



## *Terminalia catappa* (tropical almond)

Combretaceae (combretum family)

*alite* (Solomon Islands pidgin); *autara'a*, *'aua*, *'auari'i*, *'auari'iroa* (Societies); *kamani baole*, *kamani 'ula*, false *kamani* (Hawai'i); *kauariki*, *kaukauariki*, *taraire* (Cook's: Mangaia); *ma'i'i*, *koa'i'i*, *koua'i'i*, *ta'ie* (Marquesas); *natapoa* (Vanuatu: Bislama); tropical, beach, or Indian almond (English); *talie* (Samoa); *talise* (Papua New Guinea: Tok Pisin); *tavola*, *tivi* (Fiji); *telie* (Tonga, 'Uvea, Futuna, Tokelau, Tuvalu)

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### IN BRIEF

**Distribution** Naturally widespread in subtropical and tropical zones of Indian and Pacific Oceans and planted extensively throughout the tropics.

**Size** Large tree 25–40 m (82–130 ft) tall.

**Habitat** Subtropical and tropical maritime climates with annual rainfall generally 1000–3500 mm (40–140 in); elevations below 300–400 m (1000–1300 ft).

**Vegetation** Associated with coastal vegetation, especially strandline communities and beach forests including rocky shores and edges of mangrove swamps.

**Soils** Adapted to a wide range of lighter textured soil types.

**Growth rate** Fast in early years, about 2 m/yr (6.6 ft/yr).

**Main agroforestry uses** Soil stabilization, coastal protection.

**Main products** Nuts, timber.

**Yields** Kernel yield is estimated to be about 5 kg (11 lb) per tree per year; timber yields can reach 15–20 m<sup>3</sup>/ha/yr (215–286 ft<sup>3</sup>/ac/yr) (estimate).

**Intercropping** Short term crops can be interplanted during the first 2–3 years after establishment.

**Invasive potential** Has moderate potential for invasiveness into disturbed seaside habitats.

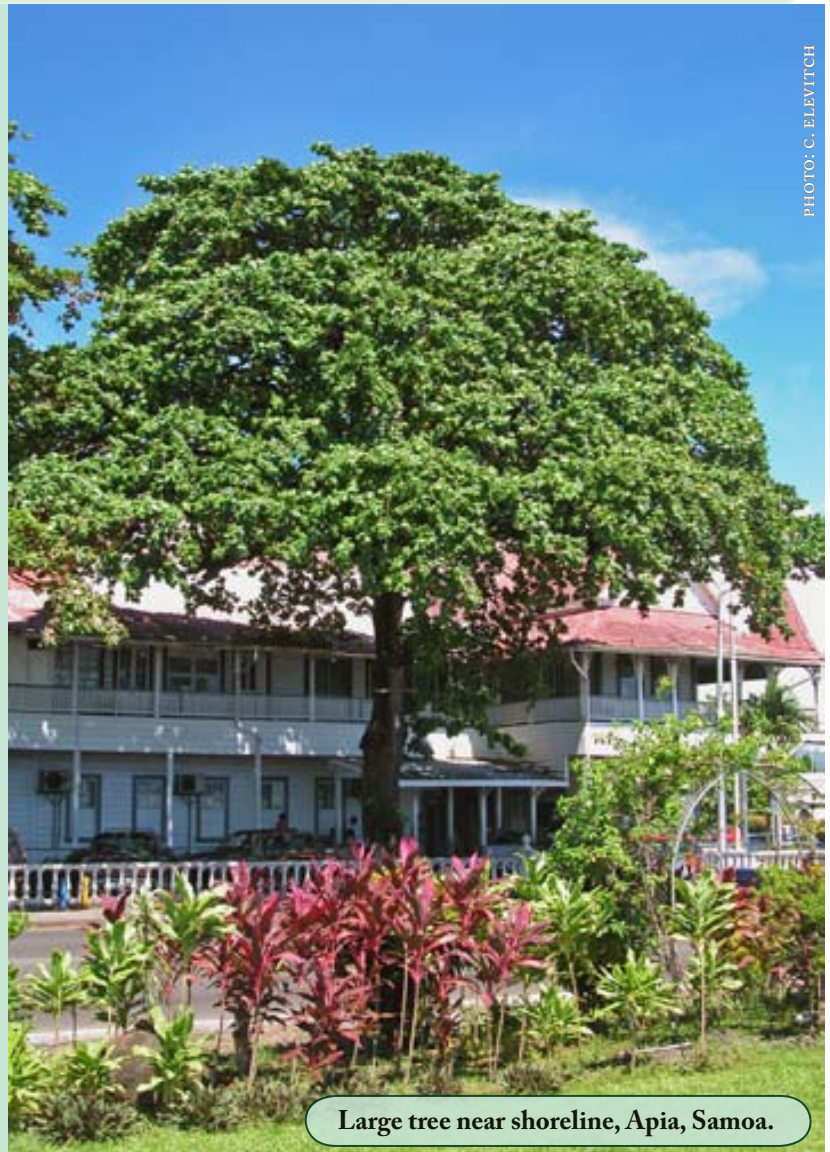


PHOTO: C. ELEVITCH

Large tree near shoreline, Apia, Samoa.

## INTRODUCTION

Tropical almond (*Terminalia catappa*) is a large, spreading tree now distributed throughout the tropics in coastal environments. The tree is tolerant of strong winds, salt spray, and moderately high salinity in the root zone. It grows principally in freely drained, well aerated, sandy soils.

The species has traditionally been very important for coastal communities, providing a wide range of non-wood products and services. It has a spreading, fibrous root system and plays a vital role in coastline stabilization. It is widely planted throughout the tropics, especially along sandy sea-shores, for shade, ornamental purposes, and edible nuts. The timber makes a useful and decorative general-purpose hardwood and is well suited for conversion into furniture and interior building timbers. Fruits are produced from about 3 years of age, and the nutritious, tasty seed kernels may be eaten immediately after extraction.

Tropical almond is easily propagated from seed, and is fast growing and flourishes with minimal maintenance in suitable environments. Selected cultivars of the species warrant wider commercial planting for joint production of timber and nuts. The tree has a demonstrated potential to naturalize in coastal plant communities, but not to adversely dominate such communities.

The productivity and marketing of cultivars with large and/or soft-shelled nuts needs to be assessed. There is also a need for experimental work to develop vegetative propagation techniques and more efficient techniques for processing fully mature fruits including drying, storage, and cracking of nuts.

## DISTRIBUTION

### Native range

Tropical almond has a vast natural distribution in near-coastal areas of the Indian Ocean, through tropical Asia, and into the Pacific Ocean. The extent to which its range has been increased through movement and dispersal by humans is difficult to determine. It extends from the Seychelles through India, the Andamans and adjacent islands, and throughout Southeast Asia (Myanmar, Thailand, the Malay Peninsula, Vietnam, the Philippines, Indonesia) to Papua New Guinea and northern Australia as far south as the Tropic of Capricorn. The species is found throughout the South Pacific region, including the Solomon Islands, Vanuatu, and Fiji. It is present on nearly all the high archipelagos of Polynesia and Micronesia but may be an aboriginal introduction to the eastern parts of its current range (including all of eastern Polynesia).

### Current distribution

Tropical almond has been introduced, and frequently naturalized, in many tropical parts of the world including Brazil, the Caribbean, and East Africa. It is naturalized in Florida and Puerto Rico. In Hawai'i, the species was introduced very early, probably before 1800, and is now naturalized at low altitudes, mainly near beach shores.

## BOTANICAL DESCRIPTION

### Preferred scientific name

*Terminalia catappa* L.

### Family

Combretaceae (combretum family)

### Non-preferred scientific names

*Phytolacca javanica* Osbeck

*Terminalia mauritiana* Blanco

*Terminalia moluccana* Lamk.

*Terminalia procera* Roxb.

### Common names

*alite* (Solomon Islands pidgin)

*'autara'a, 'aua, 'auari'i, 'auari'iroa* (Societies)

*kamani haole, kamani 'ula, false kamani* (Hawai'i)

*kauariki, kaukauariki, taraire* (Cooks: Mangaia)

*ma'i'i, koa'i'i, koua'i'i, ta'ie* (Marquesas)

*natapoa* (Vanuatu: Bislama)

tropical, beach, or Indian almond (English)

*talie* (Samoa)

*talise* (Papua New Guinea: Tok Pisin)

*tavola, tivvi* (Fiji)

*telie* (Tonga, 'Uvea, Futuna, Tokelau, Tuvalu)

### Size

Tropical almond is a medium to large tree to 25–40 m (82–130 ft) in height and with a similar crown spread in open situations. At maturity the trunk attains a diameter at breast height (dbh) of 50–150 cm (20–60 in).

### Typical form

Younger trees display a characteristic pagoda form, with a single bole and monopodial horizontal branching in regular false whorls of 4–5 branches. Along each lateral, new branches are formed in a characteristic, bifurcating pattern. The tiered crown becomes flatter with widespread branches in older specimens. The bole is usually straight and reasonably cylindrical, but in exposed coastal situations it may be



**Top left: Close-up of flowers and buds.** PHOTO: L. THOMSON **Right: Fruits on tree.** PHOTO: C. ELEVITCH **Bottom left: Horizontal branching of young trees.** PHOTO: C. ELEVITCH

crooked and/or leaning. Buttresses, when present, are up to 3 m (10 ft) in height, variable, straight to curved, thick to thin, sometimes branching. Large trees may develop big, occasionally branching buttresses and often have twisted, leaning trunks.

### Flowers

The flowers are small (4–6 mm [0.16–0.24 in] across), white or cream-colored, five-lobed, arranged on long (8–25 cm [3.2–10 in]) axillary spikes, with a mildly unpleasant smell. Within a spike the majority of the flowers are male, with only a few bisexual flowers positioned toward the base. Plants usually commence flowering and fruiting from a young age, e.g., within 2–3 years of outplanting, but this varies with site and genotype. On highly fertile sites mature fruits have been collected from 18-month-old plants. Trees may refoliate and flower very soon (e.g., within 6 weeks) after being completely defoliated by cyclonic winds.

In Hawai‘i, Fiji, Vanuatu, and Tonga flowering and fruiting occur sporadically throughout much of the year. Flowering and fruiting of cultivated trees appears to be more synchronous in Vanuatu, where flowering peaks around October to January and is followed by fruiting around March to June.

### Leaves

The leaves are arranged in close spirals, often crowded toward the ends of the upturned branchlets. The leaf blade is simple, broadly obovate, 8–25(–38) x 5–14(–19) cm (3–10[–15] x 2–6[–7] in), with (5–)8–12 pairs of secondary veins. The leaf tip is rounded and blunt, gradually tapering to a narrowly subcordate base (the latter being a useful diagnostic feature). New leaves have a covering of soft, appressed, brown hairs. Mature leaves are mostly glabrous (shiny), leathery, and dark green, turning bright yellow then vivid to dark red before falling. The trees are briefly deciduous

during the dry season, or in some environments they may lose their leaves twice in a year.

### Fruit

Typically one to five fruits develop on the basal part of the flower spike. The fruit is a sessile, laterally compressed, ovoid to ovate, smooth-skinned drupe. During maturation, it changes color from green through yellow to bright red or dark purplish-red at full maturity. Fruit size varies considerably, e.g., 3.5–7 x 2–5.5 cm (1.4–2.8 x 0.8–2.2 in), with extremes in length from 2.5 to 10 cm (1–4 in). The kernel consists of two delicate and intricately entwined cotyledons enclosed in an inconspicuous cream-colored, rarely red, testa.

In the South Pacific tropical almond growing at lower latitudes may produce fruit sporadically throughout the year, with heavier crops toward the end of the year on trees growing at higher latitudes. In New Guinea the productive period is between November and March, especially December–February. In Vanuatu the main crop is around the middle of the year (May–June), with a smaller crop around December. In Samoa fruiting occurs in June–July and February–March. In Tonga the reported fruiting season varies between island groups, e.g., September–December in the south (Tongatapu and ‘Eua) and February–May further north (Ha‘apai and Vava‘u).

### Seeds

In the Pacific islands trees exhibit large variations in the size and shape of fruits, nuts, and kernels, but it is difficult to classify this variation. For example, in Vanuatu, the nuts can be 3.9–5.1 long by 2.6–3.8 cm across (1.5–2 x 1–1.5 in) and weigh 7–14 g (0.25–0.5 oz). Kernels are in the size range of 2.2–4.4 x 8–1.4 cm (0.9–1.7 x 0.3–0.6 in) and weigh 0.1–0.9 g (0.04–0.32 oz). The percentage kernel content varies from 1% to 10%.

The rind of the fruit is a light, pithy, or corky tissue that enables the fruit to float and be dispersed by sea currents. Trees are also found away from coasts due to fruits being carried inland and dropped by frugivorous birds and bats, and as a result of deliberate planting by humans.

### Bark

The bark is gray to dark gray-brown and shallowly fissured. Continuous vertical fissuring and discontinuous horizontal cracks produce a grid appearance; the somewhat flaky bark peels off in curved or straight scales along these lines.

### Rooting habit

The trees usually have a spreading, fibrous, near-surface



**Top: Buttress of large tree, Hilo, Hawai‘i.** PHOTO: J. B. FRIDAY  
**Bottom: The extensive surface root system is exposed on this sandy, coastal slope.** PHOTO: C. ELEVITCH

lateral root system, although the species is normally deep rooted in sand (Francis 1989). Shallow lateral root systems can develop in response to high water tables, making such trees susceptible to windthrow (Wood 1970).

### Similar or look-a-like species

The genus *Terminalia* comprises about 150–250 tropical tree species. Closely related species in the South Pacific include *T. glabrata* Forst. f. and *T. littoralis* Seem.

### How to distinguish from similar species/look-a-likes

Tropical almond is distinguished from most *Terminalia* spp. by its subcordate (heart-shaped) leaf base. *T. catappa* has larger, glossy, dark green leaves, thicker branchlets, longer flower spikes, and larger fruits than *T. littoralis* (typically >3.5–5 cm [>1.4–2 in] compared with ≤ 2.5 cm [1 in] long). *T. catappa* is distinguished from the eastern Polynesian *T. glabrata* by its shorter, thicker leaf petioles typically ≤1.5 cm (0.6 in) compared with 1.5–2.5 cm (0.6–1 in) long; heart-shaped leaf base compared with cuneate to acute; and winged, typically larger fruits >3.5–5 cm (>1.4–2 in) compared with 2.5–5 cm (1–2 in) long and more strongly angled fruits. Some authors consider *T. glabrata* to be a “wild” form of *T. catappa*, and more taxonomic studies, including using molecular markers, may be needed to determine the classification status of *T. glabrata*.

## GENETICS

### Variability of species

Major variation exists in a range of economically important nut characteristics, mainly as a result of traditional selection for trees with desirable traits and their propagation by peoples in various parts of its range in Melanesia. Selection has occurred for large fruits and/or kernels and ease of cracking. In Vanuatu the variability in the species is high; variations occur mainly in fruit size, color, and shape (Walter and Sam 1993). There is little variation within the species in most parts of the Solomon Islands, except for the Santa Cruz Islands (Temotu Province) where selection has produced some large-fruited forms. Two fruit types have been reported from the Mussau Islands, Bismarck Archipelago, Papua New Guinea (Lepofsky 1992). One type has a soft



**Top: Comparison of flowering twigs of *T. littoralis* (left) and *T. catappa* (right).** PHOTO: L. THOMSON **Bottom: *T. littoralis*, ‘Upolu, Samoa.** PHOTO: C. ELEVITCH

endocarp that can easily be broken with the teeth, while the other has a hard endocarp that must be hit with a stone or cut with a knife to extract the nut; it is uncertain whether the soft-shelled trees breed true to type. The island of Iwa, in the Marshall Bennett Group (PNG), is also renowned for its soft-shelled nuts. In Tonga two forms are distinguished: those with red fruits (*telie kula*) found along beaches and those with light green fruits (*telie hina*) found inland. In a Rapid Rural Appraisal study, four folklore varieties were identified for Ha‘apai (Tonga), i.e., *‘amanu*, *lau lalahi*, *lalike*, and *kai* (Tupoulahi-Fusimalohi 1999). In Sa-

moa there is modern introduction of *T. catappa* with larger edible fruits.

In India several forms differing in leaf shape and fruit characteristics have been recognized. One type has an edible, sweet flesh (mesocarp) and is cultivated in gardens. Variation has also been reported in kernel taste and size from planted trees in the Caribbean and the southern United States.

### Known varieties

While many variants are reported (see above), the species is invariably propagated from seed, which gives rise to variation in the offspring. Accordingly there is continuous variation with intermediate forms for various characters.

The species should be highly amenable to improvement through a breeding program given

- the high level of variation in nut characteristics
- short intergeneration times, i.e., the young age, about 3–4 years, at which plants flower and fruit, and
- ready access to flowers in low lateral branches for controlled pollination (although the flowers are small and crowded).

### ASSOCIATED PLANT SPECIES

Tropical almond is a characteristic species of tropical beach forests, especially raised sandy beaches above high tide. It is also found along rocky shores, and sometimes on the



Kernels from three selected nut morphotypes of tropical almond (left) compared with wild type (right) in Vanuatu.

PHOTO: K. AKEN

### TERMINALIA TERMS

- **Fruit**—the outer skin (exocarp) and flesh (mesocarp), the shell (endocarp), and kernel.
- **Nut**—the shell (endocarp) and the kernel.
- **Kernel**—the edible kernel or seed and testa (skin surrounding testa).

edges of mangrove swamps. It may also grow as a pioneer on denuded or disturbed lands up to 300 m (1000 ft) elevation. In Vanuatu occasional seemingly wild trees in the forest are likely to be remnants of former settlements or gardens. In French Polynesia, it appears to have partly replaced the indigenous *T. glabrata*.

### Associated species commonly found in native habitats

Associated species include *Acacia simplex*, beach heliotrope (*Tournefortia argentea*), *Barringtonia asiatica*, *Calophyllum inophyllum*, beach she-oak (*Casuarina equisetifolia*), coconut (*Cocos nucifera*), *Cordia subcordata*, *Excoecaria agallocha*, *Hernandia nymphaeifolia*, beach hibiscus (*Hibiscus tiliaceus*), *Intsia bijuga*, noni (*Morinda citrifolia*), *Scaevola taccada*, *Schleinitzia insularum*, *Terminalia littoralis*, *Thespesia populnea*, and *Vitex trifoliata*.

### ENVIRONMENTAL PREFERENCES AND TOLERANCES

#### Climate

Tropical almond is well adapted to maritime subtropical and tropical climates where rainfall is usually in the range of 1000–3500 mm (40–140 in) per annum, distributed rather uniformly throughout the year or with a summer maximum. It is invariably found near the coast, at elevations of less than 300–400 m (1000–1300 ft), where there is little seasonal and diurnal variation in temperatures. The entire range is frost-free.

#### Elevation range

1–400 m (3–1310 ft).

#### Mean annual rainfall

1000–3500 (–4500) mm (40–140 [–180] in).

#### Rainfall pattern

The tree prefers climates with summer or uniform rainfall patterns.

**Dry season duration (consecutive months with <40**

**mm [1.6 in] rainfall)**

Up to 4–6 months.

**Mean annual temperature**

23–28°C (73–82°F)

**Mean maximum temperature of hottest month**

25–32°C (77–90°F)

**Mean minimum temperature of coldest month**

17–24°C (63–75°F)

**Minimum temperature tolerated**

5–7°C (41–45°F) (estimated)

**Soils**

Tropical almond naturally occurs on various coastal soils, especially raised sandy and rocky beaches. It is adapted to a wide range of lighter-textured soil types, including brackish/saline and alkaline sands over limestone, but requires good drainage when grown on heavier, clayey soils.

**Soil texture**

It prefers light to medium soils (sands, sandy loams, loams, and sandy clay loams).

**Soil drainage**

It requires freely draining soils.

**Soil acidity**

Acid to neutral/mildly alkaline soils (pH 4.0–8.5).

**Special soil tolerances**

Tropical almond tolerates shallow soils and slightly saline soils.

**Tolerances****Drought**

It is likely to be tolerant of droughts of less than 4–6 months duration and may shed leaves/canopy to withstand long dry spells.

**Full sun**

The tree grows most rapidly in full sun and regenerates mainly in open, well lit situations.

**Shade**

Tropical almond tolerates 0–25% shade. Seedlings and saplings tolerate moderate shade levels but require high light levels to grow satisfactorily, and mature trees prefer full sunlight.

**Fire**

It is resistant to low- to medium-intensity fires, with trees observed to regrow after burning during clearing operations.

**Frost**

The entire natural range is frost free. The tree is likely to be damaged at low temperatures (e.g., less than 5–7°C [41–45°F]).

**Waterlogging**

The species is not well adapted to waterlogged conditions.

**Salt spray**

The species typically grows within a short distance (<100–200 m [330–660 ft]) from the ocean and is adapted to exposure to strong, often salt-laden winds.

**Wind**

Tropical almond is adapted to strong, steady coastal winds, as well as rather frequent (every 2–5 years) exposure to



**Tropical almond can withstand coastal winds and salt spray.**

PHOTO: C. ELEVITCH

tropical cyclones over large parts of its range. While the species has overall good wind-firmness, some individuals suffer stem breakage and/or uprooting during tropical cyclones. Tropical almond may be partially defoliated by very strong winds, and this may aid its wind-firmness during cyclones.

## Abilities

### Regenerate rapidly

The species regenerates abundantly on its preferred littoral sites, notably in beds of washed-up debris and sand in strandline communities.

### Self-prune

Tropical almond produce tiers of four or five branches; as new tiers are produced by the leader apex, some of the lower branch tiers die back. The extent of self-pruning is variable, depending on genotype, density of surrounding vegetation, and light levels.

### Coppice

Seedlings and saplings coppice strongly, although the extent of regrowth after severe pruning or damage is unknown in mature trees. The main leader may be cut out of the top, sometimes more than once, to create a very wide-spreading shade or specimen tree. Excessive pruning by wind or man may cause weakening or death of mature trees.

## GROWTH AND DEVELOPMENT

### Growth rate

Under favorable conditions tropical almond is moderately fast to fast growing, with height growth in early years averaging around 1.5–2 m (5–7 ft) per year. Very fast early height growth of 3–5 m (10–16 ft) per year has been observed on fertile sites on Santo, Vanuatu. Diameter growth is about 1 cm/yr (0.4 in/yr) over the life of the tree, up to 2 cm/yr (0.8 in/yr) for widely spaced trees growing in fertile sites.

### Reaction to competition

On favorable sites the tree is able to quickly gain site control and shade out most weeds. It may be necessary to prune the lower one or two tiers of branches to reduce access for climbing weeds. This will also improve amenity as a shade tree.

## PROPAGATION

The species is readily propagated from seed. Mass vegetative propagation by rooted cuttings is also feasible.

### Propagation by seed

#### Seed collection

The timing of fruit maturation varies among regions and may be sporadic or occur more than once per year (see above under "Fruit"). Fruits are ready for collection when they are full size (which varies among trees) and have begun to show some color change (i.e., become red-purple or yellow, or brownish in the case of green-fruited forms). Mature fruits are harvested from the tree by hand and/or with the aid of long-handled pole pruners. Recently fallen fruits may be collected from the ground.

#### Seed processing

There are about 15–60 fresh fruits/kg (7–27 fruits/lb). The fleshy outer covering should be removed from the seed/nut as soon as possible after collection (within 1–2 days), e.g., by careful hammering between two flat stones. After removal of the fleshy outer covering, there are about 70–150 nuts (nut-in-shell) per kg (32–68 nuts/lb).

#### Seed storage

The seed storage behavior is unknown, but seeds appear to lose viability fairly rapidly under storage. Until effective medium-term seed storage procedures are developed it is recommended that seeds be sown within 4–6 weeks of collection.

#### Pre-planting treatments

Seeds may be sown without any pretreatment.

#### Growing area

Seeds are germinated in a freely draining potting mix in germination trays in a protected, rat-free area under cover, such as a shade house. Seedlings should be transplanted into containers as soon as is practicable after germination and emergence. Plants grow rapidly and require larger containers than many forest tree species: suitable containers include 15 cm (6 in) polybags or tapering, rigid plastic tubes (e.g., 15 cm [6 in] deep by 6.5 cm [2.6 in] square at top).

Seedlings are progressively moved to higher light levels, e.g., 30–50% shade for 1–2 weeks after transplanting, then 25% shade for 1 month, then full sun for 2 months prior to outplanting.



## Germination

Germination typically commences in 3–8 weeks, with a germination rate of greater than 50% for freshly harvested fully mature fruit.

## Media

Seedlings should be grown in a standard potting mixture or fertile, freely draining sandy loam or loam, preferably with good levels of organic matter. Incorporation of a controlled-release, complete fertilizer into the potting mixture will ensure rapid, healthy seedling growth.

## Time to outplanting

The time from germination to outplanting is about 4 months.

## Approximate size

Plants should be about 25 cm (10 in) (max. 30 cm [12 in]) tall at outplanting. Smaller seedlings about 20–25 cm (8–10 in) high may also be used.

## Guidelines for outplanting

Seedlings should be outplanted at the onset of the wet season, typically early December in the South Pacific. A typical sequence for seedling production in Vanuatu would be June, seed collection; July–August, germination; September–November, nursery phase; December–January, field planting.

## Propagation by cutting

For vegetative propagation for selected nut types, seedling hedges of better nut types can be planted. These trees can be regularly cut back to a height of about 20–30 cm (8–12 in) or, preferably, by laying seedlings flat, pinning, and cutting back new shoots. Multinode, semi-hardwood cuttings should be treated with rooting hormone (0.4% IBA powder), set in washed river sand, and rooted under mist.

## DISADVANTAGES

The species has no major drawbacks. The tree is already naturally very widespread in the Asia-Pacific region and has multiple uses, including providing important environmental services such as coastal protection. The nuts are often not utilized or highly regarded as food because of the small size of the kernels and the difficulty of extracting them, but use of selected genetic material can greatly improve the utility of tropical almond nuts as human food.



**Propagation of seedlings of better nut morphotypes for distribution to farmers, Santo, Vanuatu.** PHOTO: K. AKEN

## Potential for invasiveness

The species naturalizes readily in suitable littoral habitats, and may be regarded as a potential weed threat to native plant communities. However, the tree is usually not considered a weed problem.

## Diseases and pests

Plants are susceptible to termite attack, and damage may occur in some parts of its range. The leaves may be attacked and eaten by various insects and larvae, including rose beetles, but the plant generally recovers well from insect damage and defoliation. The Secretariat of Pacific Community Plant Protection Service has developed a list of pests and diseases that have been reported on tropical almond in different countries, including 85 insects, 13 fungi, 8 nematodes, and 3 mites (J. Wright pers. comm. 2004). Pink disease (*Corticium salmonicolor*), a fungal stem canker, was recorded on tropical almond in India.

## Host to crop pests/pathogens

The fruits are hosts for 21 fruit fly species including Caribbean fruit fly (*Anastrepha suspensa*) in Florida, and of the Mediterranean fruit fly (*Ceratitidis capitata*) in Costa Rica, as well as a fruit piercing moth (*Ophiusa coronata*)

## AGROFORESTRY/ENVIRONMENTAL PRACTICES

### Mulch/organic matter

Annual/bi-annual leaf drop results in a good buildup of organic matter under the trees.

### Soil stabilization

The well developed lateral root system helps to bind fragile sandy soils and maintain coastal shores, especially during storm surges and extreme high tides. It has been specifically planted for soil conservation in India and Tanzania.

### Crop shade/overstory

Mature trees cast a heavy, wide shade, when not in their brief deciduous phase. Tropical almond is only suitable for providing crop shade to the most shade tolerant crops such as cocoa (*Theobroma cacao*).

### Alley cropping

Tropical almond may be used in intercropping systems while the trees are still young (up to about 3 years old) and with comparatively wide-spaced alleys, e.g., 6–9 m (20–30 ft) apart. During the final 3 years of the gardening phase in a rotational gardening or shifting cultivation, rows of tropical almond can be grown together with the crops, prior to conversion to a forest plantation (and serving as improved fallow).

### Homegardens

It is a good species for inclusion in homegardens at the rate of one to three trees per garden, providing nuts for local consumption from an early age, coupled with reasonably good stability during strong winds and cyclones.

### Improved fallows

The tree makes an excellent species for inclusion in mixed-species improved fallow plantings with a duration of at least 20–25 years to allow for production of timber.

### Windbreaks

Tropical almond is an excellent species for inclusion as an upper to midstory layer in windbreaks.

### Animal fodder

The foliage is suitable for feeding tasar or katkura silkworms. In the Caribbean, the fruit is an important food for birds and many wild mammals, and it is also consumed by various livestock, including pigs.



Windbreak of tropical almond and beach she-oak (*Casuarina equisetifolia*). PHOTO: C. ELEVITCH

### Woodlot

The tree is a good species for inclusion in a mixed or single-species woodlot for provision of timber and/or nuts.

### Native animal/bird food

The fruits are consumed by birds and bats.

### Wildlife habitat

The trees provide good wildlife habitat, being among the tallest trees in beach forests. Small birds sometimes nest in the lower branches.

### Bee forage

The flowers yield nectar that is attractive to honeybees.

### Coastal protection

This a species of choice for coastal protection and soil stabilization, including beach stabilization just above the level of spring high tides. Key attributes for these roles include high salt tolerance (both foliar and soil), good cyclone

resistance, surface rooting habit, and regular shedding of leaves that provide a moderately long-lasting mulch layer under the tree.

### Ornamental

It is an attractive, long-lived tree well suited to ornamental and amenity plantings where space permits. It is especially suited to provision of shade in coastal open spaces, public parks, and along roadside verges.

## USES AND PRODUCTS

The tasty kernels or nuts of tropical almond have traditionally been incorporated, albeit in modest quantities, into the diet of peoples in coastal areas throughout much of the Asia-Pacific region. The nuts may be consumed fresh shortly after extraction from the shell or else preserved by smoking and consumed up to a year later. In some areas the nuts are mainly a snack food consumed by children, with the fleshy fruit also sometimes being consumed. In other areas tropical almond nuts were highly regarded as a human food source. Types with larger kernels and softer shells were selected and preferentially propagated and maintained in parts of Melanesia. Localities noted for good nut types include South-West Bay, Malekula (Vanuatu); Santa Cruz Islands (Solomon Islands); and Mussau Islands, Bismarck Archipelago, and Iwa Island, Marshall Bennett Group (Papua New Guinea).

In coastal areas the timber is often used in local building but is not well suited to high-decay situations (such as contact with the ground). The timber is traditionally used to make various items including canoes and drums, and as a fuelwood. The tree also has a wide range of traditional non-wood product uses. Tannin is extracted from the bark, leaves, roots, and fruit shell. The large leaves are used as wrapping material. A black dye is obtained from the bark, fruit, and foliage. Its leaves and bark have a wide range of medicinal uses.

At present the main planting of the species is for amenity plantings for coastal protection and shade, with smaller plantings of selected types for nut production. The nuts of the species remain an important local food source, and it is highly regarded as a building timber in parts of the Pacific, including Vanuatu and Samoa.

### Fruit

Children sometimes consume the outer flesh of agreeable fruit types. In the Philippines a wine is made by fermenting mature fruits.



**Superior nut morphotypes selected in Solomon Islands and introduced to Tonga in 2002.** PHOTOS: K. AKEN

### **Nut/seed**

The nuts may be consumed fresh after extraction from the shell or preserved by drying or smoking and consumed up to a year later. In some local markets in Melanesia the fresh kernels are sold in bundles or skewered on sticks (palm frond spines). Kernels are easily damaged during extraction and start to mold within 1–2 days at ambient temperatures. The sun-dried kernels yield 38–54% of a bland, yellow oil that is edible but becomes turbid on standing.

### **Medicinal**

The leaves have many medicinal uses including diaphoretic, anti-indigestion, and anti-dysentery. An infusion of the young leaves or scraped bark is occasionally taken as a potion for treating mouth infections in Tonga and Samoa and is used in the Cook Islands to bathe fractures. Young leaves are used in the Philippines to cure headache and colic. The bark is used as an astringent in dysentery and thrush.

### **Timber**

The sawn timber has a wide range of end-uses including general building construction, especially interior purposes such as flooring and furniture. Larger sound logs are suitable for veneer and plywood manufacture. The wood is not suitable for long-term ground contact.

### **Fuelwood**

The wood is suitable for use as fuelwood.

### **Craft wood/tools**

Traditional wood uses in the South Pacific include kava bowls, tool handles, clubs, walking sticks, and drums.

### **Canoe/boat/raft making**

The wood is traditionally used to make canoe hulls and paddles in the South Pacific. The wood is also used in boat-building.

### **Wrapping/parcelization**

The leaves are infrequently used to wrap and carry food.

### **Tannin/dye**

The bark and leaves (as well as fruit shells and roots) are rich in tannins and may be used for staining/coloring fabrics including tapa, tanning leather, and ink-making.

### **Oil/lubricant**

Trials have been conducted to admix kernel oil into diesel fuel.

## **URBAN AND COMMUNITY FORESTRY (By Craig R. Elevitch)**

Tropical almond is a popular ornamental and shade tree throughout the tropics. The tree has a beautiful, broad, pagoda-like canopy and attractive leaves. Part of the appeal of the species as an ornamental is the bright red–orange–yellow color of the leaves before each annual defoliation. In addition to its amenity services, the tree produces tasty nuts, traditional medicines, dye, and timber, all of which can be utilized from trees growing in urban areas. It withstands coastal conditions, including heavy salt spray and strong winds, and therefore is most commonly found in coastal urban areas. It is widely adaptable to various soils, including infertile sandy soils.

### **Size in an urban environment**

In urban environments, the tree typically reaches 15–25 m (50–80 ft) tall with a broad canopy similar in diameter to the height of the tree. The trunk can grow to 1.5 m (5 ft) in diameter at breast height. For urban environments, this is a large tree, which needs to be pruned regularly to control its size in more confined areas.

### **Rate of growth in a landscape**

With care and in favored environments, trees can grow up to 2–4 m/yr (6.6–13 ft/yr) for the first few years, although growth rates closer to 1 m/yr (3.3 ft/yr) are more typical.

### **Root system**

The root system is deep in sandy substrates. In soils with shallow water table, it can develop an extensive surface root system that could interfere with maintenance activities, such as mowing. The formation of a buttressed trunk can lift sidewalks, foundations, curbs, pipes, etc., making it inadvisable to plant the tropical almond near such structures.

### **Products commonly used in a Pacific island household**

The nuts are edible both raw and cooked, although eating quality and kernel size are variable. The nuts are an important food when in season in Vanuatu. In other areas such as Samoa, Tonga, New Guinea, and the Solomon Islands, they are eaten rarely or just nibbled on by children. In Hawai'i, few people are aware that the kernel is edible. The difficulty of extracting the kernel, variable eating quality, and absence of large-kernelled varieties may explain the lack of use of the nut in many areas. The outer flesh of the seed is also edible, although it is usually fibrous and not tasty. Fruits are cracked open to extract the kernel by a

sharp blow to the edge or by hitting the pointed apex with a hammer.

The leaves, bark, and fruit skin are used medicinally and are also used to make a black dye.

The wood is used for construction, crafts, and canoes. It is an attractive, moderately durable timber well suited to interior uses, such as framing, paneling, flooring, and furniture. It also makes good firewood.

### Light requirements

Its seedlings tolerate light shade (0–25%), although the tree performs best in full sun.

### Water/soil requirements

Tropical almond grows best in sands and loamy sands, but it can grow very well in silts, loams, and clays. It is also known to grow in the poor-quality fill that is often found in urban areas (Francis 1989).

### Life span

As an ornamental, tropical almond is expected to live about 60 years (Francis 1989) and up to 100 years in suitable environments.

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

There are many forms found regionally (see “Variability” above). There has been long-term domestication and selection of large-kernelled forms in parts of PNG, Solomon Islands, and Vanuatu. These nut morphotypes are favored for home and village gardens.

### Seasonality of leaf flush, flowering, fruiting

Trees lose their leaves once or twice a year during dry periods. Trees generally flower and fruit once annually, although in many areas such as Hawai‘i, Fiji, and Tonga, flowering and fruiting take place continuously throughout the year.



Clockwise from top left: horizontal form of pruned tree, Apia, Samoa; pollarded tree, North Kohala, Hawai‘i; tree in homegarden alongside mango, breadfruit, and rain tree, Apia, Samoa. PHOTOS: C. ELEVITCH

## Exceptional ornamental values

The large, dark green leaves are attractive and showy, especially prior to seasonal shedding. As new leaves appear, the bright green new growth is also conspicuous and attractive. In its preferred seaside environments, the deep shade cast by the tree is often very welcome to beachgoers. The broad canopy is readily identifiable and appreciated as shade. Large trees with buttressed trunks 1 m (3.3 ft) in diameter or more can make spectacular community landmarks and gathering places.

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

The form of the tree, with a single dominant trunk and horizontal spreading branches, does not lend itself to hedges or barriers.

## Birds/wildlife

Birds and bats consume the fruit.

## Maintenance requirements

In urban environments requiring a tidy appearance, the seasonal leaf and fruit drop necessitates regular removal of debris from underneath trees. Where the size of the tree must be controlled, such as in a small homegarden, the tree can be shaped at an early age to a desirable size. In this case the main stem can be cut at a desired height, favoring horizontal branches. In Samoa and elsewhere, the lower branches of the trees are sometimes weighted down so that the tree will be a more attractive or effective shade tree.

The tree can also be pollarded to control the height and canopy diameter. In pollarding, a framework of several stems is formed at a desired height by pruning the tree during its early development. These stems are then pruned back heavily every 2–5 years.

Tropical almond does not require fertilizer except in the most infertile soils. It tolerates drought, but performs better in consistently moist conditions.

## Nuisance issues

In urban areas the loss of leaves once or twice a year may be considered “messy,” but the preceding change of leaf color before dropping can be spectacular. The flowers have a slightly fetid odor, although the smell is rarely strong enough to be considered a nuisance. The trees also tend to grow rather large for urban environments.

## Hazards

Although the tree is a coastal species and adapted to withstand storm winds, branches can snap in high winds (Wal-

ter and Sam 2002). Therefore trees should be planted well clear of building structures.

## Common pest problems

Many insects and larvae feed on the leaves, including rose beetles, but trees usually recover well from periodic infestations.

## COMMERCIAL PRODUCTS

The main commercial products of tropical almond are sawn timber for local use, especially in house and building construction, and kernels for human consumption.

### Timber

The heartwood of tropical almond is variable in color, often brown to reddish-brown, with a wide, rather indistinct band of lighter colored sapwood. The timber is smooth, lustrous, elastic, tough, moderately hard, and medium-coarse in texture, often with an irregular or twisted grain. The wood is moderately dense, e.g., 530–540 kg/m<sup>3</sup> (33–34 lb/ft<sup>3</sup>) at 12% moisture content. The timber has been variously reported as seasoning rapidly with a moderate level of degrade or else as not easily seasoned. The timber is readily sawn, but interlocked grain tends to pick up during planing. Other machining characteristics are as follows: shaping, boring, and mortising are fair; turning is poor; sanding, resistance to screw splitting, and nailing properties are good.

### Nuts

In Vanuatu one local company purchases tropical almond kernels from around the country for US\$6–7 per kg (US\$2.73–3.18/lb). The kernels are checked for quality, dried, and retailed in 40 g (1.4 oz) jars in Port Vila supermarkets for more than US\$80 per kg (US\$36/lb). Demand is high, and the company would like to purchase 1000 kg (2200 lb) of kernels per year (equivalent to 30–50 mt [27–45 t] of fruits). In Port Vila and Loganville markets, fresh tropical almond kernels are sold in bundles or skewered on sticks (palm frond spines/midribs) for the equivalent of US\$12–17 per kg (US\$5.45–7.73/lb).

### Spacing

#### Timber

An appropriate initial spacing for commercial production of timber in monocultural plantings is 3 x 5 m (10 x 16 ft) (equivalent to 667 stems/ha [270 stems/ac]). Wider inter-row spacing could be used to reduce weeding costs. Intercropping with short-term crops could be done with a tree spacing of 3 x 8 m (10 x 26 ft) (i.e., 417 stems/ha



**Left: Nuts skewered onto palm leaflet midribs and sold in Port Vila market, Vanuatu; pictured: author Lex Thomson. PHOTOS: K. AKEN Right: The late Justin West standing among 2–3-year-old tropical almond trees he planted in a small plantation outside Port Vila, Efate, Vanuatu. PHOTO: B. EVANS**

[169 stems/ac]). The final density for sawlog production is about 150–200 stems/ha (61–81 stems/ac). A suitable area for commercial production would be 10 (or more) hectares (25+ ac), but even small woodlot areas of about 1 ha (2.5 ac) could be grown on a commercial basis by groups of smallholders to supply local saw mills.

### Nuts

A wide spacing is recommended, coupled with pruning out the lead shoot to encourage low, wide-spreading lateral branching. The suggested spacing is 8–9 x 8–9 m (26–30 x 26–30 ft), i.e., 123–156 trees per ha (50–63 trees/ac).

### Both nuts and timber

Suggested spacing is close within rows (e.g., 2 m [6.6 ft]) and wide between rows (e.g., 8 m [16 ft]). This gives an

initial spacing of 625 trees/ha (253 trees/ac), which is eventually thinned down to a final spacing of about 150 trees/ha (61 trees/ac) by removal of poorer formed individuals in one or two non-commercial thinning operations at age 3–6 years.

### Management objectives

The aim of management for timber production is to produce high-quality sawlogs within an economically feasible and attractive time frame; e.g., a rotation period of 20–25 years. This will include use of selected genetic material, regular maintenance in early years including frequent removal of creepers, and one or more thinnings to maintain site control and concentrate wood increment on better-formed stems. Progressive pruning of lower whorls of branches up to a height of about 12 m (39 ft) may be required to produce

less knotty sawlogs of higher value. Such pruning should be done in several steps, to maintain at least two-thirds of the canopy leaf area at any one pruning.

### Design considerations

For production of nuts, it is recommended that plantings be located in areas with good access to major marketplaces, so that extracted kernels can reach the market quickly without risk of spoiling.

### Advantages and disadvantages of growing in polycultures

Tropical almond has the potential to be well suited to growing in polycultures with other fast-growing timber species such as *Endospermum medullosum*. The fast-growing but smaller *Flueggea flexuosa* could be interplanted and harvested after 7–10 years to provide durable poles.



Intercropping with cassava and other crops on Santo, Vanuatu. PHOTO: L. THOMSON

### Yields

#### Timber

There is no data available concerning growth rate over the projected rotation length of about 20–25 years. It is likely that good-quality, well maintained plantations on fertile sites grow at about 15–20 m<sup>3</sup>/ha/yr (215–286 ft<sup>3</sup>/ac/yr).

#### Nuts

Significant amounts of fruits are produced 3–5 years after planting, with regular fruiting once or twice a year depending upon latitude, location, and health of the tree. Kernel yield is estimated to be about 5 kg (11 lb) per tree per year (or about 0.5 to 1 mt/ha/yr [0.18–0.36 t/ac/yr]), but yields might be double that for selected genetic stock grown on high-quality sites.

### Processing required

The greatest obstacle to the commercial marketing of the nut is its low kernel content and the lack of on-farm commercial storage technologies that would allow fruits to be processed in villages and the high value kernels to be transported to central processing units. For nut production, the flesh should be removed manually from fruits on-farm, and the nuts should be at least partly dried to remove surface moisture. This will considerably reduce the bulk and weight of material to be transported without spoilage to market and reduce the risk of spoilage. Drying and smoking of nuts on-farm would add considerable value and pro-

duce a more durable product with a considerably extended shelf life.

### Market

#### Timber

Markets for planted tropical almond timber are the local timber markets for general-purpose timbers.

#### Nuts

The size of the international market for nuts is likely limited. However, tropical almond nuts (along with *Canarium indicum* nuts) have the potential to behave as under-supplied niche commodities with a highly inelastic demand, commanding a price equivalent to macadamia nuts (currently more than US\$10/kg [US\$4.55/lb]) wholesale, i.e., 2.5 times the price of mainstream nuts such as almonds, providing packaging and quality are similar. High-value niche markets and value could be secured and enhanced by organic certification, promotion of tropical almond as an exotic commodity, and direct internet-based marketing. Marketing opportunities and constraints for Pacific tree nuts depend on quality control, packaging, continuity of supply, and targeting marketing toward specific groups, such as tourists.



## INTERPLANTING/FARM APPLICATIONS

### Example system 1

#### Location

Temotu Traditional Tree-based Agriculture (Santa Cruz Islands, Solomon Islands).

#### Description

Tropical almond is planted as an outer boundary tree on the windward side of multi-species, multistory agroforestry plots to protect more vulnerable species against sea spray and wind.

#### Yields/benefits

Fuelwood, timber, and kernels.

#### Spacing

About 5–8 m (16–26 ft) within rows.



### Example system 2

#### Location

Shark Bay, Santo, Vanuatu.

#### Description

Newly developed, experimental system started in January, 2000. There are no data available on yields. The benefit of intercropping is that while farmers receive early returns, while waiting for the trees to start bearing nuts. Good weeding ensures high survival and rapid early growth of trees.

#### Crop/tree interactions

During the first 2 years, various traditional root and leaf crops are grown as intercrops with similar production to pure cropping systems.

#### Spacing

Spacing is 5 x 5 m (16 x 16 ft) or 400 trees per hectare (160 trees/ac).



## PUBLIC ASSISTANCE

See general extension links at:

<http://www.traditionaltree.org/extension.html>

**Top: 2.5-year-old tropical almond trial planting at Shark Bay, Santo, Vanuatu. PHOTO: K. AKEN Bottom: same Shark Bay planting as above at 5 years old; this tree has reached 20 m (65 ft) in height. PHOTO: L. THOMSON**

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## *Terminalia catappa* (tropical almond)

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