five cultivars from 20,000 bearing trees in 1948, two of which (‘Keauhou’, HAES 246 and ‘Kakea’, HAES 508) were the basis for early commercial orchards in Hawaii, and later in Australia and other parts of the world. Cultivar trials using grafted trees were established on all the major islands of Hawaii. Other important cultivars released were ‘Ilaika’ (HAES 333), ‘Kau’ (HAES 344), ‘Keaau’ (HAES 660), ‘Mauka’ (HAES 741) and ‘Makai’ (HAES 800). In 1960, Storey visited Australia and collected additional new germplasm for evaluation in Hawaii. Richard Hamilton enthusiastically promoted the development of the macadamia industry and continued the variety selection work, as did his student, Phil Ito.

The importance of maintaining high quality standards in the developing Hawaiian industry was acknowledged by J.C. Ripperton, R.H. Maltzau and D.W. Edwards who developed effective quality assessment procedures for factories. Their simple and convenient flotation test for maturity was widely adopted. Kernels that float on tap water have at least 72% oil and are considered mature. They also developed the concept of kernel recovery (the percentage of kernel within the nut), an important quality feature, particularly in those early days when many orchards were based on variable seedling trees that produced nuts with thick shells. More recently, Cathy Cavaletto’s post-harvest research at the University of Hawaii has underpinned the high quality of macadamias in the marketplace.

From the early 1950s to the 1970s, research was carried out by B.J. Cooil, G.T. Shigueura, R.M. Warner, R.L. Fox and co-workers to overcome nutritional constraints to productivity in Hawaiian macadamia orchards and to develop leaf analysis standards for optimum production and quality. Yields were enhanced by applying phosphorus fertiliser to lava and phosphorus-fixing soils. Excess phosphorus (leaf P greater than 0.1%), however, resulted in the formation of insoluble iron phosphates in the soil and, consequently, leaf chlorosis. This work provided the basis for the development of macadamia orchards not only in Hawaii, but also in Australia and other parts of the world.

Macadamias in Australia

It was not until the early 1960s, when the Hawaiian macadamia industry was already well established, that efforts were made to develop the indigenous macadamia as a commercial crop in Australia. Colonial Sugar Refiners (CSR) imported superior selections and technical expertise from Hawaii. Other large commercial operations were soon established, with income tax incentives for investment in the industry. Although CSR imported the best varieties
from Hawaii, it became obvious their performance was often disappointing and they were not necessarily well adapted to Australian conditions. It was widely acknowledged that local research was needed to select varieties better adapted to Australian conditions, and to similarly modify the Hawaiian cultural technology.

As in Hawaii, the Australian macadamia industry was fortunate in having a large number of enthusiasts and innovators who contributed to the improvement of the industry. The most prominent of these was Norm Greber, widely regarded as the founding father of the Australian macadamia industry. He was the first Australian to successfully graft macadamia and was engaged by CSR to help develop their macadamia nursery. Norm also propagated many trees in his backyard and selected superior cultivars, including ‘Own Choice’, ‘Own Venture’, ‘Renoun’, ‘Ebony’ and ‘Greber Hybrid’. He received life membership by both the Australian and the Californian Macadamia Societies for his contribution to the development of the macadamia industry and became patron of the Australian Macadamia Society.

Stan Henry, the CSR nursery manager, subsequently developed a novel punch budding technique using a modified, spent 0.303 brass bullet shell to remove an oval patch of bark from the rootstock that was replaced with a patch containing a single bud from the commercial scion. This rapid, effective technique gave CSR a considerable advantage over nurseries employing conventional grafting techniques. The success of punch budding was largely due to careful selection of budwood with bark that lifted readily. The CSR nursery supplied all the trees for the first large-scale commercial orchards at Baffle Creek, north of Bundaberg, Maleny, Peachester, Mt Bauple and Rockhampton, totalling over 1000 ha.

In the 1970s, the first commercial processing plant was established by CSR. Soon after, other factories were established by Suncoast Gold Macadamias and by the Macadamia Processing Co and Macadamia Plantations of Australia. Today, there are about 10 factories operating in Australia.

The Australian Macadamia Society (AMS). The macadamia industry in Australia is particularly fortunate in having forged a strong and effective organisation, the Australian Macadamia Society Limited (AMS). It was established in 1974 by a small group of enthusiasts eager to share the benefits of their experience and their innovative ideas. Ever since, it has responded to needs and opportunities across the whole industry. It fosters the dissemination of information through its bimonthly News Bulletin, website, MacGroup meetings, field days and annual conferences. These very effective and powerful extension functions complement services provided by State Departments of Agriculture. Perhaps the most significant initiative of AMS was the active encouragement of research into production, processing and promotion of the crop. Initially, research was funded from a voluntary levy. In 1993, a production levy, attracting a subsidy from the Commonwealth Government, was introduced. This intensified research activity and flow-on benefits to the industry. The industry levy is currently 25.21 cents/kg total kernel of which 17.4 c/kg is for product promotion and marketing, amounting to an annual budget of about A$2 million. A further A$2 million is invested in research each year, half of which comes from the Commonwealth Government as a matching dollar for dollar subsidy. Part of the levy is also used for regular chemical residue testing to maintain Australia’s reputation for producing high quality, quality-assured kernel.

Research in Australia

One of the great challenges was the selection of genetic material better adapted to Australian environments. In Hawaii, over 100,000 trees were screened to select the commercial cultivars which are widely used today whereas, in Australia, fewer than
20,000 seedlings have been screened. Two of Henry Bell’s Hidden Valley cultivars (A4 and A16) are registered under Plant Breeders Rights legislation and are widely grown commercially, together with subsequent releases. The AMS currently funds a major plant breeding program to develop superior cultivars for Australia. To assist in the search for, and development of, better adapted cultivars, the AMS has also provided funds to conserve a wide range of germplasm from native rainforests before they are lost forever by land clearing.

Early macadamia yields in Australia were generally quite low compared with those reported from Hawaii, although some trees approached the Hawaiian yield standard of 45 kg nut-in-shell. Yields of 30 kg are more common and productivity continues to improve steadily with better technology. It seems that one of the factors contributing to lower yields in Australia, and many other countries, is harsher environments with larger diurnal and seasonal variations in temperature than the mild, equable climate of Hawaii.

Understanding the influence of environment on macadamia growth and production was an essential objective of early macadamia research (and management). The mature macadamia is capable of withstanding mild frosts to as low as -6°C for short periods, but extended periods or lower temperatures may severely damage or kill mature trees. Even where trees survive, frosts may burn off inflorescences and thus seriously reduce cropping. Optimum temperature for tree growth and photosynthesis is about 26°C. Temperature is a major factor influencing vegetative flushing which, in turn, influences floral initiation, nut growth, yield and quality.

Most genera of Proteaceae grow only in climates where there is a long dry season. Drought, however, limits yield and results in small nuts with undeveloped kernels. Research at the Maroochy Research Station in a through-draining lysimeter showed that even mild stress during nut development, particularly the oil accumulation stage, adversely affected both yield and quality.

Fortunately, the macadamia has few serious disease problems and when these occur they tend to be localised. An example is a husk spot fungus (Pseudocercospora) which induces nuts to drop early in the harvest season before they are fully mature.

In Australia, its place of origin, the macadamia is attacked by more than 150 pest species, although parasites and predators usually provide considerable control. Insects which commonly reduce yields include macadamia flower caterpillar (*Homoeosoma vagella*), fruit spotting bug (*Amblypelta nitida*), banana spotting bug (*Amblypelta lutescens*), macadamia nuthborer (*Cryptophlebia ombrodelta*) and macadamia felted coccid (*Eriococcus ironsidei*). Any of these has the capacity, during severe infestations, to destroy the crop. An integrated pest management system for insect pest control has been adopted. Pest population levels are monitored in the orchard by pest scouts and chemical sprays are only applied when threshold pest population levels are reached. This approach maximises the contribution of natural enemies in suppressing pest populations below economic threshold levels. IPM has contributed to the profitability of macadamia growing.

Early nutrition work in Australia refined the Hawaiian standards to suit Australian conditions. It was found that small, frequent applications of nitrogen, for example, effectively restricted tree growth but actually increased yield and quality of nuts. Many of the soils on which macadamias are grown in Australia are low in boron and foliar boron sprays improve both yield and quality (kernel recovery). As in Hawaii, phosphorus deficiency limited yields on phosphorus-fixing ferrosol soils.

Because of the long break-even period (10-12 years) for a net return on money invested in macadamias, the Australian industry moved towards high-density plantings to
increase early cash flow. Mechanical pruning is used to maintain hedgerows and allow normal orchard operations such as spraying and harvesting.

The AMS responded to indifferent quality by adopting stringent quality standards and financial incentives to encourage growers to sort poor quality nuts from their consignments. This significant step has enhanced Australia's reputation on world markets as a supplier of consistently high quality kernel. The industry places a lot of importance on maintaining this reputation. It has developed a ‘Code of Sound Orchard Practices’ to help achieve this.

**Commercialisation**

World consumption of macadamias accounts for only about 2-3% of all tree nuts. For example, only 25,000 t of macadamia kernels is consumed compared with 650,000 t of almonds, 370,000 t of walnuts, 330,000 t of hazelnuts, 250,000 t of cashews, 200,000 t of pistachios and 110,000 t of pecans.

There is, therefore, considerable scope for expanding world markets. The USA is still the largest market for macadamias which are particularly popular in cookies (Fig. 1). Bakery products account for about 40% of world production. Another 35% is used as snacks, 22% is coated in chocolate, mainly for the Japanese market, and about 3% is used in ice cream. The Australian industry is actively investing in the promotion of macadamias to diversify its markets, particularly into Japan, Europe and Asia.

![Fig. 1. World macadamia consumption (t) (2003).](image)

Although Australia's production of macadamias was only about 25% that of Hawaii's in 1987, Table 1 shows that it is

**Table 1. World macadamia production and exports**

<table>
<thead>
<tr>
<th>Country or region</th>
<th>Area (ha)</th>
<th>Trees (000)</th>
<th>2003 production (t)</th>
<th>Kernel recovery (%)</th>
<th>Kernel exports¹ (t)</th>
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¹Estimate
²6,400 t of Australia’s production was exported as nut-in-shell in 2002–2003.
now greater, particularly the production of kernel. Australia has a considerable advantage due to a higher kernel recovery. Nearly half the world’s macadamia exports come from Australia. Massive expansion of plantings continues, particularly in Australia and South Africa. There are now over 5 million trees planted on 15,000 ha in Australia, with production valued at around A$150 M, at the farm gate.

The future

Macadamia plantations require a large capital investment and take several years to commence bearing. There is also the risk of declining prices with increasing world production, although this has not occurred yet. The industry’s investment in promotion and marketing will secure a sound future, despite competition from countries like Brazil with low production costs. The Australian industry has developed advantages in cultural technology through its investment in research.

This investment will continue to help overcome remaining constraints to productivity and profitability. The future success of the Australian macadamia industry is assured by the enthusiasm, cohesion and innovative spirit of all those who are involved in this young, dynamic industry.

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Health Benefits

Macadamias, like other nut crops, have a high oil content (>72%) and for a long time were considered by nutritionists to be less desirable in healthy diets. Research, dietary trials and population studies, however, demonstrate that macadamias contain a range of nutritious and health promoting constituents. These include monounsaturated fats, proteins, dietary fibre, minerals, vitamins, and phytochemicals.

The composition of both raw, dried and roasted macadamias typically contain:

- Natural oils: 75%
- Moisture: 1.5%
- Protein: 9.4%
- Dietary fibre: 7.7%
- Carbohydrates: 4.7%
- Mineral matter: 1.6% including Potassium, Phosphorus, Magnesium,
Calcium, Selenium, Zinc, Copper and Iron

- Vitamins: Vit. B1, B2, B5, B6, Vit. E, plus niacin and folate
- Phytochemicals: Antioxidants including polyphenols, amino acids, selenium and flavanols plus plant sterols
- Energy value: 3000 kilojoules per 100 g (727 calories)

Macadamias contain no cholesterol or trans-fatty acids. They do contain a higher percentage of monounsaturated oils than any other natural product. Macadamia oil is similar to olive oil in composition and use. Macadamias are low in damaging saturated fats and in polyunsaturated fats that oxidise readily. Diets containing moderate fat levels promote satiety and have been shown to be sustainable and enjoyable in the long term. The desirable Mediterranean Health Pyramid diet has 40% of the food energy from fat.

Separate dietary trials with macadamias in Australia and Hawaii have demonstrated a significant reduction in total cholesterol, total triglycerides and the undesirable low-density cholesterol, but little or no effect on the desirable high-density cholesterol. They, like many tree nuts, have been shown to lower blood pressure in hypertensive people and reduce the risk of heart disease. Current research includes a full biochemical analysis and nutritional profiling of macadamias and, in the USA, a phytochemical analysis is close to completion.

Producing trees may be found in Australia from Sydney in the south, to Cairns in the north. In California, they extend from Santa Barbara just north of Los Angeles to the Mexican border. Commercial plantings have also been established in South Africa, Malawi and to a lesser extent in Kenya in Africa and in the Central American countries of Guatemala and Costa Rica and in Brazil. The conditions in these countries may give an indication of the environmental range but not optimum production.

The environment of native macadamia stands in Australia

The environment in which macadamias grow is not necessarily a good indication of optimum conditions. In the wild, macadamias grow as understorey trees in coastal and subtropical rainforests. *Macadamia integrifolia* is found on the eastern slope of the Great Dividing Range to an altitude of 300-400 metres. Distribution is from Mt Bauple in Queensland on the lower Mary River, near Maryborough, south to lower Beachmont or the Numinbah Valley, a distance of about 440 km: latitudinal range approximately 25° to 28°S. *M. tetraphylla* is found in similar country but extending further south from the Coomera River near Mt Wongawallen, and the Nerang River near Advance Town in Queensland to the Richmond River near Casino and Lismore in N.E. New South Wales, a distance of 120 km: latitudinal range approximately 28° to 29°S. At a point where these species meet, natural hybrids between the two species occur.

The macadamia tree has several features suggesting adaptation to relatively harsh environments, including sclerophyllous leaves and dense clusters of fine, proteoid roots which develop to enhance nutrient uptake from poor soils, particularly those low in phosphorus. The conditions required for optimum production, however, are quite different from those for survival.

Soils

Macadamia is adapted to a wide range of soils but heavy, impermeable clays and saline or calcareous soils are unsuitable. The trees are most suited to deep, well-drained soils with good organic matter content (3-4% carbon), medium cation exchange capacity (10-15%), and pH of 5.0 to 5.5. Macadamias may in fact be adapted to pH as low as 4.5. They do not perform well on alkaline or calcareous soil. Common nutrient deficiencies that limit growth, yield and quality are nitrogen, potassium, phosphorus, magnesium, calcium, zinc, copper, and...
boron. High levels of soil P, high Ca and high pH may all induce Fe deficiency and impede the uptake of other nutrients.

**Temperature**

Temperature has the major influence on macadamia performance and kernel quality. The mature macadamia tree is able to withstand frost for short periods to as low as -6°C, and slightly lower for *M. tetraphylla*. In practice, however, commercial trees should not be planted in frost prone areas as young trees and flowers may be killed and the trunks of mature trees may also be damaged. The incidence of frost is likely to jeopardise the commercial viability of macadamia orchards.

Glasshouse experiments have shown that the threshold temperature for macadamia growth is between 10-15°C, the greatest growth occurring at 26°C. At a constant 30°C macadamia leaves become chlorotic and distorted, indicating sensitivity of macadamias to high temperatures. The young flush growth of one variety, 781, becomes chlorotic under summer temperatures in SE Queensland.

Mean temperatures do not give the full story as the temperature extremes often have a strong influence on macadamias. At Kona in Hawaii, which is considered an ideal climate for *M. integrifolia* production, the normal minimum diurnal range is 10°C and the maximum temperature recorded is 31°C and the minimum 9°C. At Nambour in Queensland, where macadamias are grown, temperatures may reach 40.5°C and frosts occur in lower exposed sites.

Allen (1972) concluded that mean summer temperatures of around 26°C with minimum temperatures not exceeding 38°C and the absence of frosts would give good production. The best production areas in Hawaii are those where the temperatures rarely exceeds 32°C. In Australia many commercial orchards consistently experience some 35°C-35°C days and still produce reasonable crops, although high temperatures probably limit yield or quality. Some varieties develop leaf chlorosis and necrosis on the northern side of the canopy during summer.

The actual temperature occurring at vital phenological stages of the plant's annual cycle can be critical. In Hawaii, Nakata showed that night temperature influences floral development in *M. integrifolia*. Floral initiation occurred at 12, 15, 18 and 21°C, while 18°C resulted in the production of most racemes. Initiation in Queensland occurs in April when night temperatures fall well below this and consequently flowering is often excessive compared with that observed in Hawaii, possibly being wasteful of stored tree reserves, potentially limiting nut development.

In South Africa, extensive plantings have been established south of the Tropic of Capricorn in the hot Lowvelt at an altitude of approximately 200 metres. This area has a strong continental climate and often experiences high temperatures, and drying winds.

**Altitude**

In the tropics (15°N to 15°S), the required temperature range for macadamias can be achieved at higher altitudes, eg 1600 m in Kenya, 1300 m in Malawi, 800 m in Guatemala and 700 m in Costa Rica. Productivity, however, has been low at the sites below 1000 m. In Hawaii, macadamia orchards occur from just above sea level up to about 800 m but production is lower at the higher altitudes. Apart from the temperature effect, heavy cloud cover and frequent rain is believed to restrict photosynthesis and hence slow down tree development and reduce productivity at high altitudes.

**Rainfall**

The high productivity of nuts in Hawaii is correlated with well-distributed rainfall exceeding 2000 mm. Storey (1969) estimated that the minimum water
requirements for macadamia is about 1000 mm well distributed annually. Under Australian conditions, precipitation is low in late Winter/Spring (July-November) when flowering, nut set and early nut development occurs. These conditions are not considered ideal for macadamia production, another reason why the environment of origin should not be accepted as ideal for a crop.

In both Australia and Hawaii, yield responses to irrigation have been achieved in some years but not in others. Yield increases were related to number of nuts whereas Radspinner (1971) showed a correlation between rainfall and nut size. Thus, irrigation is desirable in some years in localities with less than 2000 mm annual rainfall which is unequally distributed.

Lysimeter work showed differences in sensitivity of phenological stages to mild stress. Stress during the dormant, vegetative stage when floral induction occurs is relatively tolerant of mild stress whereas nut development stages, and particularly the later stages of oil accumulation, are very sensitive to even mild water stress which restricts oil accumulation and results in low yields of very low quality kernel. Irrigation can be applied to alleviate stress at this critical stage of nut development.

Macadamia produces dense clusters of proteoid roots which are adapted to poor soils. They effectively increase root surface area for maximum absorption of water and nutrients. These contribute to enhanced tree survival during extended dry periods.

Salinity

Adverse effects due to high salinity have been noted in the field. Symptoms include chlorosis of foliage and marginal necrotic areas and a lack of vigorous growth particularly at the tips. Irrigation of macadamias with brackish water (2400 ppm total soluble salts) in Hawaii over an 8-year period had no apparent adverse effects on tree growth, yield, or production efficiency (yield per unit tree trunk area). An increase in the percentage of immature kernels, however, appeared to have been correlated with saline irrigation water (5% immature kernels compared with 1-3% irrigated with fresh, non-saline water). This level of immaturity is still considerably less than the 12% produced by unirrigated trees, but is still economically significant. Nevertheless, the impact on oil production during the final stages of kernel development may be an early indication of salinity stress.

Wind

Macadamias are very susceptible to wind damage. Growth rate in young plants is significantly reduced by damage to new vegetative flushes, potentially delaying commercial cropping by 1-2 years. Mature trees suffer loss of large limbs and in shallow soils or soils which restrict root penetration, the whole tree may be lost. Such losses significantly reduce yields but where large limbs are lost, they usually recover in 1-3 years. Locating orchards in areas subject to cyclonic and other violent wind storms is risky. In exposed trees, flowering and nut set may be affected by strong winds but once the orchard canopy develops, only external trees are at risk. Windbreaks are an effective measure to overcome the problem during the early establishment years.

Tree training may reduce susceptibility to limb breakage. Branches with to narrow crotch angles are most susceptible to splitting as are nodes with multiple branches. Tree training to a central leader should commence in the nursery to avoid later problems in the field. Pruning can only be economically carried out in the first 2-3 years of establishment to remove poorly developed limbs. Excessive pruning reduces growth rate and may increase time to commercial production. It is desirable to select varieties that have better tree structure and wide crotch angles which reduce the need for tree training to a minimum.
Humidity

Although humidity was not considered to be important for macadamias in Hawaii, it can be important in harsher environments such as those in Australia and South Africa. Excessive evapotranspiration under dry conditions will exacerbate stress. Excessive rain at flowering reduces pollen viability and hence pollination. High humidity at this critical stage can promote the development of flower blight (Botrytis) which also destroys flowers resulting in little or no nut set, and anthracnose (Colletotrichum) and husk spot (Pseudocercospora) which can reduce both yield and quality. Thus, areas with misty, foggy conditions during the flowering-early nut development stages should be avoided.

Light

Radspinner (1971) also found that rainfall in the two month period prior to flowering in Hawaii resulted in smaller nuts, presumably due to reduced light inception under cloudy conditions, and hence reduced photosynthesis and reduced production of carbohydrate.

Although the photoperiodicity of the macadamia is not confirmed, it is probably a short day (or long night) plant initiating flowers in autumn. However, temperature also has an influence.

The normal pattern is for initiation of inflorescences to occur in autumn and the floral buds to stay dormant until early spring when they all develop rapidly. In some areas such as Cairns (19°S) (or in warm autumn conditions) many floral buds, although initiated in autumn, develop soon after, producing an ‘out-of-season’ flowering. Mean monthly temperatures from June to August in Cairns are about 22°C. Temperature conditions are similar in Hawaii where flowering is spread over many months. Extended and poor flowering is reported from tropical areas but this is generally undesirable as the spread of the cropping season makes insect and disease control more difficult and increases harvesting costs. The spread of maturity also increases the chances of quality deterioration.

Since temperature has a bigger influence on flowering than light, as long as altitude can provide the required temperature range, cropping may be possible well into the tropics, irrespective of day length.

Extending the climatic adaptation of macadamias

Commercial production based on processing, relies on a uniform product of high quality. The world wide market for macadamias draws on product from various countries so it is essential that varieties have acceptable processing and quality characteristics. For consistency, particularly for the processed product, it is important to use the accepted M. integrifolia and only those interspecific crosses that satisfy commercial requirements. M. tetraphylla is an excellent tasting nut but contains residual sugars that are not present in M. integrifolia. On roasting, these sugars caramelise, giving the kernel a burnt, unattractive brown colour. This is the reason tetraphylla kernels are not commercially acceptable. They are widely grown in California, however, largely for the fresh table market. This species is adapted to cooler climates and can therefore help extend the production area (subject to market/processing requirements). There may also be opportunities to select varieties (including hybrids) that are tolerant to either hot or cold conditions.

Summary of environmental requirements

It is apparent that an equitable climate is more desirable than one of extremes, with a practical range of 0-38°C and a desirable range of 10-30°C. The most desirable level for flower initiation in April coincides with 15°C nights and nut development, with a mean daily temperature of ca. 25°C. Areas with prolonged high humidity, excessive rain or mist at flowering should be avoided.
Water requirements are fulfilled by 2000 mm equitably distributed throughout the year, although this is not important after the nuts are mature in March, particularly the dormant period 2-3 months prior to flowering (June-August). This dormancy is also under control of temperature and mean monthly temperatures of 22°C and higher at this time can result in erratic, out of season flowering. Sites at altitude may be suitable where the temperature range is satisfactory. However, they should be avoided where prolonged overcast or misty conditions occur during flowering. Windy or exposed sites should be avoided and windbreaks provided to give protection during establishment. With the exception of heavy, impermeable clays, macadamia is adaptable to a wide range of soils provided water and nutritional requirements are supplied.

**Conclusions for PNG**

Macadamias would be restricted to intermediate altitude locations in PNG.

The highly sophisticated production systems used for commercial development in Australia and elsewhere are probably not appropriate in PNG.

Insects limit commercial production in many parts of the world so good management of pests and diseases is important for ‘commercial’ production to be reliable. Rats are also frequently a problem.

There is a considerable amount of information available, based on commercial experience and research, and this could be applied to growing macadamias in PNG.

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Davenport, E.R. (?) Macadamia Activity, CSR Limited, Brisbane, Queensland
Table 1  MONTHLY MEAN TEMPERATURE DATA FOR AUSTRALIAN, HAWAIIAN AND CALIFORNIAN SITES

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Hilo temperatures represent the high and Mountain View the lower temperature range for macadamia production on the island of Hawaii.
### MONTHLY MEAN RAINFALL DATA FOR AUSTRALIAN, HAWAIIAN AND CALIFORNIAN SITES

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<th>March</th>
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<th>June</th>
<th>July</th>
<th>August</th>
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<th>October</th>
<th>November</th>
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<th>April</th>
<th>May</th>
<th>June</th>
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<th>August</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>Annual</th>
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<td>275</td>
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<td>504</td>
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<td>25.0</td>
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<td>2.5</td>
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</tbody>
</table>

*Months have been offset by 6 months for Hawaii and California to allow direct comparison of temperature and rainfall figures on a seasonal basis.
Outcomes of the Papua New Guinea Fruits and Nuts Workshop

Compiled by Mark Johnston

Introduction

Thirty six participants attended the fruits and nuts workshop that was held at the IATP Community Resource Training Centre, University of Vudal on the 11-13th October 2005. The participants included representatives from private industry, NARI, FPDA, CCI, University of Vudal, James Cook University, Australian National University, QDPI&F, ACNARS, IATP and farmers. A list of the participants and their contact details is presented in Annex 1.

The objectives of the workshop were to:
1. To review the current status of fruit and nuts in PNG
2. To identify the fruits and nuts (introduced and indigenous) with development potential in PNG
3. To determine the future development and research needs of fruits and nuts identified above.

The workshop programme had a number of broad topics with a plenary discussion following each. The broad topic areas covered were:
- Introduction and background
- Introduced fruit
- Indigenous fruit
- Introduced nuts
- Indigenous nuts
- Summary and action plan

This report presents a summary of the recommendations formulated during the plenary sessions.

Identification of the fruit and nut species with development potential in PNG

During the plenary sessions the workshop participants identified priority fruit and nuts species where they felt big impacts could be gained through research and development interventions.

Indigenous Nuts

A number of indigenous nut species were identified as having a big potential for development. This is initially for the domestic market and later for high value export markets. The nuts identified as having the biggest potential for development and commercialisation in PNG were the indigenous nuts galip, okari and pao for the lowlands and kuruka in the highlands. Aila, talis and breadfruit nut were also identified as having potential for domestication. However it was thought that their potential would be less than for galip, okari or pao, at least in the medium-term.

Introduced Nuts

The introduced nuts with development potential were identified as cashew and macadamia for niche locations in the lowlands. Potential locations for cashew are in seasonally dry areas, including coastal Central Province, southern Western Province, Markham Valley, Ramu Valley, Sepik Basin and the Sialum area on the Huon Peninsula. For macadamia, the potential growing areas are highland valleys at altitudes around 1200-1600 m above sea level.

Indigenous Fruits

Taun was also identified as an indigenous lowland fruit that had very good potential for domestication and commercialisation. It was thought to have a similar potential to rambutan if domesticated.

The domestication and commercialisation of the indigenous fruit marita may also have a big impact in the highland. However before commercialisation could be done, the market potential of marita as fresh fruit, for oil or
down stream processed products such as sauce needs to be established.

The potential of other indigenous species (such as wild mango and mon (Dracontomelon dao) for domestication were debated. It was concluded that more information on these and other indigenous species is required before an informed discussion could be made. The workshop participants recommended there is a need to study the botany and gather basic information on the lesser known indigenous species of fruits and nuts in order to assess their future domestication potential.

**Introduced Fruits**

For the introduced fruits the participants were requested to list up to five fruit species for both the lowlands and the highlands that they thought would have the most developmental potential. These results are presented in Table 1 and 2.

**Table 1. The number of times an introduced fruit species was listed by participants as having potential for development in the lowlands**

<table>
<thead>
<tr>
<th>Introduced Fruit</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mango</td>
<td>15</td>
</tr>
<tr>
<td>Rambutan</td>
<td>14</td>
</tr>
<tr>
<td>Durian</td>
<td>13</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>13</td>
</tr>
<tr>
<td>Carambola</td>
<td>9</td>
</tr>
<tr>
<td>Pawpaw</td>
<td>5</td>
</tr>
<tr>
<td>Pineapple</td>
<td>4</td>
</tr>
<tr>
<td>Banana</td>
<td>4</td>
</tr>
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<td>Citrus</td>
<td>2</td>
</tr>
<tr>
<td>Abiu</td>
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</tr>
<tr>
<td>Banana (cooking)</td>
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</tr>
<tr>
<td>Passionfruit</td>
<td>1</td>
</tr>
<tr>
<td>Jackfruit</td>
<td>1</td>
</tr>
<tr>
<td>Asian fruit</td>
<td>1</td>
</tr>
<tr>
<td>Mandarin</td>
<td>1</td>
</tr>
<tr>
<td>Orange</td>
<td>1</td>
</tr>
<tr>
<td>Pulasan</td>
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</table>

The fruit with the most potential in the lowlands were identified as mango, rambutan, durian, mangosteen and carambola (Table 1).

For the highlands citrus, particularly mandarin, was identified as the fruit with the most potential for development especially in the 600-1200 m altitude zone. Other fruit identified with good development potential for the highlands were avocado and banana. There was a group of other species identified by some participants as having some potential but this was not as clear cut as for the lowlands (Table 2).

**Research and development needs for particular species**

Table 2. The number of times an introduced fruit species was listed by participants as having potential for development in the highlands

<table>
<thead>
<tr>
<th>Introduced Fruit</th>
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</thead>
<tbody>
<tr>
<td>Citrus (mandarin and orange)</td>
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</tr>
<tr>
<td>Avocado</td>
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</tr>
<tr>
<td>Banana</td>
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<tr>
<td>Sugar fruit</td>
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</tr>
<tr>
<td>Passion fruit</td>
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</tr>
<tr>
<td>Pineapple</td>
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</tr>
<tr>
<td>Strawberry</td>
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</tr>
<tr>
<td>Apple</td>
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<tr>
<td>Berries</td>
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<tr>
<td>Pepino</td>
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</tr>
<tr>
<td>Guava</td>
<td>1</td>
</tr>
<tr>
<td>Custard apple</td>
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</table>

**Indigenous Nuts**

The indigenous nuts identified as having the biggest potential for development and commercialisation in PNG were galip, okari and pao for the lowlands and kuruka in the highlands. Aila, talis and breadfruit nut were also identified as having potential for domestication. However it was thought that their potential would be less than that for the above nuts, at least in the medium-term. The nuts ranked in order of development potential were galip, okari, pao, aila, talis and breadfruit nuts. The development potential of galip, okari and pao were thought to be fairly similar.
Galip
Galip is one of the nut species currently being researched by NARI. There is still much more research needed on domestication and commercialisation of the nut. The proposed ACIAR project will contribute to the domestication of galip by conducting tree characterisation and selection in the Islands Region; developing vegetative propagation techniques; germplasm collection and evaluation; promotion of the potential. The project will provide village based training on vegetative propagation and tree selection techniques.

There is a need to extend the activities being conducted under the ACIAR-funded project in the Islands Region to the areas of the mainland where galip grows (lowlands of Momase Region).

In addition to the activities planned in the ACIAR project, nut cracking and post harvest handling, storage, processing and packaging are areas that require significant work in order to commercialise the product.

Marketing information and promotion networking is needed for galip. The feasibility of producing other products such as oil for antiinflammatory uses, cosmetics, health products, and cooking needs to be examined.

Opportunities also exist for a regional approach to galip domestication and commercialisation particularly with marketing. A regional marketing strategy and the gathering and sharing of knowledge were proposed. There is also a need for the proposed ACIAR project to adopt a regional approach so as to include Solomon Islands and Vanuatu.

There is a need to conduct farming systems research to examine the ways in which galip can be effectively integrated into existing systems. This is particularly relevant for cocoa so as to replace the existing shade species of coconut and gliricidia which have little or no economic value respectively.

Okari, pao, aila, talis and breadfruit nuts
It was noted that okari distribution is mainly limited to the island of New Guinea. It is a well accepted nut and has good potential to be commercialised. Pao is indigenous to the Islands Region and is rarely known on the mainland but still has good prospects for domestication and commercialisation.

A domestication and commercialisation process is also needed for okari, aila, talis and breadfruit nuts. This will involve the following: review of existing information, wild and semi-domesticated resource identification and characterisation, participatory ethnobotanic studies and socio-economic evaluation, market research, germplasm collection evaluation and selection, developing vegetative propagation techniques, promotion and outreach and liaison, market development and the integration of these species into existing farming systems.

Karuka
It was noted that karuka had the potential to diversify the income earning potential in highlands areas where there are currently not many other options for villagers to obtain a cash income, particularly in the remote high altitude areas. The research and development requirements to establish a karuka industry identified were: a review of existing information, basic productivity studies, market demand and supply studies, assess potential uses and downstream processing potential, characterisation and measure variability available for selection, promotion of selected varieties, develop mass vegetative propagation methods, and determine kernel extraction and post harvest handling and storage techniques.

Introduced Nuts
Cashew
Cashew was identified as having development potential in the lowlands particularly in the seasonally dry areas (coastal Central Province, southern Western Province, Markham and Ramu valleys, the Sepik Basin and Sialum area of the Huon
Peninsula) where there are limited cash crop opportunities. It was noted that there is already one commercial cashew producer in Central Province. Others such as Ramu Sugar are interested in commercially producing cashew nut.

The main development needs at this stage are the distribution of planting materials to farmers for village testing and home industry training for local processing. Cultivars also need to be developed for both nuts and fruit production. (The use of the cashew apple is often overlooked during cultivar selection but it can be important to smallholders).

Macadamia
The performance of macadamia should be tested in the certain highlands locations particularly focusing on the highland valleys 1200-1600 m above sea level. Prior to this a range of promising new varieties should to be imported, multiplied and distributed to co-operators for village testing and evaluation in a number of locations and environments. The results of the evaluations will indicate what the potential of macadamia in PNG is likely to be.

Indigenous fruits

Taun
Taun was identified as the main indigenous fruit with potential for domestication and commercialisation. This will involve the following: review of existing information, wild and semi-domesticated resource identification and characterisation, participatory ethnobotanic studies and socio-economic evaluation, market research, germplasm collection evaluation and selection, developing vegetative propagation techniques, promotion and outreach and liaison, market development and the integration of taun into existing farming systems.

Wild mango and mon
The potential for domesticating wild mango and mon also should be assessed by wild and semi-domesticated resource identification and characterisation, participatory ethnovenic studies and socio-economic evaluation and market research studies.

Marita
For marita it was recommended that market demand studies and the potential of downstream processing into products such as sauces and information on the chemistry of the fruit oil and its market potential should be determined in order to assess its development potential.

Introduced fruits

Lowland introduced fruit
The development and promotion of fruits should focus on the agro-ecological zone best suited for the crop in locations where there is good market access. For mango, development and promotion should focus on locations in the seasonally dry climatic zone that close to the potential markets such as the costal areas of Central Province and the Markham valley. For rambutan, durian, mangosteen and carambola, the locations to focus development on should be the lowland areas without a severe dry season that are close to or have good access to the major markets especially the Port Moresby and highlands markets.

The research and developments requirements for the five species were identified as being fairly similar and are:

- Undertake a review of literature and past work.
- Determine the market demand, potential and requirements for the different fruits and their downstream processed products.
- Identify the long-term market that the industry will target and evaluate the cultivars for their acceptability to this market.
- Evaluate and assess the cultivars currently available in the country and identify potential new clones for importing and evaluation. (Cultivar evaluation is not necessary for mangosteen as its seeds are apomitic
and all plants are thought to be the one clone).

- Assess and selected cultivars on their product quality, yield performance, pest and disease resistance and their potential to extend the production season (early, late or out of season varieties).

- Develop crop management practices and recommendation packages (including agronomy, pest and disease control practices and post harvest handling and processing) based on experience both within PNG and adopted from overseas industries.

- The commercial evaluation of the cultivars and production packages with farmer co-operators and other relevant stakeholders.

- Develop efficient clone production techniques.

- Supply of selected clones to commercial nurseries for multiplication for farmers.

- Outreach and liaison, the distribution of recommended clones and information to stakeholders.

The workshop suggested that the focus should be on one or two species at a time in major agroecological zones.

**Highlands introduced fruits**

**Citrus (mandarin and orange)**

It was recommended that the focus for citrus development in the highlands be in the mid-altitudinal zone (600-1200 m asl) where citrus produced the best quality fruit have a good access to markets. This zone is between the highlands and the lowlands. Locations include, for example, Mumeng and Bulolo in Morobe Province and the Kokoda Track area of Central Province.

The research and development requirements identified for citrus in the highlands were:

- Undertake a review of literature and past work

- Identify locations with good altitude and other growing conditions close to markets

- Determine the market demand, potential and requirements for mandarins and oranges and their downstream processed products.

- Identify the long-term market that the industry will target (fresh fruit, juice etc) evaluate the cultivars for their acceptability to this market.

- Evaluate and assess the citrus cultivars currently available in the country and identify potential new clones for importing and evaluation.

- Assess and selected cultivars on their product quality, yield performance, pest and disease resistance and their potential to extend the production season (early, late or out of season varieties).

- Conduct fertiliser and crop nutrition studies for the selected cultivars.

- Develop crop management practices and recommendation packages (including agronomy, pest and disease control practices and post harvest handling and processing) based on experience within PNG and information adopted from overseas industries.

- The commercial evaluation of the cultivars and production packages with farmer co-operators and other relevant stakeholders.

- Supply of selected clones to commercial nurseries for multiplication for farmers.

- Outreach and liaison, the distribution of recommended clones and information to stakeholders.

**Avocado**

For avocado in the highlands the participants felt there was probably only limited potential for intervention and mainly for development issues. Development needs are: market demand, post harvest handling studies, and an assessment the economics of other uses for the fruit such as oil extraction.
**Banana**

The main development issues identified for banana in the highlands were post harvest and handling problems for domestically marketed fruit for both cooking and ripe bananas. Development issues and threats due to fruit fly, black sigatoka and blood disease were raised. The potential for exporting cooking bananas, particularly to New Zealand, and the market requirements should be further investigated.

**Strategies and principals**

The workshop identified the following strategies and principals that should be used to guide fruit and nut research and development activities.

- To initially target the domestic markets, then to develop export markets later
- To focus development in areas that are close to or have good access to markets
- For all species use village farmers and agribusiness co-operators in all stages of industry development particularly the evaluation of imported and selected germplasm and propagation techniques. Co-operators should receive materials for evaluation as soon as possible after they are introduced or identified as having potential.
- Use networks with NGOs and other organisations with people on the ground in the development process
- The promotion of a new species should include a package that includes the recommended cultivars, agronomic and post harvest techniques to be followed and market and quality standards.
- Improved and recommended cultivars need to be distributed to farmers and stakeholders for further multiplication.
- The development of commercial nurseries need to be encouraged throughout the country
- Any development and promotion of fruits or nuts should focus on the agro-ecological zone best suited for the crop in locations where there is good market access.

**Overarching issues**

The production and distribution of clonal planting materials of fruits and nuts is an overarching issue that was highlighted during the workshop. This is an issue at all levels from the research institutions to the farmer level.

It was felt that one of the greatest constraints limiting the development of fruits and nuts was the capacity of NARI to clonally propagate material both for its own research and initial distribution to co-operators. There is also a lack of private entrepreneurs and commercial nurseries to further clone the materials released from NARI so they are accessible to the farmers. Commercial nurseries need to be located in strategic locations for the farmers. There is a need to provide village based farmer training on propagation techniques to allow farmers to multiply recommended cultivars distributed from research institutions or commercial nurseries and their own tree selections. The availability of superior clones to farmers is the key to any fruit and nut development.

Another issue identified was the lack of fruit and nut research being conducted in the lowlands and the highlands on the New Guinea mainland. This was noted as a concern as these are many locations with good access to the main domestic markets where many fruit and nut species grow well.

**Action plan**

An action plan was devised to implement the recommendation from the workshop. The participants were divided into two groups and were asked how to best advance the development of fruits and nuts in PNG to ensure the best return on resources invested. They were asked how to progress the issues that were considered to be a very high priority. The groups were asked to first consider the general plans needed to
progress fruit and nut development and then to consider specific interventions needed to deliver maximum impact. The conclusions from the groups were combined and similar actions combined. The participants where then asked to vote on the actions they felt would have the most development impact. Each participant was given up to seven votes each. Results form this plenary session are presented in Table 3.

The activities mentioned in the action plan are a mix of general activities which will be applicable to all fruits or nuts, but there is a need to address specific activities for each species. The general plan activities tended to receive higher scores than the specific activities as the general activities tend to address needs of different species. For example the introduction of new cultivars and their evaluation with co-operator farmers would require the specific activity of improving NARI nursery capacity to produce clones for distribution.

It was also recommended that Sim Sar and Mark Johnston report in person on the workshop outcome to senior staff in a number of public institutes in PNG. These include the Department of National Planning and Monitoring, National Agricultural Research Institute, Department of Agriculture and Livestock, Fresh Produce Development Agency, Coffee Industry Corporation, Oil Palm Research Association, Oil Palm Industry Corporation and other implementing agencies.
<table>
<thead>
<tr>
<th>Table 3 Priorities for an action plan for fruit and nut development in Papua New Guinea</th>
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<tbody>
<tr>
<td>1. <strong>Village propagation</strong> - training villagers in vegetative propagation techniques to enable them to multiply improved varieties and farmers selections.</td>
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<tr>
<td>2. <strong>Village and commercial nut crackers</strong> - Identify what is available; assess and promote hand and motor driven machines.</td>
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<tr>
<td>3. <strong>Increase resources devoted to fruit and nut research and development</strong> - Encourage NARI to increase the resources including funding, personnel and other resources to enable expansion into the priority areas of fruit and nuts research.</td>
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<tr>
<td>4. <strong>Port Moresby market survey</strong> – Identify needs and limitations and develop programme to address the individual crops such as banana, guava, out of season pineapple, avocado, passionfruit, berries – assess demand by ethnic and regional groups.</td>
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<td>5. <strong>Review current knowledge</strong> - Review of literature on indigenous fruit and nuts.</td>
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<tr>
<td>6. <strong>Introduction of new cultivars</strong> - Introductions and evaluation of superior fruit and nut germplasm for evaluation in a range of environments in partnership with farmer co-operators.</td>
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<tr>
<td>7. <strong>Match crops with the environment</strong> – Promote village and commercial production of fruit and nut species with a specific regional focus, for example, cashew for dry lowlands, macadamia for highland valleys 1200 to 1600 metres, mangoes in the seasonally dry lowlands.</td>
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<tr>
<td>8. <strong>Improve linkages in the market chain</strong> – Linkages need improving between producers, transporters marketing people and research and development organisations at an early stage of industry development.</td>
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<td>9. <strong>Small scale processing</strong> – to avoid perishability, transport, storage and quarantine issues.</td>
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<td>10. <strong>Evaluation of mango cultivars</strong> – evaluate and promote new and improved mango cultivars with NARI and DAL in partnerships with co-operators with a focus in coastal Central Provinces and Markham and Ramu valleys.</td>
</tr>
<tr>
<td>11. <strong>Improve NARI capacity for fruit and nut propagation</strong> – One of the greatest constraints limiting the development of fruit and nuts is the capacity of NARI to clonally propagate material for distribution to co-operators. This needs to be substantially improved for NARI to have an impact.</td>
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<tr>
<td>12. <strong>Promotion of fruits and nuts</strong> – Promotion of the importance and potential of fruits and nuts is needed. This should be done in conjunction with the industry entrepreneurs and co-operators. This it is an integral part of the industry component development.</td>
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<tr>
<td>13. <strong>Integration of fruits and nuts into cash cropping systems</strong> - Intercropping fruit and nut trees as shade species to replace coconut and gliricidia.</td>
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<tr>
<td>14. <strong>Determine the potential uses for marita pandanus</strong> – determine oil quality and assess its production feasibility and potential for cosmetics, pharmaceuticals and cooking. Assess the feasibility of sauce production.</td>
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Annex 1

<table>
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Workshop Proceedings

1. Proceedings of the NARI Poultry Workshop


3. Highlands Horticultural Workshop Proceedings

4. Proceedings of the Cassava Workshop

5. Report on Women's Voices in the Food Chain: Shouts and Whispers from PNG Women in the Natural Resources Sectors, Volume 1
   Proceedings on Women's Voices in the Food Chain: Shouts and Whispers from PNG Women in the Natural Resources Sectors, Volume 2

6. Proceedings of the Pig Production Research and Development Workshop

7. Proceedings of the National Rabbit workshop

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