



## *Cocos nucifera* (coconut)

Areaceae (palm family)

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

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With its many uses, coconut is often called the “tree of life.”

### IN BRIEF

**Distribution** All tropical and subtropical regions.

**Size** Height at 40 years typically 20–22 m (65–72 ft); canopy has a diameter of 8–9 m (26–30 ft).

**Habitat** Usually found sea level to 150 m (490 ft), but will grow at 0–600 m (0–1970 ft) near the equator; rainfall 1500–2500 mm (60–100 in).

**Vegetation** Associated with a wide range of coastal species as well as cultivated species inland.

**Soils** Remarkably adaptable to a wide range of soil types as long as waterlogging does not occur within 1 m (3.3 ft) of the surface.

**Growth rate** Moderate, 30–50 cm (12–20 in) in height annually during the first 40 years of growth.

**Main agroforestry uses** Coastal stabilization, windbreak, overstory, and many others.

**Main uses** Staple food, wood, handicrafts, etc.; thought by many to be the “world’s most useful plant.”

**Yields** 50–80 fruits per palm/year on mature tree; optimal annual yields of 2–2.5 mt copra/ha (0.9–1.1 t/acre) can be achieved.

**Intercropping** Compatible with many agricultural species, as well as animal grazing.

**Invasive potential** There is no danger of coconuts being invasive, as the spread inland from its natural habitat can only be affected by humans. The large size of the seed and low numbers produced per palm also make its spread easy to control.

## INTRODUCTION

The coconut palm (*Cocos nucifera*) is found throughout the tropics, where it is interwoven into the lives of the local people. It is particularly important in the low islands of the Pacific where, in the absence of land-based natural resources, it provides almost all the necessities of life—food, drink, oil, medicine, fiber, timber, thatch, mats, fuel, and domestic utensils. For good reason, it has been called the “tree of heaven” and “tree of life.” Today it remains an important economic and subsistence crop in many small Pacific island states.

Coconut is believed to have its origins in the Indo-Malayan region, from whence it spread throughout the tropics. Its natural habitat was the narrow sandy coast, but it is now found on soils ranging from pure sand to clays and from moderately acidic to alkaline. It is non-invasive, and people have been largely responsible for its spread, particularly inland from its natural habitat. It thrives under warm and humid conditions but will tolerate short periods of temperatures below 21°C (70°F). Its crown of feather-like fronds and bunches of large fruits carried atop long slender stems makes it easily recognizable.

The arrival of Europeans in the Pacific in the 19<sup>th</sup> century signaled the commercialization of the plant, and coconut oil was the first vegetable oil to appear in world trade. Its demand triggered the establishment of large coconut plantations in the European colonies around the world, including in Papua New Guinea (PNG), the Solomon Islands, Fiji, Vanuatu, and Samoa. However, its importance declined after WWII with the emergence of alternative vegetable oils touted to have superior health benefits. These included soybean, groundnut, sunflower, and canola oils. More recently, competition has come from another palm, the oil palm (*Elaeis guineensis*), which produces a similar oil from its kernel. Today, coconut oil has been relegated mainly to non-food uses in the developed countries but retains its importance in producing countries for traditional uses. It continues to have an important role in subsistence agriculture in that it is well suited to mixed cropping and provides not only most of life’s necessities but also, in many Pacific islands, food for livestock such as pigs and poultry. Coconut oil and other products are also making a comeback commercially in both natural foods and cosmetic industries.

## DISTRIBUTION

### Native range

Coconut is native to coastal areas (the littoral zone) of Southeast Asia (Malaysia, Indonesia, Philippines) and Melanesia. In prehistoric times wild forms (niu kafa) are believed to have been carried eastward on ocean currents to the tropical Pacific islands (Melanesia, Polynesia, and Micronesia) and westward to coastal India, Sri Lanka, East Africa, and tropical islands (e.g., Seychelles, Andaman, Mauritius) in the Indian Ocean. In these regions, the palms were able to establish themselves on sandy and coralline coasts. Coconut is either an introduction or possibly native to the Pacific coast of Central America.

### Current distribution

The coconut palm has wide pantropical distribution. It is a ubiquitous sight in all tropical and subtropical regions 23° north and south of the equator. It is also found outside these latitudes, where it will flower, but fruits fail to develop normally. It is believed that Polynesians migrating into the Pacific 4500 years ago brought with them aboriginal selections (niu vai). At about the same time, people from Indo-Malaya were colonizing the islands of Micronesia. Malay and Arab traders spread improved coconut types west to India, Sri Lanka, and East Africa about 3000 years ago. Coconuts were introduced into West Africa and the Caribbean (including the Atlantic coast of Central



**Coconut palms growing on the foreshore of a Pacific island beach. Floating nuts would have been deposited just above the high water mark by large waves, where they then became established.** PHOTO: E. CHAN

America) during the 16<sup>th</sup> Century by European explorers. Through the involvement of people, the palm spread inland and is now grown over a wide variety of soil types and up to an altitude of 600 m (1970 ft) at the equator. It is an important plant in the lives and economies of people in the following countries:

**Southeast Asia** Burma, Indonesia, Malaysia, Philippines, Singapore, South China (Hainan), Thailand, Vietnam

**Indian Subcontinent, Indian Ocean** Bangladesh, South India, Sri Lanka, and islands of Andaman, Nicobar, Seychelles

**Africa** Cameroon, Ghana, Ivory Coast, Kenya, Madagascar, Mozambique, Nigeria, Tanzania

**Central America/Caribbean** Brazil, Ecuador, Jamaica, Mexico, Trinidad and Tobago, Venezuela

**Melanesia** Fiji, Papua New Guinea, Solomon Islands, Vanuatu

**Polynesia** Cook Islands, Hawai'i, Kiribati, Line Is, Nauru, Niue, Samoa, Tonga, Tuamotu Archipelago, Tuvalu, Society Is., Tokelau, Tuvalu

**Micronesia** Palau, Chuuk, Guam, Northern Mariana Islands, Pohnpei, Yap, Kiribati

Coconuts are found on the tropical coast of Australia but are more of a curiosity with ornamental value. Beyond 23° N and S, coconuts are grown as an ornamental in Florida and even as far south as Brisbane (26° S) Australia.

## BOTANICAL DESCRIPTION

The following description applies to the Tall variety of coconuts, which is the dominant type grown the world over.

### Preferred scientific name

*Cocos nucifera* L.

There are no other known species in the genus *Cocos*.

### Family

Arecaceae (palm family)

### Subfamily

Cocoideae

### Non-preferred scientific names

*Palma cocos* Miller

### Common names

coconut, coconut palm (English)

*ha'ari* (Society Islands)

*iru* (Palau)

*lu* (Yap, Kosrae)

*ni* (Pohnpei, Marshall Islands)

*niu* (Polynesia, Papua New Guinea, Fiji)

*niyog* (Guam)

*nizok* (N. Mariana Islands)

*nu* (Chuuk, Cook Islands)

*te ni* (Kiribati)

The local names for coconut (*niu* in Polynesia and Melanesia, *niyog* in the Philippines and Guam) are derived from the Malay word *nyiur* or *nyior*. This is often cited as proof that the species originated in the Malay-Indonesian region.

### Other regions

*coco da Bahia, coco da India, coqueiro de Bahia* (Portuguese)  
*coco, coco de agua, cocotero, palma de coco, palmera de coco* (Spanish)

*coco, cocos, cocospalm, klapperboom* (Dutch)

*coco, cocotier, cocoyer, coq au lait, noix de coco* (French)

*Kokospalme* (German)

*kelapa, nyior* (Malaysia/Indonesia)

*niyog* (Philippines, Tagalog)

### Size

A crown of fronds is borne on a single unbranched stem with aerial growth from a single growing point. A 40-year-old palm typically attains a height of 20–22 m (66–72 ft), and an 80-year-old palm may attain a height of 35–40 m (115–130 ft). The canopy has a diameter of 8–9 m (26–30 ft).

### Form

The fronds in a mature healthy palm describe a sphere and are evenly distributed in all directions from the growing tip. In heavily bearing palms, the weight of nuts may push down on the horizontal fronds, resulting in an X-shaped canopy in which no fronds are held in a near-horizontal position.

### Flowers

#### Description of flower

The coconut palm is monoecious, i.e., with male and female flowers on the same inflorescence, called a spadix, that develops within a woody sheathe or spathe. At flowering, the spathe splits lengthwise to expose the spadix. Each spadix consists of a main axis 1–1.5 m (3.3–5 ft) in length with 40–60 branches or spikelets bearing the flowers. Each spikelet carries from zero to three female flowers (“buttons”) at its base and several hundred male flowers above. Thus a spadix will have several thousand male flowers but only

40–60 buttons. The male flower has six perianth segments surrounding six stamens. The larger female flowers are globose and consist of six perianth segments in two whorls, a tricarpelate ovary and trifold stigma. Following pollination, only one carpel develops into the seed, the other two aborting. The perianth persists at the base of the mature fruit.

Anthesis is usually completed before the female flowers are receptive, encouraging cross-pollination. However, pollination can occur between flowers of successive spadices on the same palm. Under favorable growing conditions, first flowering occurs about 4–5 years after planting.

### Seasonality

Once a palm reaches maturity, a spadix (flower spike) is produced in every leaf axil. Between 12 and 15 spadices are produced throughout the year at fairly regular intervals, although drought conditions can delay the emergence of the spadix or cause it to abort. The number of female flowers per spadix varies. Since the floral primordia are initiated 12 months before the spadix emerges, the number is correlated to the growing conditions (weather, nutrition) 12 months prior to emergence.

### Leaves

Until about an age of 1 year, leaves remain entire. Thereafter the leaves (called “fronds”) are progressively more pinnate. The widely recognized coconut leaves are peripinnate (even-pinnate) with 200–250 linear-lanceolate leaflets arranged in a single plane on either side of the rachis. Fronds are 4.5–5.5 m (15–18 ft) in length, with the petiole making up a quarter of its length. Leaflets are 1.5–5 cm (0.6–2 in) wide and 50–150 cm (20–60 in) long. The expanded base of the petiole provides firm attachment for the frond to the stem. The petiole and rachis may be green or bronze, which is indicative of the fruit color. Talls in their prime produce about 12–18 leaves per year, and Dwarfs produce 20–22 leaves per year. As leaves senesce about 2.5 years after unfolding, this means Talls have 30–35 leaves in their crown at any given time.



**Top: Inflorescence showing spikelets, some bearing developing fruits at their base and all bearing or having borne hundreds of male flowers. Bottom: Fruit in different stages of development.** PHOTOS: C. ELEVITCH

### Fruit

#### Fruit description

The fruit is a fibrous drupe. It consists of, from the outside in, a thin hard skin (exocarp), a thicker layer of fibrous mesocarp (husk), the hard endocarp (shell), the white endosperm (kernel), and a large cavity filled with liquid (“water”). When immature, the exocarp is usually green,

sometimes bronze. Wide variation in fruit shape and size exist within types and populations. Fruit shapes vary from elongated to almost spherical and weigh between 850 and 3700 g (1.9–8.1 lb) when mature.

**Time to bearing**

It is not unusual for the first one or two inflorescences to carry only male flowers, with the number of female flowers increasing with age. From pollination, it takes about 12 months for the fruit to mature. The first mature fruits can be produced 5–6 years from planting. Fruits are produced throughout the year but where rainfall is seasonal, more fruits are produced in some months than others.

**Seeds**

The seed comprises the dark brown shell and kernel. The surrounding husk, which is brown and dry at maturity, always remains intact. Fruits harvested for planting are usually referred to as seednuts to differentiate them from those for non-propagation uses such as drinking, consumption, and copra. Seednuts are similar in shape to the fruit but are correspondingly smaller and weigh less due to the drying out of the husk and partial loss of water from the cavity. The nut has three micropyles or “eyes,” one of which is soft and indicates the position of the viable embryo embedded in the kernel. A nut may have more than one viable embryo, but this is rare. About 50–80 fruits per year are produced on a bearing palm.

**Modes of dissemination**

The seeds are spread by water and people. The ability of some nuts to survive up to 120 days afloat in the sea and germinate when they make landfall is the natural means by which the species could spread far from its origin without the assistance of man. However, its spread in this way is limited to the coasts. Although minor compared to water

**Hawaiian names for stages of coconut fruit development (after Handy and Handy 1972)**

Name	Meaning
‘ō‘io	unripe nut with jelly-like translucent flesh
hao hao	maturing nut with shell still white and flesh soft and white
‘ili kole	half-ripe nut, not good for extraction of cream, meat eaten raw with red salt and poi
niu o‘o	nut mature but husk not dried
niu malo‘o	nut mature, husk dry, water still present, best stage for planting
niu ō ka‘a	old nut with no water and flesh separated from shell, oil is extracted at this stage

and people, by bouncing and rolling after a fall of 10 to 20 m (33–66 ft), seeds can move as much as 10 m (33 ft) from the mother tree, often inland. The coconut, however, primarily owes its spread inland and pantropical distribution to people.

**Rooting habit**

As a monocot, the palm has no taproot but instead produces adventitious roots from the base of the stem. There are 2000–4000 adventitious roots about 1 cm (0.4 in) in diameter per palm. The depth of rooting depends much on the physical characteristics of the soil and the depth of the water table. While roots can grow as deep as 5 m (16 ft) in well drained sandy soils, most of the roots are to be found within the top 1.5 m (5 ft) of soil. Laterally, they normally spread 6 m (20 ft) but can grow as far as 30 m (100 ft) from the base in optimal conditions. Decayed roots are regularly replaced by new roots that emerge from the basal stem.

**GENETICS**

**Known varieties**

There are two distinct types according to size and stature of the palm—Talls and Dwarfs. Talls are by far the more commonly grown variety around the world. Talls are cross-pollinated and are thus highly variable, as seen in the wide variation in characteristics such as size, shape, and color of the fruit as well as fruit composition (thickness of husk, weight of endosperm), and yield. Dwarfs, on the other hand, are largely self-pollinated and thus are genetically more homogeneous. This is reflected in the more uniform appearance of the different dwarf types.

**Talls**

Talls fall into two main types. The first is niu kafa, thought to be the wild type and characterized by elongated, triangular-shaped fruits with very small elongated nuts and a high husk-to-nut ratio. Niu kafa was much valued by the early Polynesians for its long fibers used in making braided cordage known as “sennit.” Not presently grown, niu kafa has been displaced by the second type of Talls, the domesticated, large-fruited niu vai. Characteristics of the wild type can still be found in natural stands of coconuts. A whole range of nut sizes and shapes exist between the two extremes of niu kafa and niu vai.

Of the Tall varieties, those that have evolved in isolation from a narrow introduction base are more homogeneous and have become important in breeding programs to produce improved planting materials. Talls are named after the locality, island, or country in which they are found, in-

cluding homogeneous types such as ‘West African’, ‘Rennel’ from the Solomon Islands, and ‘Tagnanan’ from the Philippines. Characteristics that have been used to classify tall varieties include the floral biology, nut physiology, and germination time.

### Dwarfs

Dwarfs are smaller in stature and produce smaller nuts but in greater numbers. Their small stature makes them popular for homegardens, parks, and roadsides. Dwarf varieties are characterized by the immature fruit color and named after their country of origin, e.g., ‘Red’, ‘Yellow’, and ‘Green Malayan’, ‘Cameroon Red’, and ‘New Guinea Brown’. As the name suggests, Dwarf palms are smaller in size and stature than the Talls. The stems are slender and, unlike the Talls, do not form boles at the base. They flower and bear significantly earlier than the Talls and produce a higher number of smaller nuts. Dwarfs come into bearing at 3 years compared to 5 years for the Talls. Because of their smaller stature, homogeneity, and precocity, they are used in hybridization with Talls. Their smaller size allows for higher-density plantings, but dwarfs do not adapt to varying conditions as well as the Talls.

Distinct from the above dwarf varieties is the ‘Niu Leka Dwarf’ from Fiji, also known as ‘Samoan Dwarf’ in Hawai‘i. Its stem is thicker and shorter, but unlike the other dwarf varieties, forms a bole at its base. It has short stiff fronds and large nuts.

It is interesting to note that early germinators (Talls) are found in the Indo-Malayan region where coconuts are thought to have originated. Whether coconuts were disseminated naturally on ocean currents or by man, slow-germinating nuts would have had a better chance at sur-

## COCONUT DIVERSITY

The illustration on the opposite page shows the wide range found in fruit size, color, shape, and husk thickness as well as variation in kernel and cavity size. Varieties shown are as follows, from left to right. The country where each photograph was taken is noted in parentheses, if not the country of origin. ILLUSTRATION COURTESY R. BOURDEIX © 2005 EDITIONS DIVERSIFLORA AND CIRAD

### Top row

1. ‘Papua Yellow Dwarf’, PNG
2. ‘Tahiti Red Dwarf’, French Polynesia (Côte d’Ivoire)
3. ‘Madang Brown Dwarf’, PNG (Côte d’Ivoire)
4. ‘Cameroon Red Dwarf’, Cameroon (Côte d’Ivoire)
5. ‘Spicata Tall’, Samoa
6. ‘Rotuman Tall’, Fiji (Côte d’Ivoire)
7. ‘Rennell Tall’, Solomon Islands (Côte d’Ivoire)

### Middle row

1. ‘Niu Afa Tall’, Samoa
2. ‘Comoro Moheli Tall’, Comoro Island (Côte d’Ivoire)
3. ‘Sri Lanka Tall’, Ambakelle, Sri Lanka (Côte d’Ivoire)
4. ‘West African Tall’, Akabo, Côte d’Ivoire
5. ‘Tuvalu Tall’, Fuafatu, Tuvalu
6. ‘West African Tall’, Mensah, Côte d’Ivoire
7. ‘Miccro Laccadives Tall’, India (Côte d’Ivoire)

### Bottom row

1. ‘Vanuatu Tall’, Vanuatu (Vanuatu)
2. ‘Malayan Yellow Dwarf’, Malaysia (Côte d’Ivoire)
3. ‘Malayan Tall’, Malaysia (Côte d’Ivoire)
4. ‘Tagnanan Tall’, Philippines (Côte d’Ivoire)
5. ‘Tampakan Tall’, Philippines (the Philippines)
6. ‘Kappadam Tall’, India (Côte d’Ivoire)

### A simplified classification of coconut varieties

Variety	Main Characteristics	Germination	Examples
<b>Talls</b>	Thick stem with swollen base (bole). Late flowering (5–6 yr from outplanting). Little or no overlapping of male and female phases of an inflorescence encouraging outcrossing.	Early	‘Malayan Tall’, ‘Bali Tall’, ‘Tagnanan Tall’, ‘San Ramon Tall’
		Late	‘West African Tall’, ‘Rennel Tall’, ‘Samoan Tall’, ‘Polynesian Tall’, ‘Solomon Tall’, ‘Vanuatu Tall’, ‘Gazelle (PNG) Tall’, ‘Jamaica Tall’, ‘Panama Tall’.
<b>Dwarfs</b>	Slender stem with short internodes. Bole slight or absent. Early flowering (3 yr from outplanting). Considerable overlapping of male and female phases of an inflorescence resulting in self-pollination.	Intermediate	‘Malayan Red’, ‘Yellow’ and ‘Green’ Dwarfs, ‘Cameroon Red’ Dwarf, ‘Nias Green’ and ‘Nias Yellow’ Dwarfs, ‘PNG Brown’ Dwarf, ‘Samoan Yellow’ Dwarf.
		Intermediate	‘Niu Leka’, also known as ‘Fiji Dwarf’, and ‘Samoan Dwarf’



viving those long journeys. Early-germinating coconuts meant that in Malaysia, Indonesia, and the Philippines, ripe nuts were picked off the palms frequently, about once a month. Germination would mean both a loss of kernel (hence copra) as well as a loss of quality. In areas with slow germinating nuts such as PNG, the Solomon Islands, and Samoa (and probably other Polynesian islands), nuts are allowed to fall naturally and picked off the ground about once every 2 months throughout the year.

## ASSOCIATED PLANT SPECIES

The sandy coast is a hostile environment for plant life and does not support populations of many large plants (except coconuts). The native vegetation on sandy shores are comprised mainly of vines, grasses, and sedges is of salt spray and occasional flooding by seawater.

### Associated native species commonly found

The most common associated plant are ground creepers,

beach morning glory (*Ipomoea pes-caprae*) and beach pea (*Vigna marina*), both of which are found throughout the tropics and often dominate the sandy shores. Less common morning glory species include *Ipomoea littoralis* and *I. macrantha*. Commonly found in association with the creepers are the grasses *Lepturus repens* and *Paspalum vaginatum* and sedges such as *Fimbristylis cymosa*.

### Species commonly associated as aboriginal introduction in Pacific islands

The best-known introductions by the Polynesians and Micronesians, in addition to coconuts, are the breadfruit (*Artocarpus altilis*), banana (*Musa* spp.), yam (*Dioscorea* spp.), taro (*Colocasia esculenta*), and sugarcane (*Saccharum officinarum*). These were presumably grown together further inshore, as they are today. Other useful plants introduced by the Polynesians into the Pacific include candlenut (*Aleurites moluccana*), bamboo (*Schizostachyum glaucifolium*), wild ginger (*Zingiber zerumbet*), ti (*Cordyline fruticosa*), and paper mulberry (*Broussonetia papyrifera*).



Left: Coconut growing with breadfruit, pandanus, and ti, Kona, Hawai'i. Right: Taro growing under coconuts, Tongatapu, Tonga. PHOTOS: C. ELEVITCH



## Species commonly associated in modern times or as recent introduction

Recent introductions grown as an understory crop include the root crops giant taro (*Alocasia macrorrhiza*) and swamp taro (*Xanthosoma* spp.) and a host of other food crops and fruit trees. Cocoa (*Theobroma cacao*) and to a lesser extent robusta coffee (*Coffea canephora*) are grown as cash crops under old coconut palms in Melanesia and Samoa. Grazing cattle under coconuts is also an important Pacific island agroforestry practice.

## ENVIRONMENTAL PREFERENCES AND TOLERANCES

### Climate

A year-round warm and humid climate favors the growth of coconut. A mean annual temperature of 27°C (81°F), an evenly distributed rainfall of 1500–2500 mm (60–100 in) per annum, and relative humidity above 60% provide the ideal climatic conditions for the vigorous growth and yield of the palm. A permanent water table within easy reach of the coconut roots can offset inadequate rainfall, while amounts in excess of 2500 mm (100 in) could result in diseases of the fruit and leaves. Such conditions are normally found 20° north and south of the equator. Periods with mean daily temperatures below 21°C (70°F) adversely affect the growth and yield of the palms. Frost is fatal to seedlings and young palms when the growing point is still close to the ground. At the equator, coconut can grow and yield well up to an altitude of 600 m (1970 ft) but will only do so at sea level at latitude 23°. At the extremes of the latitudinal range, coconut only grows well on the coast of large land masses (e.g., east coast of Australia, Africa, South America, etc.) and on islands where the sea exerts a moderating influence on temperature and humidity.

### Elevation range

0–600 m (0–1970 ft) (near the equator)

### Mean annual rainfall

1500–2500 mm (60–100 in)

### Rainfall pattern

Coconut grows in climates with summer, winter, bimodal, and uniform rainfall patterns.

### Dry season duration (consecutive months with <40 mm [1.6 in] rainfall)

One month in sandy inland areas, and 3 months in clayey

inland areas. Palms will survive longer droughts, but yields will be severely depressed.

### Mean annual temperature

21–30°C (70–86°F)

### Mean maximum temperature of hottest month

28–37°C (81–99°F)

### Mean minimum temperature of coldest month

4–12°C (39–54°F)

### Minimum temperature tolerated

0°C (32°F)

### Soils

This palm has remarkable ability to adapt to a wide range of soil types. Although coarse sand is its natural habitat, best growth is obtained on deep soils with good physical and chemical properties. It is thus widely grown on loams as well as clays that are well drained.

### Soil drainage

It requires free drainage.

### Soil acidity

It tolerates alkaline soils up to pH 8 (on coralline atolls) and acid soils with pH 4.5 or higher. The ideal pH range is 5.5–7.

### Soil texture

Coconut grows on a wide range of light, medium, and heavy soils.

### Special soil tolerances

It tolerates saline and infertile soils. It grows on coralline atolls, but poorly, as these soils are shallow and infertile.

### Tolerances

#### Drought

Coconut tolerates drought poorly. Symptoms include desiccation of older fronds, spears (emerging fronds) failing to open normally, and shedding of young nuts.

#### Full sun

It thrives in full sun.

#### Shade

Coconut grows under high levels of shade, but yields are severely affected; it does best when not shaded.

## Fire

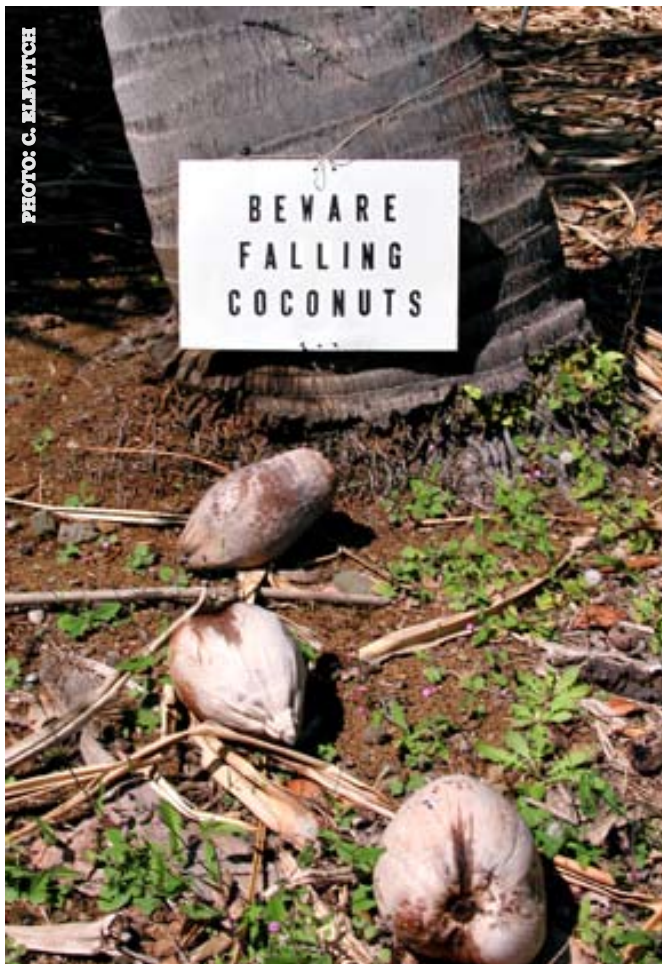
Young palms will succumb to fire, but mature palms will often survive if the canopy is far enough above the fire to escape the flames.

## Frost

It has poor tolerance of frost. Severe frost is fatal to seedlings and young palms.

## Waterlogging

Coconut does not like waterlogging within 1 m (3.3 ft) of surface, and will not survive more than 2 weeks of surface waterlogging.



## WARNING

Falling coconuts are very hazardous and present a life-threatening danger, especially in homegardens, on beaches, and other places where people spend time. One way to reduce the danger is by regularly harvesting the nuts before they ripen and fall to the ground.



Cutting off the growing tip will kill the plant, such as here where a young seedling was cut off because it sprouted in an undesirable location. PHOTO: C. ELEVITCH

## Salt spray

Coconut is able to withstand salt spray very well.

## Wind

It is able to withstand cyclonic (hurricane) winds if roots are well anchored. Flexibility in the stem and fronds reduces the cross-sectional area presented by each tree and thus reduces the drag forces they must endure. In heavy storms, fronds facing or perpendicular to the direction of the wind tend to snap off close to the base. This reduces drag forces tremendously and helps coconuts survive storms. Most coconuts survive severe storms, although some are uprooted where there is not sufficient rooting depth. In some varieties a percentage of trees will snap off at the base of the root crown.

## Abilities

### Regenerate rapidly

In favorable conditions (full sun, plenty of moisture, etc.), sprouting nuts will revegetate an area relatively quickly.

### Self-prune

Senescent fronds, the fruit stalk, and ripe nuts are shed.

### Coppice

It will die if the growing tip is cut or damaged. However, it will regrow even if many fronds are damaged or cut and even after transplanting as long as much of the root system is preserved.

### Other

Once established, it can grow on wave-washed beaches where most other plants would not survive.



A juvenile at the onset of bearing age, showing rapid vegetative growth.

PHOTO: C. ELEVITCH

## GROWTH AND DEVELOPMENT

The most rapid growth occurs between the second and fifth year in the life of a coconut palm. A stem appears under the crown after 3–4 years of growth, and stem elongation initially is 30–50 cm (12–20 in) annually but slows down in older palms (above 40 yr). Fruit production increases after the sixth year at the expense of vegetative growth. Thereafter, growth is fairly constant as yields are sustained for the next 40 years, and palm age can be roughly gauged from the length of the stem. Dry matter production in bearing palms has been estimated at 50–80 kg (110–176 lb) per year.

### Flowering and fruiting

Under favorable conditions, Talls flower 4–5 years from outplanting, and it takes 11–12 months for the fruit to ripen. Usually only 30–40% of fruits set are carried to full term; most abort within 3 months of being pollinated. The palm produces 12–15 inflorescences (spadices) per year at fairly

regular intervals, but the number of female flowers per spadix varies.

### Yields

Yields vary a great deal from place to place. Generally, commercial monocrop plantings out-yield those in homegardens. Higher yields are obtained in commercial plantings because of the higher levels of inputs (management, maintenance, fertilizers, etc). Annual yields range from 15–20 kg (33–44 lb) copra/palm or, depending on the fruit size, from 50 to 80 fruits per palm.

### Reaction to competition

Coconut competes well with most plants for nutrients and water, but aggressive grasses such as *Imperata cylindrica* retard growth and yield. Pasture grasses (including *Brachiara* spp. and *Ischaemum aristatum*) are commonly grown under old palms for cattle grazing. Coconuts grow poorly in shade. Depending on the amount of shade, seedlings planted under older palms or other trees can take up to 10 years to flower and will yield poorly.

## PROPAGATION

Coconuts are propagated solely by seed. The seednut has no dormancy and requires no special treatment to germinate. However, germination speed of seednuts varies within and among ecotypes and varieties. Some Tall varieties (e.g., Malayan Talls) germinate while still on the palm, while others like the West African Tall and most Pacific populations take up to 6 weeks.

Clonal propagation of such a genetically variable species would have obvious advantages. Since the plant does not multiply vegetatively (only very rarely does it produce vegetative shoots), attempts at clonal propagation through tissue culture have so far met with limited success. Embryo culture is employed in country-to-country exchange of planting material for breeding purposes.

### Seed collection

Seednuts may be collected throughout the year. The seeds are mature when the husk begins to lose moisture, the epicarp starts to turn brown and liquid is partially lost from the nut cavity, all of which begins to occur 11 months after pollination. Fruits fall to the ground when fully ripe after

12 months. Ripe fruits may be picked off the ground, but if it is important to know the identity of the female parent, as is the case in seed production, fruits are picked directly from the palm when the fruit is starting to turn brown. In addition to the browning of the epicarp, loss of liquid from the nut cavity when the fruit is ripe is indicated by a sloshing sound when the fruit is shaken.

Open-pollinated seednuts should be collected from healthy palms with particular attention given to heritable characters such as fruit size and amount of husk and kernel per fruit. High-yielding varieties are produced by crossing genetically disparate types with good fruit characteristics. Such hybrids may be crosses of Dwarf × Tall or Tall × Tall types. Production of such seednuts is quite involved and usually takes place in specially designed, isolated seed orchards.

### Seed processing

Within a variety or population, the speed of germination indicates vigor, precocity (early sexual maturity, i.e., flowering), and high yield; in other words, the early germinators are the best performers, whereas the slowest germinators are usually poor and are discarded. In order to exploit the speed of germination as a selection criteria, it is important to ensure that seednuts sown together be of equal ripeness. If hybrids are used, off-types need to be culled. For practical purposes, germination is indicated by emergence of the shoot through the husk, although emergence through the eye of the endocarp would have occurred 4–6 weeks earlier. Because of the size of the seednut there is no danger of contamination with weed seeds.

### Seed storage

Coconuts have no dormancy period and it is not advisable to store seednuts longer than necessary. With early-germinating types such as Malayan Talls, it is not advisable to store for any length of time. Slow germinators, such as the West African Talls and most Polynesian types, may be stored for up to a month with no ill effects as long as the water in the nut cavity does not dry out. If seednuts are to be stored for longer periods, they should be picked at 11 months of age when the epicarp is starting to turn brown and stored in a dry cool place. If fruits are picked half brown, they are stored under shade until the epicarp is completely brown before sowing.

### Pre-planting treatments

No treatment is required. Some cultivars (e.g., ‘Malayan Red’) are susceptible to infection by the fungus *Marasmiellus* spp. during germination. Mixed results were obtained

with fungicide treatments. Some pre-sowing treatments of seednuts include soaking in water and removing a slice of husk overlying the “eyes” of the nut. However, such refinements are unnecessary and only add to labor costs.

### Growing area

If large quantities of seednuts are involved, a two-stage nursery is used to facilitate seedling selection. The first stage is the germination bed, which allows selection based on the speed of germination. The second stage is the nursery where the seedlings are grown to an acceptable size for outplanting and where plants with vegetative abnormalities are culled. The germination bed should be partially shaded (up to 50%) to prevent the nut water from evaporating before germination occurs, particularly with slow-germinating types. The nursery should be in full sun where seedlings may be raised in planting bags or in-ground. Sites used for germination beds and nurseries should be well drained. Seedlings in the nursery are spaced out at 60 by 60 cm (24 by 24 in).

### Germination

Seednuts are laid flat in rows with 2/3 of the nut buried in coarse sand or soil to reduce the loss of nut water through evaporation (especially important for slow germinating varieties). The seednuts are sown right next to each other. A path every four rows will facilitate removal of germinating seednuts at weekly or fortnightly intervals. Depending on the type, germination can occur 4–6 weeks after sowing and continue over an 8-week period, by which time 75–80% of the seednuts should have germinated. Regular watering every other day during this period is important to prevent loss of water from the nut cavity through evaporation.

Germinating nuts are removed at regular intervals (weekly



**Germinating seednut ready for transplanting.** PHOTO: C. ELEVITCH

or fortnightly) and transferred to the nursery. A good time to do this is when the first compound leaf (which resembles a rabbit's ears) is fully developed and judged to be normal. Discards include those with twisted, multiple, and diseased shoots. Germinating nuts are pried out, trimmed of exposed roots, and then planted in the nursery (in-ground or container) with the soil covering two-thirds of the nut.

## Media

**Germination beds** Coarse sand to well drained friable soils are best to ease the lifting of germinating seednuts.

**Nursery** Well drained and friable soils are suitable particularly where seedlings are raised in-ground. Raised beds are recommended for in-ground nurseries if soil drainage is impeded. Black polyethylene planting bags 45 x 45 cm (18 x 18 in) (flat dimensions) hold about 30 liters (9 gal) of potting medium when filled and are suitable for holding seedlings for up to 10 months. While advantageous, (ability to provide optimal growth medium, minimize transplant shock, flexibility in time of planting out, and earlier higher yields), use of planting bags is an added cost (of bag, filling, and transport of seedlings) and smallholders sometimes prefer to raise seedlings in-ground.

## Time to outplanting

The rate of growth depends on whether seedlings are raised in planting bags or in-ground (field nursery). If raised in-ground, seedlings should be outplanted not later than 6 months old; if raised in planting bags, at 8–10 months. Roots that have developed outside the planting bags are trimmed. In the case of seedlings that are raised in-ground, seedlings are carefully lifted and the exposed roots trimmed. However, the greater the amount of roots pruned off, the greater the transplanting shock.

## Approximate size at time of outplanting

Six-month-old seedlings have 7–8 leaves and a height of about 80 cm (31.5 in) while 10-month-old seedlings will have 10–11 leaves and a height of 1.5 m (5 ft).

## Guidelines for outplanting

Nursery operations are planned so that outplanting coincides with the onset of the rainy season. Under favorable conditions, planting shock is minimized and survival rate is close to 100%.

## POTENTIAL DRAWBACKS

As a commercial crop, the long period from planting to full bearing has discouraged planting. The price of the pri-



**Symptoms of coconut heart rot.** PHOTO: S. C. NELSON

mary product, copra (dried coconut kernel), is subject to world commodity markets, and the present price for copra has been depressed in the face of competition from other vegetable oils.

## Potential for invasiveness

There is no danger of coconuts being invasive since its spread inland from its natural habitat can only be effected by humans. The large size of the seed and low numbers produced per palm also make its spread easy to control.

## Pests and diseases

Coconuts are affected by a wide range of pests and diseases, but none are more potentially damaging than those caused by viruses, viroids, and mycoplasmas. The best known is lethal yellowing disease. First identified in Jamaica, it is caused by a mycoplasma. The disease has spread to other countries in the Caribbean and Central America as well as Florida. Similar diseases have been found in palms in West Africa, Tanzania (East Africa), part of southern India, and some islands off the coast of Indonesian Kalimantan.

Cadang-cadang in the Philippines (tinangaja in Guam) is a lethal disease caused by a viroid (CCCvd), while foliar decay in Vanuatu is caused by a virus. Strict quarantine regulations governing the movement of planting material between countries have largely contained these diseases.

Fungal diseases of the frond are common, and while some varieties may be more susceptible to infection, its incidence is usually indicative of poor plant health and/or favorable conditions for the disease. Bud rot caused by the fungus *Phytophthora palmivora* is a concern, as it is usually fatal to the palm. While common, its incidence is usually low, although serious outbreaks of the disease have been reported from time to time. Cool, humid conditions favor its spread. The fungus has a pantropical distribution and besides the coconut palm also infects other palms such as oil palm (*Elaeis guineensis*) and betel nut (*Areca catechu*) as well as crops such as cocoa (fruit and stem), breadfruit (fruit), papaya (fruit), and black pepper (roots). In Hawai'i, a related fungus (*Phytophthora katusurae*) causes coconut heart rot. This disease has been reported to have killed up to 15% of the coconut palms in certain regions of Hawai'i.

Varietal differences in reaction to diseases and pests do occur. While the introduced Malayan Red Dwarf is more resistant to lethal yellowing than the local Talls in Jamaica, introduced varieties in Vanuatu were decimated by the foliar decay disease to which the local coconuts were resistant. A good example of a local variety becoming tolerant of a pest is to be found in PNG, where introduced Talls and hybrids were constantly attacked by rhinoceros beetles (*Oryctes rhinoceros* and *Scapanes australis*), but the local variety was left untouched.

### Host to crop pests/pathogens

Pests and pathogens of coconuts may also affect other palms, and vice versa, but not other crops. Economic palms such as the nipa (*Nypa fruticans*) and rattan (*Calamus* spp.) occupy different ecological zones and are thus unlikely to exchange pests and pathogens with coconut. In countries such as Malaysia, Indonesia, and PNG where oil palms have been grown in proximity to coconuts, some coconut pests (rhinoceros beetle and palm weevil) and diseases (*Ganoderma* root disease) have crossed



**Improving farm productivity by underplanting 40-year-old coconut palms with cocoa (*Theobroma cacao*) in Samoa. The cocoa is 18 months old and when mature will shade out the grasses and lay down a thick layer of leaf litter. Note the increased light penetration through the canopies of the old palms.** PHOTO: E. CHAN



**Taro and bananas growing under an old stand of coconuts, Tutuila, Samoa.** PHOTO: C. ELEVITCH

over. Betel nut (*Areca catechu*) and some ornamental palms are open to attacks by the pests and pathogens of coconuts grown nearby.



**Top: Coconut husks make long lasting mulch for many plants and work especially well for epiphytes such as orchids. Middle: Cattle grazing on pasture under mature coconuts. Bottom: Residue left after extracting coconut cream makes excellent feed for pigs and chickens. PHOTOS: C. ELEVITCH**

### **Other considerations in agroforestry**

Its relative intolerance of shade limits its usefulness in agroforestry. However, the increased light penetration in old stands (above 40 years old) allows a host of other crops to be grown under coconuts, including fuelwood species such as *Leucaena leucocephala* and *Acacia* spp. to be grown as understory trees.

## **AGROFORESTRY/ ENVIRONMENTAL PRACTICES**

### **Mulch/organic matter**

Coconut husks can be used as mulch. They are slow to decompose but are a good source of potassium. In low-rainfall areas in some countries (e.g., India and Sri Lanka), husks are buried in trenches to serve as water reservoirs during drought. Decomposed husk is placed in holes when planting coconut seedlings on sandy soils. Placed on the ground convex surface up, husks are commonly used as mulch around coconut seedlings and other plants to control weeds (Malaysia, PNG, Samoa). Fresh or dried leaves are also used for mulch. Shredded husk can also be used as mulch or in nursery potting mix.

### **Soil stabilization**

With its dense and widespread roots, coconut is used to protect sandy coasts against wave erosion.

### **Crop shade/overstory**

Coconut provides excellent overhead shade for crops requiring it. Its fixed canopy size provides a fairly constant level of shading, although this decreases with age. Besides food crops and fruit trees in homegardens, it has been successfully intercropped with cocoa and coffee (Malaysia, Indonesia, Samoa, PNG, Fiji). It may be grown at wider spacing to allow for greater light penetration, albeit at the expense of coconut yield.

### **Homegardens**

The coconut palm has a multitude of products, food and non-food, that are useful to the household. Its importance to residents in many small Pacific islands, especially atolls, cannot be overstated.

## Windbreaks

Coconut is one of the most wind-tolerant plants in the world. It makes an excellent windbreak tree. Because it has foliage only at the top, it should always be grown in a multi-row windbreak with other species that can protect from the wind below the coconut canopy.

## Silvopasture

Cattle are grazed under old coconuts in Philippines, Samoa, PNG, Vanuatu, and the Solomon Islands where the natural grasses have been replaced with improved species such as Batiki blue grass (*Ischaemum aristatum*) and Koroniva grass (*Brachiara humidicola*).

## Animal fodder

Mature nuts are split and pigs allowed to feed on the kernels, while shredded kernels are fed to pigs and poultry after the cream has been extracted for cooking. Expelled copra cake from oil mills, which has a protein content of 20% and residual oil content of 6–7%, is used in animal feeds.

## Woodlot

Shells, husks, spathes, empty bunch stalks, and petioles provide a ready and continuous source of fuel for the household.

## Host plant trellising

Pepper has been grown up trunks but not with much success. In Samoa, passion fruit vines were successfully grown on wires strung between coconut palms.

## Coastal protection

Coconuts can be used to stabilize sandy coastal areas, although its slow growth means it is 3–4 years before they are effective.

## Ornamental

The palm is a very popular ornamental, especially to give a place or locality a “tropical look.” Its drawback is that falling nuts pose a danger to humans and “de-fruiting” of palms is necessary to protect the public. Shorter and more colorful Dwarfs are also popular as ornamentals.

## USES AND PRODUCTS

The Indonesians have a saying that there is a use for the coconut palm for every day of the year. The mature kernel is eaten as food and fed to pigs and chickens. Shredded kernel is used in sweets and desserts in Indonesia and Malaysia and in chutneys in Sri Lanka and India. The cream

## COCONUT WATER—AN IDEAL DRINK

The clear liquid in the interior of a coconut is commonly referred to as “coconut water.” It is a refreshing and cool, acclaimed by many to be the “perfect drink.” In a healthy, undamaged coconut, the water is sterile. Its sodium and potassium content makes it an ideal drink for rehydration. During WWII, coconut water was used intravenously to treat patients suffering from blood loss when blood plasma was not available. It is a ready source of clean drinking water, especially after a natural disaster (cyclones, flooding). Characteristics of the water change as the coconut ages. A very young coconut (about 3–5 months, before the endosperm begins to form) has tasteless water that is somewhat astringent. Water from a mature coconut is slightly salty to the taste, although for coconuts grown well inland, the salty taste disappears. The best time to harvest a coconut for drinking is at age 6–7 months, just as the jelly-like endosperm begins to form. At this stage the water has maximum sweetness and low acidity. Nuts harvested at this age can be stored only 2–3 days before the water begins to sour.



A vendor prepares drinking coconuts for sale at market, Apia, Samoa. PHOTO: C. ELEVITCH

extracted from the shredded kernel is used in curries and sweets and in the Pacific islands for the flavoring of local dishes. The oil from the kernel is used in cooking, in oil lamps, in torches for illumination, to prepare ointments, and as hair oil. The water from immature nuts is drunk as a beverage throughout the tropics, and the jelly-like kernel is eaten. Husk fibers are made into ropes, and the whole husks and shells are used for fuel. Shells are also used as containers and drinking vessels. Sap obtained by tapping



the unopened spathe may be made into palm sugar or allowed to ferment into an alcoholic drink (toddy).

Mature green fronds are woven into baskets and mats, used as thatching for dwellings, and used to decorate houses. The midribs of leaflets are bundled together into brooms. Dried fronds, spathes, and empty bunch stalks are used for fuel.

### Staple food

Coconut cream is obtained by squeezing the grated kernel. It is used in cooking with taro, bananas, fish, etc., in the Pacific islands and with rice in Indonesia and Malaysia.

### Fruit

Jellylike young kernel of the immature nut is especially tasty, and a good food for babies. The sweet water from the nut is a popular and refreshing drink. The mature ker-

## HAWAIIAN COCONUT RIDDLES

(Neal 1965)

- ◇ Three walls and you reach water.
- ◇ A man with three eyes; he can cry out of only one.
- ◇ Something goes up brown and comes down white.
- ◇ My sweet water spring suspended in air.

nel is eaten fresh, or dried and grated for myriad dishes, cakes, and confections, but it is usually extracted for coconut cream in the Pacific. In Micronesia and atoll Polynesia, the young husk of some cultivars is eaten. In India and Sri Lanka, mature kernel is shredded and used in making chutneys. In Malaysia and Indonesia, shredded kernel is



Clockwise from left: Tava Taupu fashions a section of a coconut trunk into a drum at Pu'uhonua O Honaunau, Kona, Hawai'i. Lo'i Pepe Letoga quickly weaves fronds into a carrying basket, Uafato, Samoa. Sennit rope woven from coconut fiber. PHOTOS: C. ELEVITCH

used in a variety of local desserts. The haustorium (often called the “apple”) in the germinating seed is sweet and somewhat spongy and is a valued foodstuff in Polynesia and Micronesia.

### Leaf vegetable

The heart of the palm comprising the young tender shoots surrounding the bud (“coconut cabbage”) is a delicacy used in salads. Since harvesting it kills the palm, it is only available when palms are being felled.

### Beverage/drink/tea

Nut water from immature nuts (7–8 months) makes a refreshing drink. The ‘King’ coconut in Sri Lanka is prized for its extra sweet nut water, while a dwarf green variety in Thailand has nut water that is aromatic.

Obtained by tapping the unopened spadix, the sap is collected in a vessel and allowed to ferment into an intoxicating drink (“toddy” or “tuba”). The unfermented and fermented toddy and syrup are of considerable importance in Micronesia and on atolls; these are popular in India, Sri Lanka, Malaysia, Philippines, Tuvalu, and Micronesia. The toddy can be distilled to produce a strongly alcoholic drink (“arrack”). Freshly fermented toddy is used in place of yeast for making local bread.

### Honey

Bees are the main pollinators for coconuts, which produce copious quantities of flowers nearly continually. Coconut honey is of exceptional quality.

### Medicinal

The young leaves are chewed to a paste and applied to cuts to stop bleeding. Water from a young nut contains sugar and other nutrients and is sterile fresh out of a nut. This



Male flowers with ever-present attending bees. PHOTO: C. ELEVITCH

## DEFINITIONS

**Copra** The dried coconut meat (endosperm) from which oil is expelled. In ripe nuts, the endosperm contains about 50% water and 35–40% oil.

**Desiccated coconut** Finely shredded, bleached and dried coconut meat (endosperm). As it is directly consumed in confections (e.g., candy bars), stringent hygiene standards are maintained in its production.

**Coconut milk** White emulsion obtained by squeezing freshly shredded meat (endosperm) mixed with water.

**Coconut cream** Obtained by centrifuging coconut milk whereby the cream separates from rest of the milk (“skim milk”).

water is fed to infants with diarrhea and, in emergencies, used intravenously as a saline drip (Solomon Islands).

### Sweetener

Fresh sap from the inflorescence obtained in the same way as for toddy is boiled down to produce palm sugar (“jaggery”) that is popular in India, Sri Lanka, Vietnam, Indonesia, and Malaysia but not in the Pacific islands.

### Timber

The old stems are used for fence posts, poles, sawn timber, roofing shingles, and furniture. Treatment with chromated copper arsenate is necessary to prolong life, especially if used outdoors. It has become a specialty wood especially for furniture and flooring, but it is economically viable only if large scale plantings are available to provide an adequate source of old stems, e.g., in the Philippines, Solomon Islands, Samoa, and Vanuatu.

### Fuelwood

The shell is used dried or converted to shell charcoal for cooking or drying of kernels. Husks, spathes, empty bunch stalks and petioles—virtually all plant parts—can also be burned.

### Craft wood/tools

The trunk and shells are fashioned into carvings, kitchen utensils, and axe handles. In Hawai‘i, the base of the trunk has been used to make food containers and hula drums. In the Cook Islands, the hollowed-out trunk is used as a container in which “bush beer” is fermented.

### Canoe/boat/raft making

The wood is used for small canoe hulls and paddles.

### Fiber/weaving/clothing

Mature green fronds are woven into baskets, hats, mats, thatch, trays, fans, aquatic barriers, and all manner of plaited ware. The young leaves from a germinating nut are flexible and are used to make a foot harness tied between the feet for climbing coconuts. The unfurled immature leaves

are used for making skirts, body ornamentation, and baskets.

### Rope/cordage/string

Coir is the fiber obtained from the husk. The longest and finest fibers are spun into ropes, cordage, strings, and mats, while the thicker and shorter fibers are used in making brushes and as stuffing for seats and cushions.

### Wrapping/parcelization

Green fronds are woven into all sizes of baskets for carrying food and other goods. In Indonesia and Malaysia, fronds are woven into little baskets in which rice is cooked.

### Thatch/roofing/mats

Mature green fronds are commonly used as thatch for village dwellings in the Pacific islands. Coir is used for making door mats. Mid-ribs are stripped from the lamina and bundled to form a broom.

### Body ornamentation/garlands

The nut shells are fashioned into earrings, brooches, necklaces, and buttons.

### Tannin/dye

When traditional colorants for tapa cloth are mixed with coconut oil, the colors are deeper and longer lasting. The charred husk is used to make a black dye in Tokelau.

### Fragrance

In Hawai'i, the male flowers were heated in coconut oil to perfume tapa cloth. The bark is used to scent body oil.

### Cosmetic/soap/perfume

Oil, often scented with blossoms of the Tahitian gardenia (*Gardenia taitensis*) or ylang-ylang (*Cananga odorata*), is used in body massages and for the hair. The oil is also used in making soap.

### Oil/lubricant

Lauric oils, the dominant fatty acid (45–48%) in coconut oil, are obtained from kernels and used for cooking as well as in detergents, soaps, cosmetics, etc. The oily kernel is chewed and spat on the ocean to “calm” the water and see below the surface.



**Top:** A palm carrying hundreds of very small nuts. Known in Malaysia as “palm with a thousand nuts” (kelapa beribu ribu), it occurs only rarely and has only a curiosity value. PHOTO: E. CHAN **Bottom:** Branched coconuts are rare. This old coconut on Tongatapu, Tonga, has three branches with full tops loaded with coconuts. PHOTO: C. ELEVITCH



**Left: Kava (*Piper methysticum*) and bananas grown as an understory crop, Tongatapu, Tonga. Right: Mixed garden with breadfruit, vi (*Spondias dulcis*), coffee, and many other crops, Kona, Hawai'i.** PHOTOS: C. ELEVITCH

### **Illumination/torches**

The seed oil is used in lamps and torches. Traditionally in Hawai'i and elsewhere, bits of dry husk were used as tinder in making fire by friction. The coconut midrib was used to string oil-rich nuts, such as candlenut (*Aleurites moluccana*), for torches.

### **Boundary marker**

In Hawai'i, leaves were tied around coconuts as boundary markers, to ward off evil spirits, or as a sign of no trespassing (kapu). Specific trees or two trees planted together have served as boundary markers in Tuvalu.

### **Ceremonial/religious importance**

Coconuts, bananas, and kava were traditional religious offerings in Hawai'i. The flowers are used in connection with religious rituals in Tahiti. The water of immature nuts is considered a sacred offering to visitors in Kiribati, and is used in divination in Hawai'i. To commemorate events,

young coconut palms are bent to grow in odd shapes. Nuts are offered to deities in Hindu ceremonies.

### **Other**

The burlap-like sheath at the base of each frond is used for a filter/strainer or to squeeze medicinal plants or coconut oil. It's also used to wrap bait for deep-sea fishing or to wrap the root-ball of transplanted seedlings.

## **URBAN AND COMMUNITY FORESTRY**

The coconut palm is the most widely grown palm in tropical homegardens. Most of its parts find some use in the home. Its non-invasive nature, compact rooting habit, a non-branching stem and a crown limited in spread makes it very compatible with other plants in a park or street. More than any other plant, the coconut palm symbolizes the tropical coast. Falling nuts are a serious hazard, and fallen nuts and leaves (fronds) left on the ground are un-

sightly. The dwarf coconut with its variously colored fruits and smaller stature provides an attractive alternative to the tall types and is often more suitable for urban environments.

### Size in an urban environment

Tall cultivars generally reach 20–30 m (65–100 ft) with a canopy spread of 8–9 m (26–30 ft). Dwarf cultivars grow up to 10–15 m (33–50 ft) in height, with a canopy spread of 4.5–6 m (15–20 ft).

### Rate of growth in a landscape

Initially growth is rapid as new fronds progressively increase in length until they approach a maximum size for the palm. At an age of 3–4 years, plants may reach a height of 4.5–5.5 m (15–18 ft) to the tip of the tallest leaf, and a trunk begins to form at the base under the crown of leaves. Thereafter height is put on at the trunk at the moderate rate of 30–50 cm (12–20 in).

### Root system

Coconuts have a very dense, fibrous root system that is mostly within 1.5 m (5 ft) of the soil surface. Coconut roots do not damage foundations and rarely raise sidewalks, although the roots often do overgrow the edges of surface objects such as pavement. The root system is compatible with many other plants as evidenced by the large number of species that are successfully intercropped with coconut.

### Products commonly used in Pacific island households

One of the most useful plants, coconut provides numerous products commonly used in households. Perhaps the most common product in the Pacific is coconut milk (or cream) which is extracted from the freshly grated endosperm of the mature fruit. The water from the nut cavity of young nuts is a wonderful drink that is aseptic in healthy fruits. Eighteen to twenty-four coconut palms in their prime could provide one person with a daily supply of pure drinking water when consumed at a rate of three drinking nuts per day. The nut, shell and husk, fronds, and other



Left: Fish cooked in underground oven wrapped in coconut leaf. Right: Grating coconut for cream is a morning ritual in many Pacific islands. Both photos were taken in Alafua, Samoa. PHOTO: C. ELEVITCH

palm parts are used to fashion household items, crafts, etc. The wood is durable and strong and can be used for building, furniture, and tools.

### Light requirements

Young seedlings can be established in partial shade, but older palms require full sun to reach optimal productivity and vigor.

### Water/soil requirements

Coconuts can grow in a wide variety of soils from coarse substrates to clay so long as the soil has good drainage and aeration. It tolerates a wide range of pH. Although the palm prefers environments with uniform rainfall (1000–2000 mm [40–80 in] annually) and high relative humidity, it can survive in arid areas given adequate soil moisture. In arid areas, irrigation, run-off from structures such as roofs and pavement, or even household graywater can be employed to keep soil moisture above minimum levels. Graywater from showers, laundries, and sinks is ideal, as these sources contain some nutrients, although harmful chemicals such as lye, solvents, bleach, etc., should not be used for irrigation. Also, proper health precautions and local regulations for graywater should be observed.

### Life span

Tall coconut varieties can reach an age of 100 years, although productivity declines after age 40. Dwarf varieties have a shorter lifespan of about 70 years.

### Varieties favored for use in homegardens or public areas

In urban areas, Dwarf varieties are often more practical due to their compact size. Their dense crowns give them an appearance in the landscape that is often considered more attractive than Tall varieties. Because of the smaller crown size, a few Dwarfs can be planted in the same area as one or two Talls.

### Seasonality of leaf flush, flowering, fruiting

In optimal conditions with uniform soil moisture, high humidity, and favorable temperatures, coconuts grow continually throughout the year.



**Top:** Larry Kunitake shows a 'Niu Leka' dwarf coconut growing in his mixed homegarden. **Bottom:** Landscaping with coconuts in Apia, Samoa.

PHOTOS: C. ELEVITCH

### Exceptional ornamental values

The sight of a coconut palm is a universal icon of tropical environments, appreciated by all. Living close to coconuts gives the added pleasure of the soft tapping noise produced by fronds gently blowing in the breeze.

## Use as living fence, hedge, or visual/noise barrier

Because of the denser crown, dwarfs can be used as a living fence, if shorter plants are underplanted once trunks form.

## Birds/wildlife

The palms attract a wide range of insect pollinators, including large numbers of honeybees.

## Maintenance requirements

In its prime, a coconut produces about 12–15 leaves and 50–80 fruits per year, which means about that many leaves and fruits will drop from each palm annually. From an esthetic perspective, fallen leaves and fruit may need to be removed regularly to keep a tidy appearance. This material can be used as mulch where it is not an eyesore, if not used for other purposes.

In many private and public urban areas falling fruit and fronds present a life-threatening danger to people and animals. This requires regular maintenance to remove larger fruits and browning (senescent) fronds before they fall. As to the frequency for removing immature nuts to ensure that no one is injured or killed by a falling nut, consider the following: although nuts may fall at any stage of development, most fall during the first 3 months (no damage from these) or after reaching maturity. Unusually strong winds and storms can knock off fruits at any stage of development. Fronds do not fall off before browning, except in the worst of storms.

To ensure safety, nuts should be removed well before they reach maturity, and fronds should be removed before they brown and fall off. Nut pruning, however regular or severe, will not adversely affect palm growth (although it affects the appearance of the palm). Removing nuts older than 8 months old will substantially reduce the hazard of falling nuts.

In private urban environments, where drinking nuts are desired, nuts aged 6–8 months could be picked every 3–4 months by someone in a cherry picker, with a knife attached to a pole, or by climbing the palm. This results in palms having nuts always younger than 8 months, still well before nut maturity. This method leaves the remote possibility that someone can be hit by a falling nut that is less than 8 months old but large enough to cause harm.

In public urban environments such as parks, along streets, and in landscaping, a much more cautious pruning regime is required. Here fruit stalks are removed before they reach an age of 3–4 months, ensuring that no fruit develops beyond a size that would fall harmlessly to the ground. In addition to the open fruit stalks, the unopened spathes at the

top of the crown should be nicked open if possible, which will cause it to decay and not bear fruit.

Fronds are less of a problem, and pruning fronds that are browning along with two or three younger ones substantially reduces risk without any appreciable effect on growth.

## Special considerations regarding leaf, branch, and fruit drop

Generally, coconut palms can withstand high winds and floods. In storms, some fronds may snap off, which tends to lower wind drag and helps the plants survive.

## Nuisance issues

None.

## Hazards

Falling nuts present a very serious danger to people and animals, which is of special concern in urban and public environments. This often necessitates the regular removal of immature fruits well before they mature and fall naturally (see “Maintenance requirements” above).

## Common pest problems

A variety of serious diseases affect coconut (see “Pests and

## Composition of selected vegetable oils (adapted from Enig 2000).

	Coconut	Palm kernel*	Palm*	Soy	Olive	Canola	Cocoa
Fatty Acid							
Caprylic C <sub>8</sub> **	8	4					
Capric C <sub>10</sub>	7	4					
Lauric C <sub>12</sub>	49	50					
Myristic C <sub>14</sub>	18	16					
Palmitic C <sub>16</sub>	8	8	45	11	14	4	24
Stearic C <sub>18</sub>	2	2	5	4	2	2	35
Oleic C <sub>18:1</sub>	6	14	39	23	71	59	38
Linoleic C <sub>18:2</sub>	2	2	9	53	10	23	2
α-linoleic C <sub>18:3</sub>				8	1	10	

\* from the oil palm *E. guineensis*.

\*\* # of carbon atoms:# of double bonds per molecule. The first five fatty acids are saturated and the last three are unsaturated.



**A heavy-bearing palm resulting from a cross between the 'Malayan Yellow' Dwarf and the 'West African' Tall. Yields up to 32 kg (70 lb) copra per palm per year have been recorded.** PHOTO: E. CHAN

diseases" above). Generally, these are not treatable or preventable. Mulching with organic materials such as grass and plant clippings or compost will help conserve soil moisture while providing a steady source of organic nutrients, thereby encouraging plant health.

## COMMERCIAL PRODUCTS

The primary coconut products traded internationally are derived from the fruit: copra and desiccated coconut, coconut cream and protein, whole mature nuts, coir, and activated carbon from shells. Young drinking nuts, coconut water (fresh, canned or frozen), and palm sugar are important in local economies and have a ready market in developed countries with large Asian populations. The other primary products in local economies include shell charcoal, mature nuts for cooking and food uses, brooms, ropes, and coconut shell products, some of which may find niche markets overseas. For many Pacific island states, copra and its by-product, copra press cake, are the only important exports.

### Spacing

As a monocrop, it is planted 9 m (30 ft) apart in a triangular pattern. If intercropping is planned, wider spacings and planting patterns are adopted. However, less attention is paid to spacing and planting patterns on small family farms. Commercial plantations can cover several hundred hectares, but 90% of the world's copra production comes from small family farms. As processing of copra is a simple operation, there is no minimum plantation size for com-

mercial production, but 5 ha (12 ac) would usefully occupy a household.

### Management objectives and design considerations

Site selection for commercial production should be stringent concerning soil and climate. Optimal growing conditions shorten the non-productive phase and ensure high yields. Vigorous growth reduces weed competition and pest attacks. Fertilizer may be necessary although the cost-effectiveness of fertilizers should be taken into account in view of the low commodity price. Intercropping with suitable cash crops should be considered to increase economic returns.

### Design considerations

Use of slow-germinating types (which includes most Pacific island varieties) ensures that nuts may be harvested after falling to the ground at wider time intervals. Mature nuts and copra are bulky, so easy access (good roads, available transport) to markets are important.

### Advantages and disadvantages of growing in polycultures

Coconut does not thrive if shaded, even if the shade is only from the side. Underplanting old palms (above 40 years old) with crops such as cocoa, coffee, and taro not only suppresses weeds but also increases returns from the land.

### Estimated yield

Optimal annual yields of 2–2.5 mt copra/ha (0.9–1.1 t/ac) are attained in the fourth or fifth year of bearing.

### On-farm processing methods

Copra production is a simple process in which a farmer is able to add value to the product. Larger farms have specially-built dryers which in their simplest form consist of a raised drying platform beneath which a fire (usually of coconut shells and husks) is lit. Desiccated coconut, cream, and protein products are not suited to farm-level processing.

Copra is produced in one of two ways. The Indo-Malayan region produces mainly cup copra while the Pacific islands produce finger copra as well as cup copra. Cup copra production requires the removal of the husk from the nuts, which are then split into two halves. The half nuts are then sun dried over 10–12 days or more. In a forced hot-air dryer it takes about 4 days. The partially dried kernel separates easily from the shell and the kernel is dried to less than 7% moisture. In finger copra, the fruit (husk and all) is split



into halves with an axe and the kernel sliced into narrow strips and pried away from the shell. The finger cuts are then dried the same way, but drying time is less. Because the husk is not separated from the shell in the finger cut method, shell charcoal production is not possible.

### Markets

The market for copra and coconut oil is worldwide. All large and medium-sized producers including PNG, Solomon Islands, and Samoa have oil mills and export mainly the oil. World exports of coconut oil in 2002 was 1822 million mt (2 million t) compared to only 0.160 mt (0.176 t) of copra exported. Desiccated coconut production is dominated by the Philippines, Sri Lanka, and Indonesia, which together exported 239,000 mt (263,500 t) in 2002. Pacific island states suffer the disadvantage of being small, isolated producers far from the major markets in Europe and the USA. However, organizations such as the EU provide assistance in the form preferential tariffs to imports from the Pacific islands as well as price support.

## INTERPLANTING/FARM APPLICATIONS

### Example system

#### Location

Papua New Guinea, Samoa, Malaysia, and Indonesia.

#### Description

There is a long-established practice (40–50 years) of planting cocoa trees under old coconut palms. Cocoa dry bean yields vary from 400 kg/ha (356 lb/ac) for village farms to 1 mt/ha (0.45 t/ac) for commercial plantations. Associated copra yields are 1–1.5 mt/ha (0.45–0.67 t/ac).

#### Crop/tree interactions

The coconut provides shade for the cocoa and protection from wind, and the coconuts benefit by default as the cocoa shades out weeds, builds up leaf litter, and shares fertilizers not usually applied to coconuts.

#### Spacing/density

Cocoa planted at 3 x 3 m (10 x 10 ft) intervals.

## PUBLIC ASSISTANCE AND AGROFORESTRY EXTENSION

Extension offices for agroforestry and forestry in the Pacific: <http://www.traditionaltree.org/extension.html>

## GENETIC RESOURCES

Important collections are located at:

PRAP's Production and Dissemination of Improved Coconut Cultivars is based in Saraoutou Research Station, Vanuatu.

International Coconut Genebank (ICG) for the South Pacific is located at PNG Cocoa and Coconut Research Institute, Rabaul, East New Britain, Papua New Guinea.

The Coconut Genetic Resources Network (COGENT), under the auspices of the IPGRI (formerly IBPRI), coordinates activities on genetic resources from exploration to enhancement of germplasm.

## INTERNET

Asian & Pacific Coconut Community: <<http://www.apcc-sec.org>>.

Traditional Pacific Island Crops Coconut (*Cocos nucifera*) Internet Resources: <<http://libweb.hawaii.edu/libdept/scitech/agnic/coconut.html>>.

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Traditional Tree Initiative—Species Profiles for Pacific Island Agroforestry ([www.traditionaltree.org](http://www.traditionaltree.org))

## *Cocos nucifera* (coconut)

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