

Specialty Crops for Pacific Island Agroforestry (<http://agroforestry.net/scps>)

**Farm and Forestry
Production and Marketing profile for**

Coconut

(Cocos nucifera)

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USES AND PRODUCTS

Except for the fairly recent commercialisation of coconut water from immature fruit, the principal products of the coconut palm come from the whole mature fruit: the husk fibre for ropes and mats (geotextiles, woven from coconut fibre, are used to stabilise fragile soils); the shell for charcoal (excellent for activation); and the kernel for oil (emulsified as cream or milk). Desiccated coconut was developed in the late 19th century (after 1895) and husk cortex (cocopeat) in the mid 20th century (after 1949). Copra (dried kernel) was the major item on international markets for much of the 20th century, as a source of oil for food preparation, candle, and soap making and glycerine for high explosives. Traditional uses, that are less important in a global context, include toddy (sap, from which sugar is crystallised by boiling or alcohol or vinegar are fermented); leaves woven for baskets and for shelter (atap), or for hats and party skirts; frond stems and dry bunch stalks for fuel; shell for cups, curios, and buttons; and structural and ornamental timber from the trunk. Two uses that may have future commercial prospects are coconut oil as a supplement or replacement for petroleum-based fuels, and heart of palm.

For the past 150 years, the primary cash-earning product has been copra, the dried kernel, from which coconut oil is extracted. Coconut oil was important as a raw material for candles, soaps, shampoos, body lotions, and even for nitroglycerine explosives. Coconut oil, emulsified as milk or cream, together with desiccated kernel, is also an ingredient in bakery, confectionery, and dairy products. Recent technology known as Direct Micro Expelling (DME) for extracting oil mechanically from coconut at the village level is being established in the South Pacific. The DME method requires a modest investment in equipment to shred the

Exports of Coconut oil 2007 (provisional data from Cocioinfo International, Vol 15, July 2008)

Country	Exports in metric tonnes (MT)
Fiji	5,503
India	3,677
Indonesia	739,923
Malaysia	130,000
Marshall Islands	5,608
Papua New Guinea	53,482
Philippines	886,561
Samoa	500
Solomon Island	5,000
Sri Lanka 2300	2,300
Thailand	500
Vietnam	N/A
Vanuatu	3,000

kernel from the opened nut, dry it to a specified degree, and press out clear “virgin” oil in about 1 hour.

In Indonesia and Philippines, a traditional method of fermenting coconut milk for 24 hours to allow breakdown of the emulsion and natural separation of oil has also been commercialized to supply growing local and export markets that recognise the nutraceutical benefits of virgin coconut oil. There is little difference in the chemistry of virgin coconut oil (VCO) and RBD (refined, bleached, and deodorised) oil derived from copra, but the clarity, gentle aroma, absence of any free fatty acid, and lack of any browning endow VCO with a high status in the health food market.

In some isolated locations, where imported diesel fuel is very expensive, raw and esterified coconut oil has been adopted as an accessible alternative. It is unlikely to be exported for this purpose, however, because biodiesel from African oil palm or other vegetable oils is cheaper to produce.



Left: Copra drying in the village of Hanaiapa, island of Hiva Oa, Marquesas, French Polynesia. Right: Young coconuts trimmed of their husks sold for drinking in Apia, Samoa.



Left: Coconut fibre cordage is very durable in marine uses. Right: Commercial coconut oils sold in a Hawai'i health food store.

Coconut milk and cream obtained by grating and pressing fresh kernel are consumed daily as ingredients in fish, grain (e.g., rice), and root (e.g., taro, cassava) dishes, both in subsistence, and, increasingly, in cosmopolitan cuisine.

Coconut water in the immature fruit is a safe, sweet, and refreshing drink that can be particularly important where fresh water is scarce. Used for medical and athletic rehydration it is now commercially available in cans, bottles, or naturally “packaged” trimmed fruit.

Coconut fibre has been valued traditionally for twine and rope making, mats, mattresses and upholstery. It is especially resilient in maritime uses. New products include geotextiles that comprise coarse nets of coconut twine that help to stabilize soil on steep slopes. The dust-like cortex from between the fibres in the coconut husk is now marketed as cocopeat, which performs as water “sponge” in horticultural potting mixes. Once seen only as a waste product, it is a sustainable alternative to peat moss from irreplaceable wetlands.

Coconut shells have obvious uses as cups and containers but can also be burned, as is often done when drying copra. Shells are converted to charcoal by farmers, especially in Philippines and Indonesia, and then further processed to activated charcoal in large regional factories. The high quality of activated coconut shell charcoal makes it ideal for air filtration and the separation of gold from its mineral matrix.

Scale of commercial production worldwide

Data for total production that includes all local consumption are not available. An estimate of six nuts per household per day has been made for domestic consumption in coastal Melanesia.

NOMENCLATURE

Preferred scientific name and author

Cocos nucifera L

Family

Arecaceae (palm family)

Subfamily

Arecales; Arecaceae; Arecoideae; Cocoseae; Attaleinae; Cocos

Non-preferred scientific names

Before 1910 many South American palm genera were classified as *Cocos* but now *C. nucifera* is considered monospecific, despite pantropical distribution. Sub-specific epithets *typica*, *nana*, *javanica*, etc., have limited usefulness.

Common names

Pacific islands

Chuuk, Cook Islands: *nu*
 English: coconut, coconut palm
 Guam: *niyog*
 Kiribati: *te ni*
 N. Mariana Islands: *nizok*
 Palau: *iru*
 Pohnpei, Marshall Islands: *ni*
 Polynesia, Papua New Guinea, Fiji: *niu*
 Society Islands: *ha'ari*
 Yap, Kosrae: *lu*

Other regions

Dutch: *coco*, *cocos*, *cocospalm*, *klapperboom*
 French: *coco*, *cocotier*, *cocoyer*, *coq au lait*, *noix de coco*
 German: *Kokospalme*
 Malaysia/Indonesia: *kelapa*, *nyior*
 Philippines, Tagalog: *niyog*
 Portuguese: *coco da Bahia*, *coco da India*, *coqueiro de Bahia*
 Spanish: *coco*, *coco de agua*, *cocotero*, *palma de coco*, *palmera de coco*

BRIEF BOTANICAL DESCRIPTION

A palm with Tall and Dwarf forms, as well as intermediate hybrids, both natural and artificial. The Tall varieties show characteristics of introgression between two ancestral forms, wild and domestic, whilst dwarf varieties are predominately domestic cultivars. In favourable environments, Tall varieties begin flowering in 6 years, achieve maximum fruit production around 25 years and have been known to live for more than 100 years, reaching more than 30 m in height. Dwarf types are more precocious, flowering after 4 years, but have a shorter life up to 60 years or more, and despite their name may attain 20 m in height. The typical frond length of coconut palms aged 10–35 years is 6 m (Tall) and 4.5 m (Dwarf). A healthy palm's assembly of 20–30 fronds forms a crown that occupies a spherical shape from around 15 years of age. Each frond emerges as a vertical “spear” from the apex of growth, and may have an inflorescence in its axil about 10 months later.

Male and female flowers are separate but borne on the same inflorescence and exposed to both wind and insect pollination. In the Dwarf, both sets of flowers are active at the same time (except for the ‘Niu Leka’ Dwarf). This allows for self-pollination but does not prevent cross-pollination from a neighbouring palm, whether Tall, Dwarf, or hybrid. In the Tall, the male flowers are spent before the female flowers are receptive, generally requiring cross-pollination from another palm. In conditions where growth is particularly rapid, self-pollination is sometimes possible from male flowers on the next inflorescence to open. The fruit take about 6 months to reach maximum size (full of watery endosperm), and another 6 months to mature (when the kernel is fully formed).

The large fruit (also called seednut or nut) ranges in diameter (100–250 mm) and shape (from long and angular to almost spherical) depending on variety and growing conditions. It has a thin shiny outer skin (coloured either green, yellow, orange, or bronze until it ripens a dry brown). Beneath the skin a thick zone of parallel fibres (husk) encloses a hard-shelled nut that ranges from a pointed egg shape to a flat-bottomed sphere, again depending on variety. The nut shell is 3–6 mm thick, and lined by a very thin brown testa that forms an outer coating on the kernel, which is of fairly uniform thickness in the range 9–16 mm. The embryo is embedded in the kernel below the “soft eye” of the shell, and the internal cavity is filled with liquid (“coconut water”) until maturity when an air space develops, indicated by a splashing sound in response to shaking the fruit. The cavity volume of a spherical nut of diameter 120 mm at the early water stage is around 700 mL and this is reduced to around 270 mL when the kernel is fully formed. The water in the immature nut contains sugars, plant growth hormones, and inorganic salts and is good to drink. Although the water is



Coconut palms leaning toward the ocean in response to reflected light. The ocean is the primary mode of seed dispersal. Madang, PNG.

often called juice, it should not be called “milk” which is a water emulsion of coconut oil squeezed from the fresh kernel.

DISTRIBUTION

Native range

Ancestral palms were present on Gondwana and over the intervening 80 million years since that great landmass broke up, the coconut evolved a highly successful sea-going seed that could travel between the separating plates. It was able to colonise many scattered tropical strands, especially coral atolls or newly emerged volcanic islands, free from competing vegetation and browsing or grazing animals. It had a theoretical native range anywhere between the east coast of Africa and the west coast of America, wherever currents were favourable in the Pacific and Indian Oceans (but not the Atlantic). The site for domestication, 8–17,000 years ago, is thought to be the low lying, sub-continental Sunda land mass, now mostly below sea level, which makes

the continental coast and larger islands of Malesia the centre of diversity.

Current distribution

Modern coconut populations, showing characteristics from both wild and domestic ancestors, have a worldwide tropical distribution on all continents (except Antarctica) and on any but the smallest tropical oceanic islands. They were taken into agricultural cultivation wherever and whenever there was human settlement. It seems very likely that wild coconut palms were widespread on the island strands and large landmasses throughout Southeast Asia (Indonesia, Philippines, etc.), Melanesia (PNG, Solomons, Vanuatu, Fiji Islands, New Caledonia, etc.), Polynesia (Tonga, Samoa, Cook Islands, French Polynesia, Hawai'i, Tuvalu, Niue, etc.), and Micronesia (Kiribati, Guam, Federated States of Micronesia, etc.). This widespread presence contributed to the settlement of these lands by voyaging people, of whom the Polynesians are notable in the last 4,000 years. Even though they would be carrying desirable domestic type seednuts on their voyages, these would take several years



Illustration of the wide range found in fruit size, color, shape, and husk thickness as well as variation in kernel and cavity size.

to come into production, so on first arrival it is very likely that voyagers chose to settle near where the wild coconut provided sweet, uncontaminated drinking water, husk fibre (coir) for cordage when sailing, and oil for hair and body. Coconut was a key food source, which was combined with fish, shellfish, and other items from the ocean. Once settlements were secure, then coconuts would have also been planted away from the strand, inland and upland, that the palm cannot reach naturally. This also happened over many millennia in Asia (India, Bangladesh, Burma, Cambodia, Hainan (China), Malaysia, Sri Lanka, Thailand and Vietnam) and, to a lesser extent, in East Africa (Kenya, Madagascar, Mozambique, Somalia and Tanzania). Although medieval Europeans were aware of coconut shells, as oriental novelties brought overland, and travellers like Marco Polo saw and described coconut palms it was not until 1499 that viable seednuts were carried by boat back to Portugal. Taken from Indian or East African palm populations by Vasco da Gama and subsequent Portuguese navigators, some palms were established on the Atlantic Cape Verde islands (west of modern Senegal). From there, within only 50 years, they were carried to the Caribbean and to the Atlantic coasts of Africa and South America. This quick realisation of the maritime value of coconuts led the 16th and 17th century Spanish colonial rulers to decree that coconut palms should be extensively planted to provide cordage and supply drinking water for the annual fleet of galleons that carried oriental luxuries, from Manila to Acapulco *en route* to Spain. As a result, the coconut populations on the American Pacific coast from Mexico to Peru and cultural practices such as toddy tapping, came from the Philippines.

Thereafter, all sailing ships invariably took coconuts on board at the first opportunity, which meant that they became the first crop plant to achieve a worldwide tropical distribution. Subsequently, the increasing industrial demand for vegetable oil to supplement the supply of animal fats in Europe and North America took advantage of cheap and readily available copra (dried kernel) collected by schooners trading between Pacific islands. By the early 20th century this great demand resulted in extensive investment in large plantations on humid tropical lowlands around the world. These were of great importance to the economies of Philippines, Indonesia, India, Sri Lanka, Malaysia, Melanesia, Polynesia, Mozambique, many Caribbean islands, Brazil and Mexico. Plantation scale production declined in the late 20th century due to declining demand for coconut oil and economic changes following independence from colonial rule). However, the area under coconut continues to expand, mostly through smallholder plantings, especially in India, Indonesia, Philippines, Vietnam, Brazil, and the South Pacific.

ENVIRONMENTAL PREFERENCES AND TOLERANCES

Climate

The coconut thrives in the tropics (23°N–23°S), wherever the mean temperature is 28°C, the maximum is not more than 34°C, and the minimum not less than 22°C. Ideally, the midday relative humidity is greater than 60%, there is no prolonged soil water deficit, and no excessive soil salinity. Coconut favors an accessible groundwater table refreshed by a well distributed rainfall regime totalling at least 2,000 mm per year (or equivalent irrigation) to match a mean daily evapotranspiration of 5.5 mm. Unless there is some access to ground water, the dry season should not exceed 3 months.

Soils

The coconut thrives on an alkaline sandy soil that has a fluctuating fresh water table 0.5–1.0 m below the surface, which is the typical situation on the strand environment where the coconut evolved. Where the strand is highly calcareous and therefore alkaline (derived from reef detritus, as on atolls), micronutrient deficiency may limit growth particularly where rainfall is marginal.

Away from the strand, coconut does well on deep sandy and silty loam soils (e.g., on riverine levees and plains) across a broad pH range of 4.5–8.6. Cracking clay soils of high pH, often derived from basalt or other volcanic parent rocks, are suitable where the dry season is less than 3 months duration. Coconut does poorly where there is sodic clay subsoil (where the sodium cation dominates the calcium cation), because it is generally highly compacted and resistant to penetration by the thick primary roots.

Elevation, rainfall, and temperature

Elevation range	lower: sea level upper: 1,000 m in the tropics
Mean annual rainfall	lower: 2,000 mm. Coconut can grow where there is less rainfall but only where the fresh water table is accessible to the roots. upper: 4,000 mm
Rainfall pattern	Coconut prefers uniformly distributed rainfall.
Dry season duration (consecutive months with <40 mm [1.6 in] rainfall)	6 months where there is some access to ground water, otherwise 3 months.
Mean annual temperature	lower: 22°C (Hainan, China) upper: 33°C
Minimum temperature tolerated	7°C (In Florida, USA and Hainan, China, mature coconut palms have survived brief sub-zero periods.)

Ancient soils derived from basalt and other volcanic parent materials are generally highly leached, making the vegetation dependent upon nutrient release from decaying organic residue. The turnover of residue after long-term coconut cultivation is insufficient to meet the needs of the crop and yield declines unless fertilizer is applied (see “Agroforestry/interplanting practices”). Using husks as mulch in the field after harvesting returns potash to the soil, improves water holding in sandy soils, and aeration in clay soils. Where husks are taken away for coir fibre production the residual coir dust can be returned, as cocopeat, especially where intercrops are planted. But if rhinoceros beetle (*Oryctes* spp.) is present, the husks and cocopeat should not be left in decomposing heaps at risk of becoming beetle breeding sites.

The coconut does not tolerate waterlogging, and will produce fresh, pneumatophore-bearing roots, at or above ground level in response to seasonal or prolonged high water tables. A pneumatophore is a tiny branch from the epidermis of the root that provides rapid access of oxygen to roots that are alternately flooded and exposed. Although it copes with brief incursions of seawater, any groundwater salinity above 8mS/cm is quite limiting on production. Note that while the soil requirements for visual amenity planting of palms (golf course, hotel landscaping, etc.) are the same as those for commercial production, the other requirements are less stringent, especially where nut production is not a priority.

GROWTH AND DEVELOPMENT

The kernel is the sole source of energy for growth prior to shoot emergence and development of the first green leaf. There is no significant leaf area development for another 2 months, after which photosynthesis and kernel are partner sources of growth energy for about 12 months. The kernel is a critical food reserve during dry weather that limits photosynthesis. The seedling Relative Growth Rate (i.e., rate of size increase in relation to the initial size of the plant) is extremely high at first. By the time the kernel is exhausted, the seedling has 8 or 9 active leaves, each one about double the surface area of the one before. Early leaves on the coconut seedling are “entire,” meaning that no leaflets are apparent. In some varieties split leaflets appear as early as the 6th leaf while others retain entire leaves until 15 have appeared.

The transition from leaf to frond is complete when there are solely leaflets borne along the petiole (in about 100 offset pairs). In the period prior to first flowering each frond is longer than the one before and the frequency of emergence of new fronds increases from one every 6 weeks at the seedling stage to one every 25–30 days soon after first flowering. Frond length may increase a little beyond first flowering while the number of fronds retained in an active phase increases up to around 30 by 12 years of age in



Left: Shoot and root emerging through the husk of a young coconut. Right: Newly opened inflorescence showing the numerous male flowers (some have opened and fallen off, many as yet unopened) and a smaller number of rounded, female flowers.

good environmental conditions. The palm then has a very large crown and its investment in trunk growth diminishes from that time forward while fruit production increases to a maximum around 20 years of age. Maximum production may be sustained for a further 20 years before a gradual decline begins, marked by a steady decline in the length and frequency of appearance of the fronds. The decline might continue for decades while the palm remains healthy. Reduction in frond size due to drought results in a narrowing of the palm's stem until they are formed under improved conditions, when both leaf and stem return to normal. Old age, permanently waterlogged soil, or disease, can all lead to "pencil pointing" of the stem as the terminal bud declines, eventually leading to death.

Flowering and fruiting

When the stem girth and leaf length have reached full size (determined by variety and environment), the palm will begin to flower and set fruit. Under ideal conditions a Dwarf palm flowers within 3 years of planting in the field and a Tall palm within 6 years. The term "Dwarf" applies to varieties that have little or no bole (an enlarged stem base) and the first bunches of fruit are produced at, or close to, ground level. Tall varieties develop boles before they flower, especially those with an erect growth habit. There is some difference between Tall populations. The Rennell variety from the Solomon Islands, for example, flowers within 5 years, while West Coast Tall of India takes 6–8 years. Early flowering results in a small bole while late flowering results in a large one.

In the warm, humid tropics there is no seasonality of flowering and fruit maturation. The interval from pollination to mature fruit is about 12 months. Where there is a cool season, however, frond emergence and flowering slow down and the time from flowering to fruit maturity may extend to 14 months. As may be expected, there are also varietal differences in rate of maturation.

AGROFORESTRY AND ENVIRONMENTAL SERVICES

Agroforestry/interplanting practices

After planting, there is a period of about 5 years during which the pre-bearing coconut palms produce no crop and intercept a small but increasing fraction of available solar radiation. This is a time when many food crops such as maize, cassava, and others can be grown between the palms.

Once maximum shade has been established the palms intercept more than 80% of the sunlight so few crops can be considered. Where long-term intercropping is required, the density of Tall palms can be reduced (at the time of planting) below the usual figure of about 160 palms/ha to a value that depends on the nature of the intercrop and the desired yield. As the plantation ages, particularly beyond 40 years, light interception falls gradually and a practical intercropping opportunity is presented for cacao, coffee, vanilla, some annual crops, and pastures. Dwarf and hybrid varieties can also be intercropped, making due allowance both for higher planting density and lower leaf canopies. Grazing animals in the plantation also benefit from the lower temperature provided by the shade of mature palms. The export of nutrients from the plantation in animal products may affect the nutrient status of coconut palms, depending on soil fertility.

Environmental services

The coconut palm, configured in a plantation layout, has a strong impact on the environment within the plantation extending to the height of the palms. The velocity of wind is markedly reduced at ground level and there is a windbreak effect that apparently diminishes little up to the height of the canopy. The uniformity of canopy height appears to deflect upwards much of the energy of the wind so that intercrops or buildings within the plantation are greatly protected from damage.



Single rows of coconut palms across a field of sugarcane for example, or double rows in a parallel pattern, provide valuable wind protection for the more fragile sugar crop. It is generally found that wind reduction is useful for a distance five times the height of the windbreak. The top of the canopy of Tall palms reaches 10 m within 10 years of establishment, extending to 30 m by 50 years of age.



The coconut palm provides very effective stabilization of sand dunes adjacent to the strand, particularly in preventing wind erosion. The fibrous root system of the palm establishes a network of roots close to the soil surface as well as a dense root matrix extending deep into a sandy soil profile. The coconut root mass can withstand quite robustly the breaking surf during a very high tide or a tsunami, thus filling an important environmental role of landscape protection. The impact of sea level rise has led to loss of many strand coconut palms around the world. However, these are naturally replaced as fallen nuts germinate after being washed above the high tide mark. Likewise, a very high tide combined with a powerful wind may completely undermine the root mass, causing the palms to fall over. In this case, the palm often continues to grow almost horizontally, dropping nuts into the sea where they may float to another beach or even another land mass.

PROPAGATION AND PLANTING

The coconut palm is propagated from seed only. There is no dormancy and, in the humid tropics, the sprout emerges through the husk within 2 months of harvesting. The rate of germination depends on the variety and the local climate. Dwarf varieties, and those Tall varieties with predominantly domestic characteristics can germinate while the bunch of nuts is still on the palm. The embryo emerges through the one “soft eye” in the shell but the husk conceals the developing sprout. After germinating, the shoot takes around 2 months to emerge through the husk. By the time the shoot emerges, a few roots have spread through the lower husk and are also emerging through it if it is moist. If harvesting is delayed in the wet season, the first green leaves can emerge.



In contrast, for Tall varieties with predominantly wild characteristics, it appears that the husk of the fruit must almost dry out before the seed (nut) within is ready to germinate from the stimulus of being re-moistened. Generally at least 90% of a batch of seeds will germinate. About 10% of seedlings fail to thrive due to pathogenic infection of the seed interior, due perhaps to a fracture of the shell during the first 3 months after sprouting. The least vigorous 20–30% of seedlings should be culled from the nursery before field planting and discarded. Ideally, once a vigorous sprout is visible, the seed is transferred to a large polybag (400 × 350 mm, flat dimensions) filled with soil and kept in the nursery for 6–10

Top: Coconut agroforests fill the landscape in Samoa and many other Pacific islands where traditional agricultural systems are still common. Middle: Crops such as taro and banana growing in a mixed agroforest that includes coconut. Tutuila, American Samoa. Bottom: Cattle grazing in an ancient coconut plantation. Tongatapu, Tonga.



© Mike Foale
 Typical dense root system of the strand palm exposed by severe tidal erosion. Mozambique.

months, with close protection from insects and pathogens, generous supplementation with fertilizer, and adequate irrigation during any dry season. If a polybag is not used, transplanting to the field should be done at 6 months so that



© Craig Elevitch
 Left: New coastal planting of Dwarf palms for windbreak and soil stabilization. 'Upolu, Samoa. Right: Double row of coconuts planted as a home wind break. Hāwi, North Kohala, Hawai'i.

there is adequate remaining kernel in the nut to support regeneration of damaged roots.

Outplanting techniques

Commonly, seedlings are planted out bare root, requiring special care to reduce root damage. Preparation of the planting hole depends on soil type and fertility. Ideally, a seedling hole 60 cm square and 60 cm deep is backfilled with topsoil mixed with additional decayed organic matter and 100 g of NPK fertilizer (8:1:16) or similar. The nut is placed with the top of the husk just visible so that its base is about 100 mm below the level of the surrounding soil. A basin formed around the planting hole may help in collecting surface water during rainfall. In areas prone to a seasonally high groundwater table or short duration flooding, coconut seedlings are planted on bunds (e.g., embankments, levees, etc).

Transplanting a polybag seedling requires a hole of about 30 cm diameter and 50 cm deep into which the compact root ball of earth is placed directly. The gap between the root ball and hole edges is backfilled with topsoil worked down the side to fill all gaps. The seedling would have already received 100 g fertilizer in the nursery, which is adequate for the first few months in the field.

CULTIVATION

Variability of species and known varieties

Although the general impression is that the two main morphological types of coconut palm, the Tall and the Dwarf, represent the main diversity of type, this is misleading. The wild coconut grew for millennia on the strands of widely scattered, but virtually identical, seashore habitats (except for differences in insect and pathogen populations in adjacent ecosystems) on a multitude of large and small islands in the Pacific and Indian Oceans before being taken, by human activity in the last 5–15 thousand years, inland, upland and



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Left: New field planted with coconuts together with short term crops including sweetpotato and ti. Dededo, Guam. Right: Taro (*Colocasia esculenta*) growing under coconuts. Tongatapu, Tonga.

to coastlines it could not reach by floating. The result of this dispersal is that specific adaptation has developed in many different locations to unique insect and microbial challenges. There has also been adaptation to brief low temperature extremes and even to seasonal low temperature in the case of Hainan Island, and to extended duration of the dry season. Successful commercial varieties in the last 150 years are closely related to the landrace of the region and attempts to introduce exotic germplasm often fail due to a local pests and diseases.

Basic crop management

Tall palms are commonly planted at 8.5 m spacing in a triangular array, giving a density of 160 palms/ha, while the Dwarf does well at 7 m spacing, giving 236 palms/ha. If the rainfall is below 2,500 mm/year or if there is a dry season

more than 3 months duration, a 20% lower density is recommended. Different spacings may be adopted where permanent intercrops are to be planted or when the coconut palms are intended for (hybrid) seed production.

Generally NPK (8:1:16) fertilizer should be applied in the following series: Year 1—200 g/palm; Year 2—400 g/palm; Year 3—600 g/palm; and 600 g/palm/year thereafter. The ratios given refer to the proportion of nitrogen (N), phosphorus (P) and potassium (K). Where possible, local formulations should be made up allowing the NPK proportions to be varied according to local experience, guided by the results of foliar analysis. Critical levels below which the plant may not achieve its potential rate of growth (measured in the 14th frond from the top of a mature palm) are as follows:

Major elements (% dry matter)

N	P	K	Mg	Ca	Na	Cl	S
1.80	0.12	0.80	0.25	0.40	–	0.55	0.18

Trace elements (parts per million of dry matter)

B	Mn	Fe	Cu	Mo	Zn	Al
10	30	50	5	0.15	15	38*

*Aluminium is not essential but always present; likely to be toxic above 100 parts per million

Coconut fruit mature in a regular sequence, almost monthly, allowing very orderly division of a plantation into sectors that are harvested (by cutting the bunch stalk or by picking up individual nuts after they fall to the ground) at 4–6 weekly intervals. The fruit are either transported to a central point for efficient processing of whatever components will be processed at the plantation level, or they are sold to a processing centre. Sometimes the husk is removed and left in the field as mulch.



Toddy collection by container placed beneath the cut end of a bound inflorescence. Sikiana, Solomons.

Special horticultural techniques

Commercial production of toddy (as a drink or for conversion to syrup, sugar, alcohol, or vinegar) requires knowledge of the tapping technique and the skill to apply it. The ability to climb the trunk without using ladders or mechanical aids is also useful. A climbing method widely used in Indonesia involves the climber placing a stout bolt of cloth around the trunk and wrapping it securely onto each forearm. The climber then uses the cloth to take the weight of the body when stepping onto small footholds previously cut into the palm trunk. Generally these footholds do not injure the palm, but that risk can be minimised by tying pieces of husk at intervals up the trunk instead. In India a climbing device has been invented comprising an inexpensive pair of frames that each have a cable gripping the trunk. With one foot on each frame, these are raised in turn by hand allowing the gripping cables to slide up the trunk.

Advantages and disadvantages of growing in polycultures

The coconut lends itself particularly well to polyculture because of its longevity and the gradual decline in light interception (allowing increased light penetration) after about 40 years of age. Intercrops have become increasingly important as the return from coconut production has declined greatly in recent decades. The coconut is well known for being easy to propagate and manage as the fruit suffers little loss of value over a period of 3 months from maturity, and making copra is a comparatively less demanding process compared with processing many other tropical crops. Smallholders have difficulty where new polyculture crops require additional propagation and pruning skills and greater intensity of management such as in the case of cocoa or cloves, which must be harvested within a few days of being ready to process.

PESTS AND DISEASES

Susceptibility and resistance to pests and diseases

The coconut is host to many pests and diseases but nevertheless has achieved worldwide, pantropical distribution. Any established population of palms has evolved over a very long period within reach of the pests and pathogens of the neighbouring ecosystem and has developed a degree of resistance to the most persistent of these through natural selection. But that may only become apparent when pests or disease spread or coconut genotypes are transferred to new or distant locations. For example, the *Brontispa* leaf beetle (*Brontispa longissima*) is endemic on palms in Solomon Islands, yet serious damage is not evident in adult populations in those islands. However, recently the leaf beetle entered some coconut populations in Philippines, Indonesia, and Vietnam, resulting in the death of many palms. As a con-

trasting example, the resistance of some Southeast Asian varieties to the lethal yellowing (LY) phytoplasma was only recognised some 10–15 years after they were exposed to that disease in Jamaica.

Preventing and treating problem pests and diseases

Except in the nursery, and during the first 2–4 years in the field, it is difficult to protect the coconut palm with chemical sprays, due to its rapidly increasing height. Chemicals are available that reduce the severity of insect, fungal or bacterial assaults on young palms, but these treatments are generally difficult for the smallholder to purchase and apply.

The primary action to reduce pests and diseases is to use the locally proven coconut variety, where that is known not to be at serious risk, as is the case with Foliar Decay in Vanuatu (but, unfortunately, not to Cadang-Cadang in the Philippines or to rhinoceros beetle anywhere). However, there are serious pests and diseases outside the Pacific region. For instance, the *Aceria* fruit mite is a serious pest in the Americas and Africa, and is currently active in south Asia. Likewise, the Lethal Yellowing (LY) phytoplasma has done great damage to coconut populations in some Caribbean islands and along the Gulf coasts of north and central America, as well as east and west Africa. Other phytoplasma infections are under investigation in Sri Lanka, Malaysia, and Indonesia. Quarantine regulations restricting the movement of all planting material (not only coconut) need to be followed. Failure to do so may be why the *Brontispa* leaf beetle has spread from places in the Pacific where the local palms show resistance, to regions in Southeast Asia where its damage is enormous. Fortunately this beetle has several natural predators, so that a conventional biological control approach could eventually reduce its impact. There is also accumulating evidence that some LY outbreaks have not become epidemic for similar reasons.

Every part of the coconut palm can be host to one or more pests and worldwide the list (too long to include here), ranges from termites to rats and includes bugs, beetles and weevils, butterflies and moths, swarms of locusts and even elephants. Simply removing plant materials which provide habitat in the plantation can be effective against some pests, especially the *Oryctes* rhinoceros beetle (that occurs in Africa, Asia, and the Pacific) and the *Scapanes* rhinoceros beetle (in Melanesia). These beetles breed in decaying tree trunks and can kill young palms by burrowing between the leaf bases into the soft tissue of the growing point (older palms that may survive exhibit characteristic “scissor” cuts to their foliage). The palm weevil (*Rhynchophorus* sp.) breeds in living trunks and is now almost worldwide, having recently reached Europe.

The only known virus of coconuts causes Foliar Decay of non-adapted palms in Vanuatu. Its spread can be blocked by

destroying the breeding sites of the insect (*Myndus taffinii*) that transmits the virus.

DISADVANTAGES OF THIS CROP

As a cash crop coconut suffers from a drawback shared with other perennial crops, that the farmer is locked in to its products even when the market is depressed and the return for effort is very low.

Although it has many products (food, drink, fibre, fuel, etc.), their production cost is difficult to lower by mechanization and easy to substitute from other crops or synthesize from petroleum. Even the particularly high lauric content of coconut oil can be matched by palm kernel oil or genetically modified canola.

Yield declines steadily from about 40 years of age. It is hard to make the decision to replant when there is still some production. The yield of an old palm is well below that of a young producing palm, but there will be a wait of 6–7 years for a replacement palm to begin production. The farmer



Top: Rhinoceros beetle (*Oryctes rhinoceros*) larva, a serious pest for coconut, betel nut, and other palms, as well as pandanus. The beetle was detected on Guam in September 2007. Bottom: Falling coconuts and fronds can be dangerous, especially in public places where people are caught unawares.

must make the short-term sacrifice to get the long-term benefit of replanting. He can spread the replanting operation over a period of years so that some new palms are bearing before all the old palms have been removed, thus avoiding a period of very low income.

The cost of harvesting fruit is significant and costs increase with the age of the palms because they grow ever taller.

The coconut is quite susceptible to lightning strikes that can destroy as many as 50 palms in one event, which can be a great setback for a smallholder.

Many coconut areas are remote from markets and require expensive sea or land transport. The smallholder has a weak position in the market and often becomes dependent upon small buyers for a fair deal. Very often the farmer becomes indebted to the buyer and sinks ever deeper into poverty.

The risk of injury or death from a falling coconut fruit has become exaggerated in many urban settings as insurance agencies seek to gain high premiums for protection against this risk. Serious injury is rare when common sense avoidance of the target zone of falling fruit and fronds is practiced. A circular barrier attached partway up the trunk and known as “Coconet” is used by some resorts to catch falling fruit, but its cost is beyond the reach of most palm owners. There are also psychological reasons for disliking coconut palms held by those who associate plantation agriculture with colonial exploitation such as slavery, black birding, or indentured labour from Indochina.

Potential for invasiveness

The coconut is not invasive, as natural movement of its seed is solely via the ocean or a stream leading to the seed being carried only to strand locations. This distribution of the sea-going seed of the coconut has been happening for millions of years. Only human intervention has taken the coconut away from its niche on the strand, to locations where it will not survive indefinitely without attention. In some cases where it is described as a weed, it has been confused with a more competitive South American palm, *Syagrus romanzoffiana*, which was once known as *Cocos australis*, with the common name of “cocos palm.”

COMMERCIAL PRODUCTION

Postharvest handling and processing for commercial use

Oil became an international trade commodity from the mid-19th century giving rise to tropical plantations funded from Europe and North America. The commodity chain for oil involved either splitting the nut for half-nut drying (before separating the kernel from the shell in one piece) or cutting the fresh kernel from the shell before drying. The half-nuts may be sun dried or kiln dried with hot air or



Dehusked mature nuts for sale by the basketful. Apia, Samoa.

smoke; the fresh cut kernel requires kiln drying, preferably with fan-driven hot air. The end product was copra that was dry enough to be transported in sacks or in bulk to factories where it was pressed to produce crude coconut oil. This oil was further refined, bleached, and deodorized to meet the standard for use as cooking oil or shortening, and for the production of candles, soaps, and lotions.

Methods of processing

Mature fruit for local markets may simply be dehusked (completely or partially) and immature fruit for water may have some husk trimmed.

Copra

Processing of mature kernel to copra requires a simple drier where the fire is located beneath a rack on which fresh split

nuts are placed. After an approximately 24-hour drying period, the kernel loosens from the shell and is removed and undergoes a final drying phase. Copra and oil quality are improved if the smoke is kept away from the kernel by using indirect heating.



Top: Shredding coconut kernel using simple motor-driven graters. Bottom: Lever-operated Direct Micro Expelling press. Both photos: Fiji.

Value-added product summary

Part	Product	Process
Fruit	Decoration	Trimming for display
Nut	Mature nut	Dehusking of fruit
Husk	Fibre	Retting of husk
Husk	Cocopeat	Separation from fibre
Husk	Organic fertiliser	Ferment cocopeat with manure & nutrients
Kernel	Fresh kernel	Slice or shred from half-nut
Kernel	Copra	Drying of kernel
Kernel	Desiccated	Deshell, shred, and dry
Oil	Virgin oil	Separation from cream or by pressing of dry shredded kernel
Oil	Industrial oil	Heat & press ground copra
Oil	RBD oil	Refine, bleach, deodorize
Water	Nata de coco	Culture mature water
Water	Preserved	Extract and package
Shell	Curios	Polish, sculpt, and paint
Shell	Charcoal	Ignite in special burner
Shell	Activated carbon	Charcoal heated
Sap	Toddy	Collect from unopened flower spathe & ferment (or boil)
Leaflet	Curios	Weaving—hat, skirt, etc.
Leaflet	Thatching	Weave into panels
Fronde	Fencing	Strip leaflets off
Trunk	Timber	Dry, mill, veneer, polish

Milk

Coconut milk (also called cream) is produced locally on a small scale in the kitchen or on a larger mechanized scale for extraction of the oil. The kitchen process of shredding using a fixed grater (or comb) and squeezing the shredded coconut kernel through a straining cloth has been used since antiquity. Coconut milk can be produced for the local market by squeezing 3–6 litres of shredded kernel and water through a sack located on a firm wooden bench. Pressure is exerted on the sack by a long broad plank that has one end joined by a hinge to the edge of the bench, and the other end forced down in a levering action to increase pressure on the shredded coconut. This system achieves a reasonably high yield of milk.

Oil

Traditionally in Asia oil has been separated by standing coconut milk for 24–48 hours. The emulsion separates into a layer of water at the bottom, oil in the middle, and a frothy emulsion residue floating on the top. This oil product, known as virgin oil after filtration, can also be made by partially drying shredded coconut and applying moderate pressure – a process known as Direct Micro-Expelling



Left: Canned coconut water produced in Thailand for export. Right: Business billboard for coconut timber producer. Apia, Samoa.

(DME). Industrial oil separation from copra requires very high pressure.

Other products

Coconut milk can be spray-dried to produce a powder that has achieved some market success outside the coconut world in place of canned liquid coconut cream.

There is a wide range of products derived from the two main forms of coconut oil: refined industrial oil and virgin oil (VCO). Coconut soap has excellent lathering qualities, even in seawater, and many scented coconut lotions are available to soothe raw or sore skin. Virgin coconut oil has become popular as a dietary supplement due to extensive Internet marketing, where it is reported to cure many internal ills as well as providing a general energy boost. Coconut oil cannot be registered as a pharmaceutical but is referred to in the industry as a “nutriceutical.” There is a particularly favourable response in people with a hypothyroid condition.

Standards

No accepted international standards have been established although the Asia Pacific Coconut Community has drawn up draft standards for VCO.

VCO

For reference, the following is the Philippine National Standard for VCO:

- Colour: Water white or water clear
- Free fatty acid (as lauric): 0.2% max
- Moisture (volatile at 105°C): 0.2% max
- Peroxide value: 3 max
- Total plate count: <10 cfu
- Food additive: none permitted
- Contaminants: less than iron 5 ppm; copper 0.4 ppm; lead 0.1 ppm; arsenic 0.1 ppm

Milk/Cream

Standards for coconut milk/cream are presented in the following table.

Product storage requirements and shelf life

Product	Storage life
Fresh water nut	10 days uncooled; 5 weeks refrigerated at 5°C
Mature nut	3 months uncooled. 4 months cooled.
Copra	Many months when dried to 6% moisture or less.
Fresh kernel	One day uncooled. 4 days cooled.
Extracted water	6 hours uncooled. 3 days cooled.
Virgin oil	Comprising 92% saturated fatty acids, oil is very stable, indefinite storage life at ambient temperature
RBD oil	Derived from copra-extracted oil, indefinite storage life at ambient temperature.
Desiccated coconut (DC)	For long term storage at ambient temperature, a preservative is usually added.
Canned coconut milk and cream	Ambient temperature for up to 2 years.

Standard for coconut milk/cream products (FAO 1999, 2003)

Product	Total Solids (% m/m)	Non-fat Solids (% m/m)*	Fat (% m/m)	Moisture (% m/m)	pH
	min.–max.	min.		max.	min.
Skim Coconut Milk	5 max.	-	3.75 max.	95.0	5.9
Light Coconut Milk	6.6–12.6	1.6	5.0 min.	93.4	5.9
Coconut Milk	12.7–25.3	2.7	10.0 min.	87.3	5.9
Coconut Cream	25.4–37.3	5.4	20.0 min.	74.6	5.9
Coconut Cream Concentrate	37.4–46.1	8.4	29.0 min.	62.6	5.9
Concentrated Coconut Cream	46.2 min.	11.2	35.0 min.	53.8	5.9

* %m/m is the percentage calculated from the mass of the component divided by the mass of the whole

Recommended labelling for products

There are no universal codes for quality of coconut products. Some countries require nutritional and energy information on the label of canned products such as cream, milk, and water.

There are strict rules regarding the use of the organic label. The terms “virgin” and “extra virgin” lack clear definition.

The labels on desiccated coconut often do not carry details of the use of preservatives or the amount of added ingredients such as sugar.

SMALL SCALE PRODUCTION

Growing commercially

The size of a commercial coconut grove depends on the principal market that is available. If fresh fruit can be sold directly to retail customers, even one palm can generate worthwhile supplementary income when harvesting is inexpensive. There can be as many as 80 palms on 0.5 ha with good productivity potential (i.e., climate, rainfall, and fertility). The next most convenient product is copra, as it requires investment only in a drier and basic dehusking and extraction tools. Besides copra, coconut husks and charcoal from the shell may also be marketable locally.

Once established, the palms may require some fertilizer to sustain productivity. Organic fertilizers including manure from farm animals, processed coconut husks, and residues from intercrops have a role.

Worthwhile production from Tall palms begins about 6–7 years from planting; hybrid and dwarf palms 6–12 months earlier. It is necessary to protect small, young palms from grazing animals, and at all ages from the attack of insects



Hand grating coconut kernel and squeezing milk through a bundle of plant fiber. ‘Upolu, Samoa.



such as rhinoceros beetle (use poison baits and keep the land free of breeding sites for the pest).

Adding value

The kernel of the mature fruit can be processed to add value in several different ways, for copra and for virgin oil. Copra making is simple, although incomplete drying and smoke drying should be avoided, as the buyer will pay much less for poor quality.

Virgin oil production requires a significant investment in specialized equipment and will only succeed when several producers combine their efforts to control quality and strengthen marketing. The traditional oil separation by leaving extracted coconut milk standing for 24+ hours requires a set of clear-walled buckets and filtration equipment to clarify the floating oil. A shredding, drying, and pressing method known, as Direct Micro-Expelling requires start-up equipment valued at US\$4,000. It is a rapid technique, delivering oil within an hour of splitting nuts in half for kernel extraction. Ideally a group of small farmers would invest jointly in equipment and training for this manufacturing process.

Coconut shell can be converted to charcoal quite readily in a suitable pit on a farm. Husks can be sold where there is a local processor performing fibre and cocopeat extraction.

Household use

The coconut provides basic food and drinking fluid to tens of thousands of Pacific islanders, and millions of people in all the tropical countries of southeast and south Asia and throughout the humid tropics. On the Pacific atolls, that are home to a population of about a quarter million people, the coconut (estimated population of a million) provides more than half of the dietary energy and its water is an essential source of drinking fluid. Toddy is also important in the nutrition of children on drier atolls that lack fruit trees, being a good source of vitamins when fresh. In other regions such as the Philippines, there are 1.5 million coconut farmers as well as 24 million other people who gain some income from coconuts.

Almost universally in the coconut heartlands of Asia and the Pacific, the use of cream extracted from the coconut kernel is a daily adjunct to whatever food is being prepared. The cream is rich in oil, up to 33%. A high proportion of urban dwellers purchase whole nuts or shredded kernel from the fresh food markets.

Nutrition

Coconut water (from the immature nut) is delicious and refreshing. It is also credited with a fa-

avourable impact on the digestive system and a capacity to reduce the incidence of kidney stones.

Fresh kernel has an attractive taste and contributes protein, fibre, and especially medium-chain triglycerides (MCTs) to the diet. MCTs comprise 65% of the lipid mix in coconut

oil. The MCTs are incorporated rapidly into the body's energy cycle via the liver, raising vigour and helping to "burn off" accumulated fat, thereby reducing the risk of obesity. Claims that coconut oil contributes to heart disease are false. Heart disease is very rare among populations using coco-



Top left: Untreated, raw coconut shells burn quickly and hot for cooking. 'Upolu, Samoa. Top right: Coconut oil for sale as cooking oil in local grocery store. Koror, Palau. Bottom right: Coconut husk used as mulch for ornamental landscape. 'Upolu, Samoa. Bottom left: Coconut shell charcoal.



A highly productive young cultivated palm. Vanuatu.

nut in their traditional diet, combined with fish (a source of omega-3 fat) and pig or poultry meats (sources of omega-6 fats). Coconut oil will only raise LDL cholesterol when there is a deficiency of omega-3 and omega-6 oils in the diet.

Ninety-two percent of the lipids in coconut oil comprise saturated molecules that create no demand for antioxidants, as it is only unsaturated fat molecules that easily release the free radicals that antioxidants neutralise. This contrasts with the polyunsaturated oils that have been promoted vigorously to consumers in industrialized countries.

Import replacement

By weight, fresh coconut kernel comprises around 50% water, 33% oil, 4% protein and 13% fibre and soluble carbohydrate. As the energy value of a unit of oil is 2.3 times greater than the same amount of carbohydrate, oil in the diet can replace a very high proportion of starch-based foods such as rice, root crops, and bread. Rice and flour are imports in practically all Pacific islands and may lead to diabetes if they dominate the diet. The health of many urbanized islanders has been harmed by the reduction of coconut in their diet

(Price 2008). Coconut oil has also been shown to reduce the impact of Type-2 diabetes.

YIELD

Expected range of yield per plant

The Tall coconut annually produces about a dozen bunches in sequence and can yield 100 medium size nuts per year during its best years, from 15 to 30 years of age. Fruit size is genetically controlled but varies a little with the number of fruit per bunch, which, in turn, depends on the weather at the time of pollination and the total weight of nuts already carried. Large-fruited palms bear fewer fruit and small-fruited palms bear more, with the combined weight of fruit being similar. A medium-sized fruit contains a nut of diameter 105–125 mm. In small fruit the diameter is less than 105 mm and in large it is greater than 125 mm. Shedding of unfertilised female flowers (buttons) happens in the first 2 or 3 months after flowering, so nuts on the four youngest bunches should not be included when estimating the potential yield by a simple count (and bunches of ripe nuts should be harvested before counting).

The yield of coir fibre, shell, and kernel from the ripe fruit varies both within and between genetically diverse populations, but can be predicted from fruit component analysis (FCA) data. The yield of fresh kernel is 45–50% of fresh nut weight (after the husk is removed) and would be 250–400 g from medium nuts, equivalent to 83–133 g oil. A high-yielding palm produces 48 kg or more of fresh kernel per year, equivalent to 25 kg of copra.

Husk thickness varies between 40–70% (fresh fruit weight) with the best coir fibres coming from long, angular fruited tall types. The dry husk of medium-sized fruit would be in the range of 200–400 g of which about two-thirds is fibre and the remainder is cocopeat—a dust-like material, once discarded but now extensively traded.

Shell accounts for 25–30% of the nut weight and ranges in thickness from 3–6 mm and therefore the yield of charcoal varies a great deal. A shell weighing 150 g yields around 60 g of charcoal.

The water content at the time of harvest may be 20–35% of nut weight. It no longer fills the cavity and is not as pleasant, to drink, as the tender nut water from the immature fruit. After harvesting it continues to be absorbed by the kernel and when totally depleted the nut is no longer considered to be viable.

The yield capacity of a Dwarf palm is perhaps 20% less than a neighbouring Tall palms, but higher planting density can produce the same yield per unit area. Hybrids between dwarf and tall varieties, that are readily made in commercial

quantities, combine precocity of the dwarf and robustness of the tall and may display hybrid vigour.

Recommended planting density

Monocrop or pure stand palms are planted at a density that allows the tips of horizontally held mature leaves to touch. A spacing of 8.5 m between Tall palms results in 160 palms/ha if arranged on a triangular pattern or 138 on a square pattern. The Tall palm at full maturity has a crown about 30% wider (at 12 m) than a Dwarf crown. Spacing dwarf palms at 7 m in a triangular pattern results in a density of 236 palms/ha. At these densities the interception of light by the palm canopy reduces or prevents weed growth. Lower densities are necessary if intercrops are planted.

If the annual rainfall is much below 2,500 mm, the density should be reduced by 20%. Likewise, if there is a regular dry season exceeding 3 months in duration, density should be reduced.

MARKETS

Local markets

Mature nuts have a shelf life of many weeks and dehusking is done just prior to sale to avoid cracking due to rapid drying of the shell. Presentation to local markets is very simple. No packaging is necessary but a tuft of fibre is retained to reduce the risk of cracking. The presence of a small germinated sprout usually does not detract from value at farmers' and roadside markets. Many tourists are fascinated to find the haustorium (the spongy organ that grows to fill the cavity and extract nutrition from the kernel to support the seedling) inside a sprouted nut.

Immature water nuts, on the other hand, have a short shelf life without refrigeration (8 days maximum) and must reach the market without delay. Besides local markets, large quantities are taken to nearby cities if there is a suitable road.

Export markets

Copra and coconut oil exports have dwindled to low levels during the last two decades but have fluctuated with the world price of mineral oil in 2007/8, showing a sharp rise in price and then a steep fall. For example, farmers on Milne Bay islands in PNG made no copra with the price at 40 toea/kg, but copra making resumed when the price rose to 60 toea/kg and ceased again when the price fell.

About half a million dehusked mature nuts are exported from Polynesia to Australia for the fresh market. New Zealand and Japan are also significant nut importers from Pacific countries. While Australia and New Zealand import from the south Pacific, the U.S., Canada, and European countries import fresh nuts mostly from the Caribbean or Africa;



Top and middle: Roadside sales of drinking and mature coconuts from small farms. Savai'i, Samoa. Bottom: Coconut candies made from all local ingredients. Kahalu'u, Hawai'i.

Middle East countries from Sri Lanka and India; and China from the Philippines and Vietnam.

On remote islands coconut oil is competitive with imported diesel as fuel, and some may be “exported” to ships plying regional trade routes. Filtered oil from the pressing of copra is used without conversion to derivative forms such as esters, while coconut oil blended with diesel is popular for small motor vehicles.

Virgin Coconut Oil (VCO) is produced in the Pacific by the DME technique of cold pressing of semi-dried (temperature not exceeding 60°C) grated kernel. This contrasts with the traditional emulsion-breakdown method that allows gravity separation of VCO from coconut milk (kernel-derived emulsion) of Southeast Asian countries. Exports from several countries of a few tens of thousands of litres/year are steadily growing. VCO has on average a retail market value twice that of copra-derived RBD oil.

Specialty markets

Virgin Coconut Oil has found its way into health food shops in industrialised countries. The remarkable health-giving properties of coconut oil are gradually being recognized, now that its health advantage relative to competing edible oils has been recognised. Organic certification of the source farms and of the processing facilities for VCO expands the market to health food stores, thereby improving the value. Price would also be boosted by Fair Trade labelling.

Branding possibilities

There are indeed branding possibilities arising from the traditional place of coconut products in the diet and in the domestic technologies of Pacific peoples. The historical recognition by visiting navigators of the great health and strength of peoples in many coastal tribes of the Pacific highlights the contribution of coconut to human well being. The macapuno (kopyor) variety, with its highly flavoured gelatinous kernel, commands a premium price. It is not yet available in the Pacific, although it is commercially grown in Philippines and Indonesia.

Internet sales

The Internet has the potential to boost sales a great deal, especially for such high value items as VCO. There would be an advantage for producers to group together to achieve greater marketing presence. Internet technology provides an opportunity for any individual to enter the market, but there is the risk that competition among many small sellers will force the price down. Collaborative marketing has much to offer.

EXAMPLE SUCCESSES

Mesak Mateus near Tibobo village, North Sulawesi

Mesak Mateus (71 years) owns 200 coconut palms on 1.5 ha interplanted with banana and clove. He employs two climbers every 3 months costing US\$0.12/palm to pick an average of 20–30 fruit per palm. Total production is around 10 MT copra/yr and 4 MT charcoal/yr, all processed by Mateus. There is no local market for husks. Gross income from coconut products is currently estimated at US\$6,000 for copra and US\$588 for charcoal at early 2008 prices. He relies on additional income from cloves and bananas to support his family of four.

James, VCO producer on Malaita, Solomon Islands

James, a mechanic and community leader, invested in VCO production in 2004. The production unit comprised a shed housing two driers of 5 m² drying plate area and four motorised (electric) grating machines.

The coconut fruit is dehusked, then the nut is then split and the kernel grated on the grating machine. Husk and shell provide fuel for the driers. Fifteen nuts are required to generate 1 kg of VCO for which the labour of twelve workers and two supervisors are paid US\$0.50. The teams produce around 75 kg/day of VCO and 115 kg of residue.

The factory door prices are: US\$2/kg for VCO and US\$0.20/kg for residue, giving a gross return of US\$173/day.

The daily operating costs are US\$37.50 for labour and US\$45 for the fruit, plus the fuel for a tractor and trailer and a generator to drive the electric motors of the graters. Total operating cost is approximately US\$100/day.

The fruit is purchased from 28 farmers at US\$0.04 each. About 1,100 fruit are collected each working day giving each farmer an average income for fruit sale of US\$1.57/day.

Samoan farmers

Samoan farmers (business names not known) have a contract to supply the principal importer of fresh mature coconuts into Australia. Fruit is collected and dehusked in Samoa, then loaded into a refrigerated container and shipped to Sydney. From there supplies are distributed to more than 1,200 supermarket outlets in Australia retailing for AU\$2.50–3.00 per nut. The supermarkets report increasing sales in 2008 over previous years.

ECONOMIC ANALYSIS

Expenses of production

In the context of a subsistence farm operation in Solomon Islands or Fiji that includes coconut as a cash crop for example, costs are difficult to estimate. The daily wage rate for skilled work could range from US\$2–5. Fruit picking

Product and price table

Approximate prices in US\$ for coconut products in the East Asia Growth Area region (mid 2006). Items in bold are the primary values that drive farmer and processor income. Adapted from Foale et al. 2006.

Raw material	Product	Farm gate	Retail (local)	Export F.O.B. \$/MT	Comment
Fruit	Whole, immature	0.08 ea	0.20 each	NA	Fresh for drinking
	Whole, mature	0.05–0.07 ea			Supply to local processors
Nut	Dehusked, mature	0.04–0.06 ea		250/thousand	Per fresh nut, local and export
Husk	Whole piece	0.005–0.01			Husk from one fruit
	Coir, raw			125–200	Compressed in bales
	Coir, twined			300	Baled 10 m lengths of twine
	Coir, net			500+	Geotextile matting
	Pith			160	Briquette for horticulture
Shell	Raw	0.015/kg			Dried during copra making
	Charcoal	0.14/kg	0.20/kg		Retail for domestic cooking
	Charcoal granule			198	Raw material to activated carbon processor
	Charcoal briquette			560	Overseas fuel market
	Activated carbon			780	Local manufacture
Kernel	Smoke copra	0.28–0.34/kg		235	Universal farmer product/kg
	White copra	0.35–0.40/kg			Limited local demand—copra mills
	Copra cake			88	By-product of oil extraction
	Coconut flour		8/kg		Limited supply from white copra milling
Oil	Crude			N/A	Not usually exported—refined first
	RBD		70/L	700	RBD=Refined, Bleached, Deodorised. Retail for cooking.
	Virgin (VCO)	2.50/L	3–10/L	3/L	Highly variable price and quality
	Cream/milk			750	Scant information—competitive
	Desiccated DC			680	Seasonal demand—diverse customers
Water	Fresh mature ¹	0.10/L			Supplied to Nata de Coco processors
	Nata de Coco		0.77/kg		No sustained export yet achieved
	Preserved			N/A	Growing supplies in cans and other containers
	Frozen			N/A	New export from Gorontalo
	Vinegar		N/A		Traditional product. Low export prospect
Trunk	Lumber (each)	5–8/ea		N/A	Expanding supplies from old plantings
	House framing	5–8/ea		N/A	Filling niche of scarce forest timber
	Milled flooring	5–8/ea		N/A	Strong export demand

¹Estimate only

costs are up to US\$0.15 per palm for water nuts. Ten nuts per climb gives a cost of US\$0.015/nut. Three workers with a suitable copra drier could process 7,000 fruit/week (18 man-days, worth US\$30) yielding 1.5 MT copra. Their tasks would be collecting fallen or harvested fruit, dehusking and splitting the nuts, fuelling the fire in the drier, separating the drying kernel from the half shell, and bagging. Husk and shell products are also possible.

There is less work if the kernel is cut from split fruit in heaps in the field. This is common in the South Pacific where the husk and shell (not separated) are often left in the field.

However, increasingly husk and shell are needed as fuel in the copra drier.

Expected income per plant

The table below sets out information on a wide range of products. These are all found in Philippines and Indonesia and their prices to the producer and the processor were current in 2006. There was more than a doubling in the price of copra and coconut oil early in 2007/8 responding to the sharp rise in global crude oil price, followed by a fall, and this high variability in price is likely in the future.

The following calculated values per unit and per tree are rough estimates taking into account the likely differing effect of oil price on different products.

Estimated farm gate prices per unit and per palm that produces 100 fruit/year (\$US).

Product	Per unit	Per palm
water nut (each)	\$0.20	\$20.00
mature fruit (each)	\$0.15	\$15.00
dehusked nut (each)	\$0.12	\$12.00
husk (from 1 fruit)	\$0.01	\$1.00
shell (kg)	\$0.015	\$0.30
charcoal (kg)	\$0.14	\$1.12
copra (kg)	\$0.60	\$13.00
virgin oil (litre)	\$2.50	\$25.00
trunk (each)	\$10.00	\$10.00

FURTHER RESEARCH

Potential for crop improvement

The Tall palm is mostly cross-breeding so that a high-yielding palm can be open-pollinated by unselected, “average” palms from the surrounding population. Seed from the outstanding palm would still give rise to an “above average” population, but the improvement is small.

Hybrids made by mass controlled pollination of emasculated Dwarf mother palms in isolated seed gardens with pollen collected from selected Tall (or, in a few cases, Dwarf) varieties have been popular because they are more precocious than the Tall parent, more robust than the Dwarf parent and produce more fruit weight than either parent. Fruit size of these hybrids is smaller and oil percentage slightly less than the Tall parent and, like any other new planting material they may suffer from local pests and disease strains if taken to environments in which they have not first been tested. The obvious answer is to make hybrids between locally adapted parents, as was successfully done in Jamaica 30 years ago using varieties tested for resistance to lethal yellowing disease. Since dependability of production is more important to most smallholders than raising yield potential, it is worth knowing that, under guidance from COGENT (see “Genetic resources”), locally adapted genotypes are being maintained in living collections (since coconuts cannot be routinely conserved in seedbanks).

Ancient Polynesians used numerous small islands to create and conserve their coconut varieties. The geographical remoteness of these islands ensured the reproductive isolation needed for breeding (Bourdeix et al. 2007). This breeding strategy of using isolated islands to preserve interesting and potentially useful populations of coconut that possess unique traits such as sweet husk shows promise even today.

Improving potential for family or community farming

The most necessary direction for improving income of coconut farmers rests in building a stronger marketing position. Family farming with coconut can only improve through greater community participation, because the average family farm is usually in the 1–2 ha range. Community action could be directed to communal processing of fruit to derive multiple products on a scale that attracts market interest.

Genetic resources where collections exist

There has been a global project since 1992 known as COGENT (Coconut Genetic Resources Network coordinated by Bioversity International funded by the World Bank and other donors) that provides marshalling of resources to operate a series of centres for the establishment of genetic resources plantations. The material included represents the major coconut populations of the region concerned, as well as including unusual and even quirky traits such as aromatic water in the nut.

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- A coconut knowledge network for information exchange about *Cocos nucifera* <http://groups.google.com/group/coconut>

OTHER RESOURCES

Public assistance

Asia Pacific Coconut Community (APCC). <http://www.apccsec.org>

Internet

Coconut Research Center <http://www.coconutresearchcenter.org>

Kokonut Pacific <http://www.kokonutpacific.com.au>

Coconut Time Line: Key knowledge on the coconut palm and where to find the information <http://cocos.arecaceae.com>

Specialty Crops for Pacific Island Agroforestry (<http://agroforestry.net/scps>)

Farm and Forestry Production and Marketing profile for Coconut (*Cocos nucifera*)

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Recommended citation: Foale, M., and H. Harries. 2011 (revised). Farm and Forestry Production and Marketing Profile for Coconut (*Cocos nucifera*). In: Elevitch, C.R. (ed.). Specialty Crops for Pacific Island Agroforestry. Permanent Agriculture Resources (PAR), Hōlualoa, Hawai'i. <http://agroforestry.net/scps>

Version history: November 2009, February 2011

Series editor: Craig R. Elevitch

Publisher: Permanent Agriculture Resources (PAR), PO Box 428, Hōlualoa, Hawai'i 96725, USA; Tel: 808-324-4427; Fax: 808-324-4129; Email: par@agroforestry.net; Web: <http://www.agroforestry.net>. This institution is an equal opportunity provider.

Acknowledgments: The authors thank Maria Luz C. George, Bioversity Senior Scientist and COGENT Coordinator (2006–09), for the recommendation to contribute to this project. The support and encouragement of Craig Elevitch, the project editor, is gratefully acknowledged. Provision of a working environment to Mike Foale by the University of Queensland School of Land Crops and Food Sciences is much appreciated. Our thanks to Roland Bourdeix and Tevita Kete for their input regarding this publication. Special thanks to Roland Bourdeix for permission to use the coconut diversity photo.

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Sponsors: Publication was made possible by generous support of the United States Department of Agriculture Western Region Sustainable Agriculture Research and Education (USDA-WSARE) Program. This material is based upon work supported by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, and Agricultural Experiment Station, Utah State University, under Cooperative Agreement 2007-47001-03798.

