Species Profiles for Pacific Island Agroforestry
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Aleurites moluccana (kukui)

Euphorbiaceae (spurge family)

'*ama* (Marquesas); candlenut, candleberry, varnish tree, Indian or Belgaum walnut (English); *kukui, kuikui* (Hawai'i); *lama* (Samoa); *lauci, nggerenggere, sikeci, sikeli, sikethi, toto, tuitui, tutui, waiwai* (Fiji); *lumbang* (Guam); *raguar* (Caroline Islands); *rama* (Mangareva); *sakan* (Palau); *sakan, shakan* (Pohnpei); *tahii, tahiri, tiairi, ti'a'iri, tutui* (Moorea [French Polynesia]); *tuitui* (Mangaia [Cook Islands], Futuna, Makatea, Niue, Tonga, Tubuai, Uvea); *tutu'i, ti'a'iri* (Society Islands); *tutui* (Rimatara, Rurutu, Tahiti)

Craig R. Elevitch and Harley I. Manner

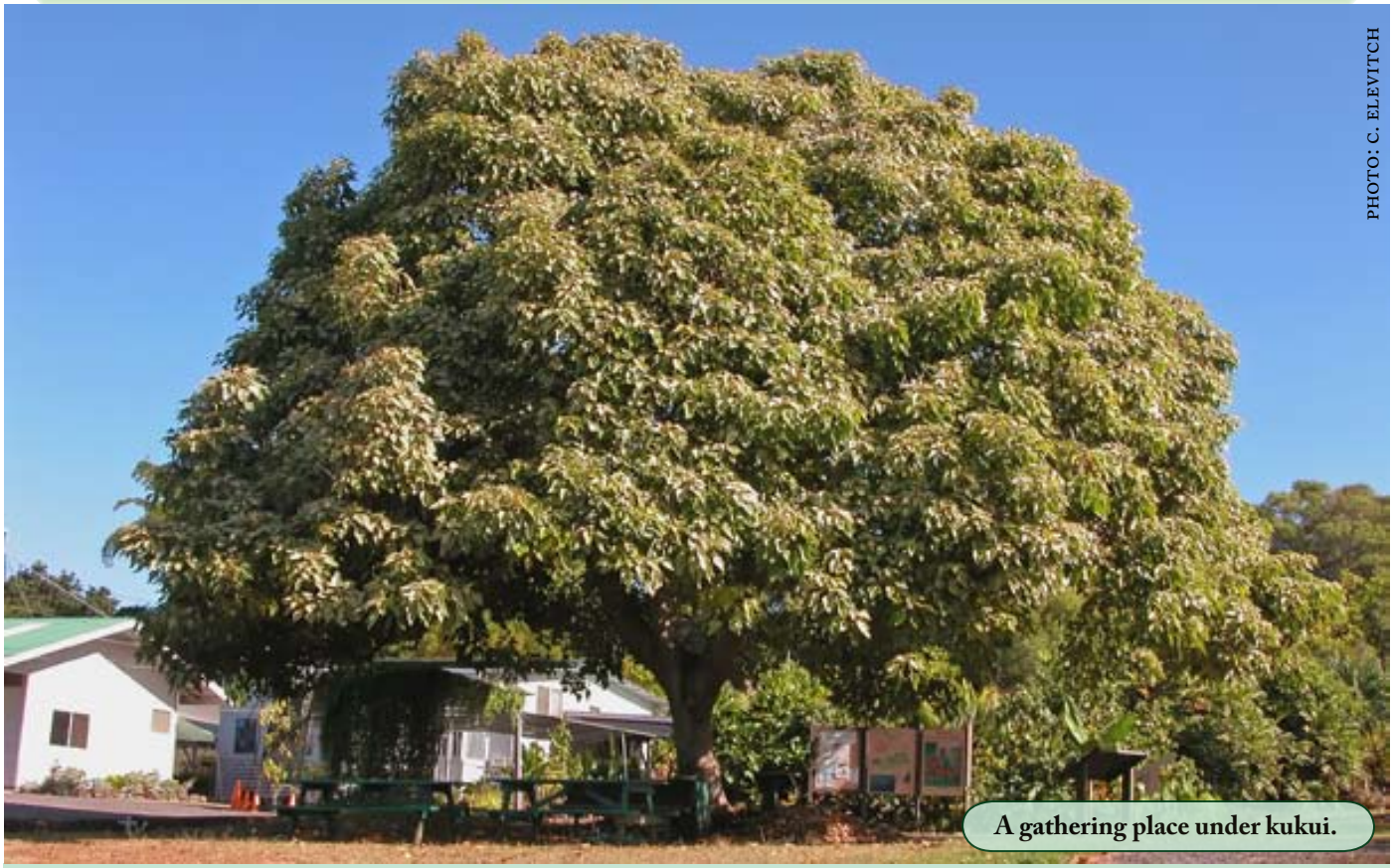


PHOTO: C. ELEVITCH

A gathering place under kukui.

IN BRIEF

Distribution Widespread throughout the tropics.

Size Typically reaches 10–15 m (33–50 ft), with similar crown diameter.

Habitat Subtropical dry to wet and tropical very dry to wet forest climates. Typically 0–700 m (0–2300 ft) with rainfall of 640–4290 mm (25–170 in).

Vegetation Associated with a wide variety of cultivated plants.

Soils Prefers light and medium textured soils; grows even on basalt, red loams, stony clay ground, sand, and limestone.

Growth rate Moderately fast growing in favorable conditions, growing 0.5–1.5 m (1.6–5 ft) per year.

Main agroforestry uses Windbreak, screen/hedge, soil stabilization, homegardens.

Main products Oil from seed, nut shells for leis.

Yields 80 kg (176 lb) seeds per tree/year in cultivation.

Intercropping Planted as a boundary or windbreak tree.

Invasive potential Moderate, has naturalized in many areas. Rarely considered a pest.

INTRODUCTION

Kukui is one of the great domesticated multipurpose trees of the world. It is one of the most useful trees introduced by the aboriginal people of the Pacific islands. A tall, spreading tree in open areas, it commonly attains heights of 10 m (33 ft) and a canopy diameter about as wide as the tree is tall. Kukui grows in homegardens, in and around farms, and naturalized along streams, gulches, and valley slopes. It is easily recognized by its characteristic silvery gray-green foliage, which is particularly ornamental.

Kukui is native to the Indo-Malaysia region and was introduced in ancient times throughout the Pacific islands. It can grow in a wide range of dry to wet tropical and subtropical habitats but is most at home in the moist tropics with annual rainfall of 2000 mm (80 in) or greater. Kukui tolerates drought and wind and grows readily on poor soils as well as steep slopes. Due to its many traditional uses and its role in ecosystems, kukui is recognized as the official state tree of Hawai'i.

The traditional uses of kukui are extensive. Throughout Polynesia kukui is known in local languages by names whose root means "light," referring to the traditional use of seeds and oil which were burned for illumination. Many parts of the plant including the seeds, leaves, flowers, and bark were used in traditional medicine. Caution is advised in using the plant medicinally or for consumption, as all parts of the tree are toxic. Dyes extracted from various plant parts were used to color tapa cloth and canoes, as well as in tattooing. Today, in addition to its traditional uses, kukui has found commercial uses, particularly in the cosmetics industry.

In urban areas, kukui makes a lovely shade tree or visual screen. In agricultural systems it can be integrated for use in windbreaks, shade, soil stabilization, and improved fallow. Kukui can regenerate and naturalize where planted, and it has been described as a moderate invader in certain areas. However, it is rarely considered invasive or problematic.

DISTRIBUTION

Native range

Kukui is native to Indo-Malaysia. It thrives in moist tropical regions up to 1200 m (3940 ft) elevation.

Current distribution

Kukui is today widespread throughout the tropics. It was introduced aboriginally throughout the Pacific islands and is now a common tree of the Pacific at elevations up to 700 m (2300 ft). In Hawai'i, kukui has naturalized in forests on all the main islands and is commonly found in cultivation. It is particularly at home in moderately moist valleys, where it has become a conspicuous part of the landscape.

Elsewhere in the Pacific, it is primarily found in cultivation in villages and plantations or in secondary growth following cultivation or along stream banks. The tree is also found in Puerto Rico, the Virgin Islands, Malagasy, Sri Lanka, southern India, Bangladesh, Brazil, the West Indies, and the Gulf Coast of the United States.

BOTANICAL DESCRIPTION

Preferred scientific name

Aleurites moluccana (L.) Willd.

Family Euphorbiaceae (spurge family)

Non-preferred scientific names

Synonyms no longer in use include:

Aleurites javanica Gand.
Aleurites remyi Sherff
Aleurites triloba Forster & Forster f.
Camirium moluccanum (L.) Ktze.
Croton moluccanus L.
Jatropha moluccana L.

Common names

Candlenut, candleberry, varnish tree, Indian or Belgaum walnut (English)

The roots of the Polynesian names below mean "light," referring to the ancient use of burning the nuts or oil extracted from the nuts to provide illumination:

'ama (Marquesas)
kukui, *kuikui* (Hawai'i)
lama (Samoa)
rama (Mangareva)
tahii, *tahiri*, *tiairi*, *ti'a'iri*, *tutui* (Moorea, French Polynesia)
tuitui (Mangaia [Cook Islands], Futuna, Makatea, Niue, Tonga, Tubuai, Uvea)
tutu'i, *ti'a'iri* (Society Islands)
tutui (Rimatara, Rurutu, Tahiti)

Other common names from the Pacific include:

lauci, *nggerenggere*, *sikeci*, *sikeli*, *sikethi*, *toto*, *tuitui*, *tutui*, *waiwai* (Fiji)
lumbang (Guam)
raguar (Caroline Islands)
sakan (Palau)
sakan, *shakan* (Pohnpei)

Names from other world regions include:


Left: Kukui often is found in the regrowth of abandoned agricultural sites, such as here in American Samoa. (pictured: Tuipuavai Tago) Right: The distinctive canopy often stands out in the landscape, such as here on the slopes of Waipi'o Valley, Hawai'i. PHOTOS: C. ELEVITCH

arbol llorón, *avellano*, *avellano criollo*, *nogal de la India*, *nuez* (Spanish)
bancoulier, *noyer de bancoul*, *noyer des Moluques*, *aleurites*, *noisette*, *noix*, *noyer*, *noyer des Indes* (French)
calumbàn, *noz da India* (Portuguese)
kamiri (Indonesian)
kandeltri (Bislama, Vanuatu)
Kerzennussbaum, *Lichtnussbaum* (German)
le noix de Bancoul (French, Vanuatu)
lèrit, *nwa*, *nwazèt* (Creole)
ragaur (Carolinian)
tung (trade name)

Size and form

Kukui is a large spreading tree that can reach 20 m (66 ft) in height and 0.9 m (3 ft) trunk diameter, although it typically reaches 10–15 m (33–50 ft) when growing in the open. Crooked trunks and irregular, wide, spreading or pendulous side branches are typical. In narrow valleys kukui usually has a branchless trunk and achieves its greatest height. Dense clusters of kukui are often seen in areas favorable to its growth, with the inner trees having tall trunks with relatively few side branches and trees on the edge having outer side branches and foliage often down to the ground.

Flowers

Kukui is monoecious (having both male and female flowers on the same plant). The greenish-white, fragrant flowers are arranged in a 10–15 cm (4–6 in) terminal panicled cyme, with many small male flowers surrounding the female flowers. The corolla is whitish with five free petals, dingy white to creamy in color, oblong in shape and up to 1.3 cm (0.5 in) in length. The ovary is pubescent, superior, and two-celled, each with one ovule. Staminate flowers are longer and thinner than pistillate flowers.

The plant typically flowers in the spring, although flowers can be found nearly any time of year in many areas.

Leaves

This tree is easily discernible by its very distinctive leaves, which are three- to five-nerved from the base, alternate, and simple, with entire, wavy margins. The leaf blades are 10–20 cm (4–8 in) long with two glands at the junction of the




Upper left: The scientific name for kukui, *Aleurites*, comes from the Greek word for "floury," referring to the dusted-flour appearance of young leaves and flower buds. Upper right: Trees often flower nearly continuously. Lower right: Ripe fruit in tree. Lower left: Bark is smooth and light gray in color, often with lichen growth in moist areas. PHOTOS: C. ELEVITCH

leaf base and petiole that secrete a sweetish sap. Leaves of young plants and those of the lower branches are three- to five-lobed with a rounded, heart-shaped base (subcordate), while the apex is acute (sharp). Younger leaves are usually simple and deltoid to ovate in shape. The upper surface of young leaves is whitish with a silvery gloss, becoming dark green with age. The underside is rusty stellate-pubescent when young (having a hairy glossy indument).

Fruit

The green to brownish fruit is a laterally compressed, ovoid to globose indehiscent drupe 5–6 cm (2–2.4 in) long by 5–7 cm (2–2.8 in) wide. It has also been described as being "round, hard apple-shaped" with fleshy to leathery husks. The nuts contain an oil similar to tung oil from *Aleurites fordii*.

Seeds

The seeds are contained within a hard, black, rough shell elliptical in shape and about 2.5–3.5 (1–1.4 in) cm long. The shells are similar in shape and texture to walnuts, although smaller and thicker. There are about 100–120 seeds (with shells on, but with husks removed) per kilogram (45–55 seeds/lb).

Similar species

Aleurites trisperma Blanco is a small tree similar to kukui (*A. moluccana*). Unlike kukui, *A. trisperma* has unlobed leaves and prominently ridged three-seeded fruits.

GENETICS

Variability

There is great variability in kukui, particularly in the leaves,

which can vary tremendously in size, shape, color, and texture, even on a single tree. For example, leaves of young plants and of the lower branches are three- to five-lobed while older leaves and those of the upper branches are usually simple and deltoid to ovate in shape. Fruits can range in size up to 4 cm (1.6 in) in diameter.

Known varieties

The variety aulanii is named for small-fruited plants from Waipiʻo Valley, Hawaiʻi (Wagner et al. 1999). The variety katoi (mango-leafed kukui) has "narrow, lanceolate leaves with lateral lobes obscure or absent" (Stuppy et al. undated). The remyi variety, also the probable result of aboriginal Hawaiian selection, has "lengthened, simple lanceolate leaves (with or without obscure lobes) or deeply lobed leaves with the lateral lobes very narrow and the terminal lobe much elongated," while a cultivar from New Caledonia has orbicular leaves (Stuppy et al. undated). A variety found in Vanuatu (Maewo) has seeds which can be eaten without any apparent toxic effect (Walter and Sam 2002).

Culturally important related species

In China, tung oil is produced from *Aleurites fordii* (Stone 1970). In Japan, *A. cordata* is used for the same purpose, while other related species are *A. montana* and *A. trisperma* (Anon. undated [2]).

ASSOCIATED PLANT SPECIES

As kukui is an aboriginal introduction to the Pacific islands, it is generally found in disturbed mesic (moderately moist) forest habitats. In Hawaiʻi, it is very conspicuous along stream valleys and ravines. However, it can also be found in association with native species. It is found in cultivated forest remnants in the Marquesas and other high volcanic islands of the Pacific.

Associated native species commonly found

On Mangaia (Cook Islands), kukui is found in "disturbed native" mixed-species forest dominated by the native tree species *Elaeocarpus floridanus* and *Hernandia moerenhoutiana* (Merlin 1991). Introduced species associated with kukui include *Cocos nucifera*, *Morinda citrifolia*, *Hibiscus tiliaceus*, and *Psidium guajava*.

In Pahole Gulch, Oʻahu, Hawaiʻi, kukui is a dominant species in a forest composed of *Diospyros hillebrandii, D. sandwicensis*, *Pisonia umbellifera*, and *P. brunoniana* (Mueller-Dombois and Fosberg 1998). Kukui is also a dominant in non-native forests of the Pahole Gulch Natural Area, composed of *Syzygium cumini*, *Psidium* spp., *Schinus terebinthifolius*, and *Eucalyptus* (Mueller-Dombois and Fosberg 1998).

> Hawaiian sayings (Pukui 1983)
>
> *He kumu kukui i heʻe ka pīlali.*
> "A kukui tree oozing with gum."
> (A prosperous person.)
>
> *Ka malu hālau loa o ke kukui.*
> "The long shelter of the kukui trees."
> (A kukui grove shelters like a house.)
>
> *Pupuhi kukui—malino ke kai.*
> "Spewed kukui nuts—calm sea."
> (Pour oil on troubled waters.)

On Moorea (Fr. Polynesia), kukui, *Hibiscus tiliaceus*, *Rhus taitensis*, and other trees are found on the sides of valleys. On rocky slopes, kukui is found in association with indigenous species such as *Pisonia umbellifera*, *Boehmeria virgata*, *Pandanus* sp., *Freycinetia impavida*, *Hernandia* sp., *Cyclophyllum barbatum*, *Macaranga* sp., *Weinmannia parviflora*, *Glochidion* sp., *Neonauclea forsteri*, *Ixora moorensis*, and *Tarenna sambucina* (Mueller-Dombois and Fosberg 1998).

Species commonly associated as aboriginal introduction in Pacific islands

In Tahiti, kukui is found in the submontane rain and valley forests in association with native species along with breadfruit (*Artocarpus altilis*), mango (*Mangifera indica*), and coconut (*Cocos nucifera*) (Mueller-Dombois and Fosberg 1998).

In the Marquesas, this species is found in formerly cultivated valley bottomlands. The vegetation here has been described as a mesophytic (medium moisture) forest composed largely of food and other useful plants such as *Artocarpus*, *Annona*, *Ceiba*, *Cocos*, *Citrus*, *Coffea*, *Syzygium*, *Inga*, *Inocarpus*, *Mangifera*, *Pandanus*, *Persea*, *Psidium*, *Pometia*, and *Spondias* (Mueller-Dombois and Fosberg 1998, Decker 1992). On Eiao Island (Marquesas), kukui is found in the gulches with *Pisonia grandis*, *Hibiscus tiliaceus*, *Thespesia populnea*, *Dodonea viscosa*, and *Annona squamosa* (Mueller-Dombois and Fosberg 1998).

ENVIRONMENTAL PREFERENCES AND TOLERANCES

Climate

This species has a large geographical distribution. Climati-

cally it is found in subtropical dry and wet climates and tropical very dry to wet forest climates. In Hawai'i, the species is found between 0 and 700 m (0–2300 ft) (Wagner et al. 1999). Near the equator, the tree is reported to grow on a variety of soils up to 2000 m (6560 ft), although it is more likely that it has an upper limit of about 1200 m (3940 ft).

Elevation range

0–700 m (0–2300 ft) (Hawai'i), but can grow up to 1200 m (3940 ft) closer to equator.

Mean annual rainfall

640–4290 mm (25–170 in) (mean of 14 cases, 1940 mm [76 in]) (Duke 1983)

Rainfall pattern

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

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

3–5 months or longer, as the species is often found along streams that may have subsurface water even after longer dry spells

Mean annual temperature

19–27°C (66–81°F)

Mean maximum temperature of hottest month

26–30°C (79–86°F)

Mean minimum temperature of coldest month

8–13°C (46–55°F)

Minimum temperature tolerated

8°C (46°F) (estimate)

Soils

Said to occur on a variety of soils, including red loams, stony clay ground, sand, and limestone. As evidenced by its relative absence in Northern Guam (which is underlain by limestone), kukui does not seem to prefer alkaline soils. However, its presence on Mangaia, which has Makatea soils with some limestone, suggests a tolerance of neutral to slightly alkaline soils. The species is dominant on moist, well drained acidic soils (perhaps Inceptisols and Andosols) of the high volcanic islands of the Pacific Basin.

Soil texture

The tree prefers light and medium texture soils (sands, sandy loams, loams, and sandy clay loams).

Soil drainage

It requires free drainage.

Soil acidity

It grows in lightly acidic to alkaline soils (pH 5–8).

Special soil tolerances

Kukui tolerates infertile soils.

Tolerances

Drought

Kukui is quite drought tolerant once well established. However, it flourishes in moist environments.

Full sun

The tree prefers full sun and can grow as a pioneer species in open areas with suitable rainfall.

Shade

Kukui can grow in a modest amount of shade, up to 25%.

Fire

The species is probably intolerant of fire.

Frost

It is probably intolerant of frost, as it is generally confined to the lower slopes of pali (steep slopes) that do not experience frost (up to about 700 m [2300 ft] in Hawai'i).

Waterlogging

Although the species is an indicator of stream courses, it favors well drained, moist soils.

Salt spray

Kukui tolerates a modest amount of salt spray and is occasionally found growing near the coast.

Wind

It tolerates both steady and storm winds and makes a suitable windbreak tree, especially in a multi-row windbreak.

Abilities

Regenerate rapidly

The tree can grow well even on relatively poor sites, provided ample soil moisture is available, particularly during establishment.

Coppice

Kukui regrows very well even after severe pruning, although it has a tendency to die after two or more prunings

in quick succession.

Other

Kukui is known for its ability to grow well on slopes, even steep gulches and cliffs.

GROWTH AND DEVELOPMENT

There is little direct information on the growth and development of kukui. It is said that the tree is quick growing and readily colonizes disturbed gaps and forest margins. Given these characteristics, kukui probably has growth rates comparable to other common secondary forest tree species. The tree requires little attention once it is established.

Flowering and fruiting

Flowering and fruiting begins at 3–4 years old. In many places flowering and fruiting take place almost continuously, frequently with flowers and fruits of all stages of ripeness occurring on each tree.

Reaction to competition

Kukui can hold its own even in the presence of grasses and other herbaceous weeds.

PROPAGATION

Propagation of kukui seedlings is easily done by seed. Although the seeds can take up to 3–4 months to germinate, they are large and quickly grow into strong, stout seedlings ready for field planting. Seedlings are not finicky about growing location (tolerating sun or partial shade), nor do they require special growing medium or watering regimes. Due to the quick growth of germinating seeds into seedlings, seeds lend themselves to either being direct-seeded in the field or pregerminated in the nursery, then direct-seeded. Kukui can also be propagated by cuttings, but this is uncommon and may not yield a plant that grows as vigorously as a seedling.

Seed collection

Kukui flowers and fruits intermittently throughout the year. Mature fruits can be picked from the tree or collected from the ground.

Ripe fruit can often be collected from underneath the lower canopy (top), or seeds can be collected from the ground under trees with the husk already deteriorated (bottom). PHOTOS: C. ELEVITCH

Seed processing

If the fruits are fresh, they are allowed to decay a few days in a moist area, which facilitates peeling off the thick, leathery outer husk. This exposes the hard shell that encloses the seed. There are about 100–120 seeds per kg (45–55 seeds/lb) with husk removed and shells on. Typically, germination is about 80% over the course of several months.

To improve the germination rate, bad seeds can be floated off in water.

Seed storage

Seeds can be stored for several months when dried to 10–12% moisture content. Often seeds lying on the ground under trees are viable and can be used successfully.

Pre-planting treatments

Untreated seeds germinate in about 4 months. Sun warming of a moist medium is thought to hasten and improve germination. Cracking the seed coat (shell) and soaking overnight in water may also hasten germination. Fungi growing on the seed coat may become a problem for germinating seeds, so treating the seeds with a fungicide prior to sowing may be helpful in reducing fungal problems. Seed scarification with acid does not benefit germination.

Growing area

Kukui seeds can grow in moderate shade, but full sun also works and may hasten germination.

Germination

Seeds can be direct-seeded in containers or pregerminated in beds. When seeds are pregerminated in a bed, it is best to transplant the seeds just as they begin to germinate when the seed cracks open. Pregerminated seeds can either be planted in nursery containers or direct-sown in the field.

Media

Because kukui germinants have a large, thick taproot, it is recommended that seedlings are grown in 2–4 liter (1/2–1 gallon) root-training containers. Use a well drained potting medium such as 50% peat moss, 25% perlite, and 25% vermiculite, amended with a little compost, dolomite lime, gypsum, and 14–14–14 slow-release fertilizer. Potting media should also be inoculated with mycorrhizal fungi from a reputable commercial source, particularly if the trees will be planted in degraded soils.

Time to outplanting

After germination, plants are ready to be transplanted into the field after about 3–4 months.

Approximate size for outplanting

Trees are ready to outplant when they have attained a height of about 25 cm (10 in) and stem diameter of 12 mm (0.5 in).

Guidelines for outplanting

It has been reported that 200–300 seedlings are planted per hectare for oil seed production. In windbreaks, kukui can be planted 3–4 m (10–13 ft) apart in the row.

DISADVANTAGES

There are very few disadvantages to planting the widely adapted and multipurpose kukui tree. Perhaps the biggest commercial disadvantage is that no large markets exist for any kukui products. Also, it is so easy to grow in many environments that there is no clear commercial advantage to growing it in any specific place. For example, any kukui product that can be produced in Hawai'i can be easily reproduced in other tropical regions where the costs of land and labor are cheaper.

Potential for invasiveness

Kukui has naturalized in several Pacific islands, particularly in Hawai'i, and has the potential to become established outside of cultivation. Despite this, kukui is rarely considered a harmful invasive or pest species.

Susceptibility to pests/pathogens

The following fungi are known to attack kukui: *Cephalosporium* sp., *Clitocybe tabescens*, *Fomes hawaiensis*, *Gloeosporium aleuriticum*, *Physalospora rhodina*, *Polyporus gilvus*, *Pythium ultimum*, *Sclerotium rolfsii*, *Sphaeronema reinkingii*, *Trametes corrugata*, *Xylaria curta*, *Ustulina deusta*. Nematodes include *Meloidogyne* sp. (Duke 1983).

AGROFORESTRY/ENVIRONMENTAL PRACTICES

Mulch/organic matter

Kukui leaves make a good mulch. To preserve the health of the tree and encourage rapid regrowth, only a small percentage of the leaves (less than 20%) should be removed at any one time.

Soil stabilization

Kukui grows well on steep slopes and in gulches. Along with koa (*Acacia koa*), kukui was one of the first trees planted by the Hawai'i Division of Forestry for watershed rehabilitation.

Crop shade/overstory

Although not considered overly competitive with other plants, kukui's dense shade limits its use as shade for light-demanding crops.

Alley cropping

Although kukui will regrow after severe pruning, its moderate growth rate makes it unsuitable for frequent pruning for mulch in an alley cropping system.

Homegardens

Because of its usefulness and beauty, kukui is grown in homegardens throughout the Pacific and elsewhere in the tropics.

Living fences/visual screen/boundary markers

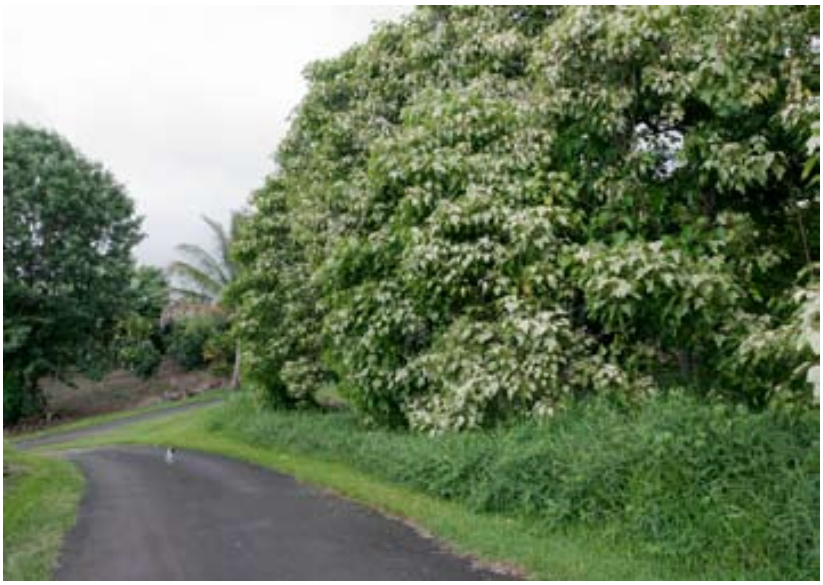
It is often used as a living fence or boundary marker in Tonga, Hawai'i, and elsewhere. Planted densely as a double row on 2 x 2 m (6.5 x 6.5 ft) or 3 x 3 m (10 x 10 ft) spacing, kukui makes a wonderful visual screen.

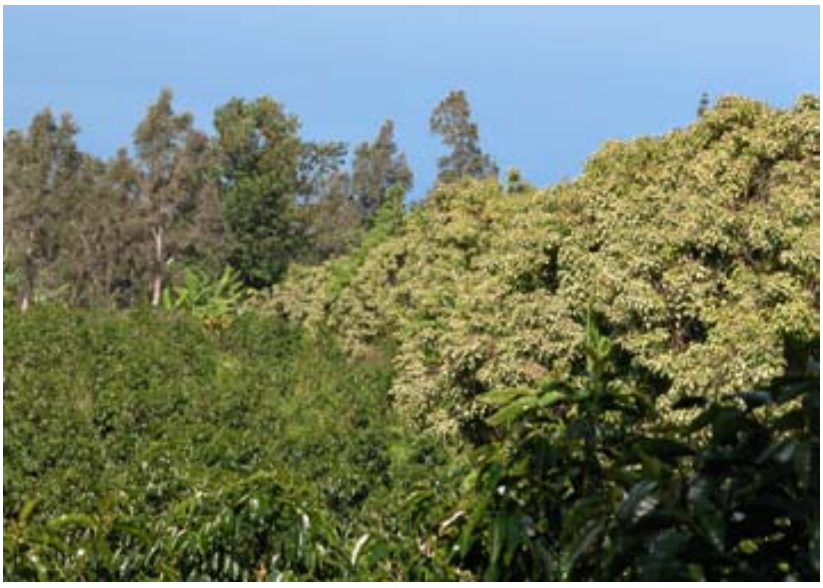
Windbreaks

Kukui makes a good windbreak component, particularly in a multi-row windbreak.

Ornamental

Kukui is widely used as an ornamental tree for its thick silvery-green foliage. This is perhaps its most common use in cultivation.





Kukui makes an excellent screen along roads and boundaries. Top: Privacy hedge along driveway. Bottom: Boundary hedge next to coffee plantation.
PHOTOS: C. ELEVITCH

USES AND PRODUCTS

With its innumerable uses, kukui was disseminated aboriginally throughout the Pacific islands. Virtually all parts of the tree—leaves, fruits, bark, wood, roots, sap, flowers, etc.—were useful for medicine, illumination, housing, dyes, food, ornamentation, and many other uses. Even today, many of kukui's traditional applications are still in use. During the 19th century kukui oil was a commercial export of Hawai'i, and it has recently been revitalized as a commercial product there and elsewhere in the Pacific.

Nut/seed

The raw seeds are toxic and have a strong purgative effect, but cooked seeds can be eaten sparingly, especially as a condiment. Some varieties, such one found in Vanuatu (Maewo), have no apparent toxic effect (Walter and Sam 2002).

Medicinal

Folk remedies are reported for general weakness due to stomach or bowel disorder in children, asthma, bad breath, skin sores or ulcers, "swollen womb," and rejuvenating the body after poisoning (Kaaiakamanu and Akina 1922). Kukui nut oil makes a strong laxative and is sometimes used like castor oil. The leaves have been used for poultices for deep contusions and swellings.

Flavoring/spice

Hawaiians have traditionally used the roasted, pounded kukui seed kernel mixed with salt and seaweed or chili peppers as a condiment called 'inamona.

Kukui is the official tree of the State of Hawai'i because of "the multiplicity of its uses to the ancient Hawaiians for light, fuel, medicine, dye, and ornament, as well as the distinctive beauty of its light-green foliage which embellishes many of the slopes of our beloved mountains." (Neal 1965)

Animal fodder

After removal of the oil, the remaining seed cake has been used for cattle fodder.

Timber

The wood is straw colored and very light weight (sp. gr. 0.35). Because it is not resistant to decay or insect attack, it is rarely utilized for timber. The wood is readily colonized by fungi and has been used successfully as a substrate for growing mushrooms, particularly the ear fungus (*Auricularia* sp.) known in Hawai'i as pepeiao. After heavy rains, deadwood under kukui trees often has large quantities of edible fungus.

Fuelwood

The wood can be burned as a low-quality fuel.

Canoe/boat/raft making

The Hawaiians used the easily worked wood for short-lived, light-weight canoes and fishnet floats.

Rope/cordage/string

A bark infusion with water was used by Hawaiians to preserve fishnets.

Resin/gum/glue/latex

The whitish sap was painted on tapa cloth to make it more durable and waterproof.

Body ornamentation/garlands

The empty shells are strung to make a popular lei. The mature black seeds and immature white to brown seeds are commonly used in lei making, polished and unpolished. The shells, which can be polished to a high luster, are fashioned into earrings and other costume jewelry. The leaves with or without the flower clusters are woven into impressive leis.

Tannin/dye

Hawaiians used the seed husk to make a black dye for tattooing and the root bark to make a dye to paint canoes. The soot from burned seed kernels (traditionally used for illumination) is used for an indelible black dye in tattooing and tapa cloth, particularly in Samoa and Tonga (Whistler 1991).

Toxin/insecticide/fish poison

Kukui oil can protect cotton bolls from the boll weevil and prevent feeding by the striped cucumber beetle.

Cosmetic/soap/perfume

Oil extracted from the seed can be made into soap. Chewed seeds are used as a soap substitute. Refined kukui oil is today widely sold in the cosmetic industry and may currently be kukui's primary commercial product.

Fertilizer

After removal of the oil, the remaining seed cake has been used for fertilizer.

Due to its light weight, poor durability, and crooked form, the wood is rarely used for timber. PHOTO: C. ELEVITCH

Oil/lubricant

Oil extracted from the seeds was traditionally used by Hawaiians as a preservative for surfboards. The oil can also be used as a basis for paint or varnish, burned as an illuminant, made into soap, and used for waterproofing paper. Today kukui nut oil is marketed as a skin moisturizer and protectant. With chemical modification the oil can also be burned as fuel in diesel engines.

Illumination/torches

The oily kernels are dried and strung on a skewer such as a coconut leaf midrib. Each nut in the string burns for about 3 minutes and emits a somewhat fragrant smoke.

Ceremonial/religious importance

The likeness of a pig's head carved from kukui wood is set on an altar for the Hawaiian festival of Makahiki (Kamehameha Schools 1994).

Other

The seeds have been used as toys such as marbles and tops. The crushed seeds have been used mixed with other ingredients as fish bait (Abbot 1992).

URBAN AND COMMUNITY FORESTRY

Kukui is found in homegardens and community areas throughout the tropics. It has many traditional products for home use such as a condiment, medicines, dye, and utility wood. The tree is also highly prized for its amenity services including shade, living fence, and ornament.

Size in an urban environment

Kukui typically reaches 10–15 m (33–50 ft) tall with a broad canopy when grown in the open, with dense foliage often growing down to the ground. When grown in the shade of nearby trees, kukui grows more upright, with a dominant main stem and little side foliage. Trunk diameter at maturity can reach 1.5 m (5 ft). The tree tolerates pruning very well and can be controlled in size and shape as desired.

Rate of growth in a landscape

In favorable conditions young trees can grow 1–2

Top: The kukui kernel has numerous uses including medicine, condiment, and a basis for oil and soap. Bottom: The sap which wells up at the stem attachment just after harvesting young kukui fruits is used traditionally by Hawaiians to treat cuts and skin sores. PHOTOS: C. ELEVITCH

m/yr (3.3–6.6 ft) in height. As trees grow older, the rate of growth declines.

Root system

There is no indication of the root system interfering with other plants, pipes, or structures.

Products commonly used in a Pacific island household

The flavorful but somewhat toxic kernels are consumed to varying degrees throughout the Pacific. In Hawai'i the seeds are traditionally roasted and crushed together with sea salt to prepare a condiment called 'inamona. The crushed, roasted kernel is frequently used in small quantities in Indonesian and Malaysian cuisine. In Samoa the kernels are eaten by children, although more than 2–3 kernels can cause nausea, vomiting, abdominal pains, or diarrhea.

Various parts of the plants are used in traditional medicine throughout Oceania (Thaman and Whistler 1996, Whistler 2000, Walter and Sam 2002). A black dye used to dye tapa cloth is made from the fruit, bark, or roots. Leaves, flowers, and seeds are used in making leis in Hawai'i. The leaves and young branches are considered to be an excellent mulch material and were formerly used to mulch taro in Hawai'i. Many more uses are listed in "Uses and products" above.

Light requirements

Kukui prefers full sun and grows more upright and spindly in partial shade.

Water/soil requirements

The tree grows in a wide variety of soils, including infertile soils. It requires free drainage.

Life span

There is no data available, but kukui trees are estimated to live 40–60 years.

Varieties favored for use in homegardens or public areas

There are many forms found regionally (see "Variability" above). These selections would be favored for home and village gardens.

Seasonality of leaf flush, flowering, fruiting

In optimal conditions with ample moisture available, leaf flush, flowering, and fruiting are nearly continuous.

Exceptional ornamental values

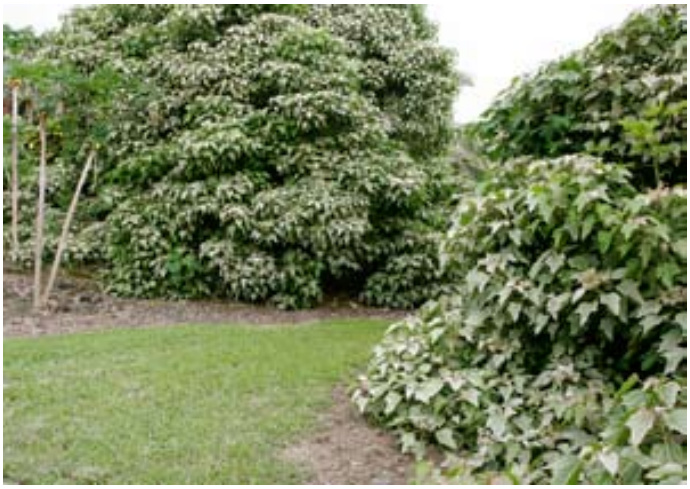
The silver-gray foliage stands out in the landscape. Kukui is also recognizable by its domed and dense canopy. Trees are often in flower; the white to cream-colored flowers are attractive and slightly fragrant.

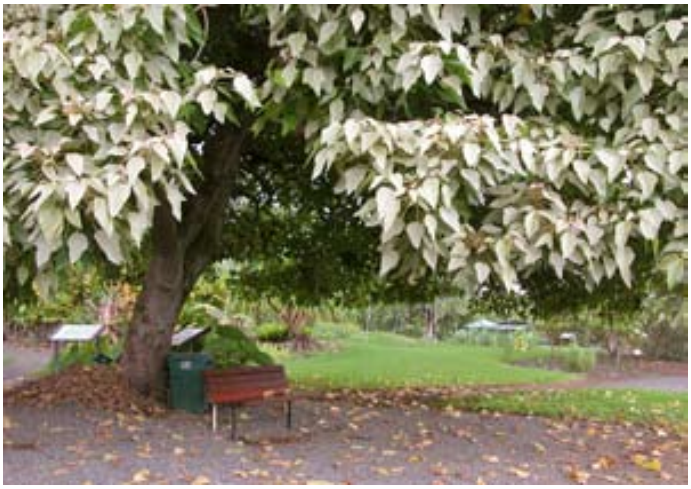
Use as living fence, hedge or visual/noise barrier

Given ample sunlight and space, kukui's dense crown makes a very good visual barrier, particularly since foliage tends to extend down to the ground. A row of trees planted 3–5 m (10–16 ft) apart forms a solid canopy.

Birds/wildlife

Many types of birds find shelter in the kukui canopy.





Left: In open areas, the foliage usually extends down to the ground. Right: When pruned up, the area under the canopy makes a wonderful sitting area. PHOTOS: C. ELEVITCH

Maintenance requirements

Young seedlings benefit from regular weeding and irrigation if necessary. Once established, trees require little care. Kukui does not require fertilizer except in the most infertile soils. It tolerates drought but will grow best in consistently moist conditions. The dense canopy tends to suppress weed growth within the drip line. The tree regrows well after pruning. If desired, lower branches can be pruned up along the perimeter to open a view underneath the canopy. The tree can also be pollarded to control the height and canopy diameter (Salim et al. nd). 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 2–3 years.

Special considerations regarding leaf, branch, and fruit drop

Kukui holds its branches very well in normal conditions and even in storms. The ground beneath the trees is often covered with fruits and seeds.

Nuisance issues

None.

Hazards

Newly fallen fruits are hard and round, about the size of golf balls. They present a real danger on streets or sidewalks where people could easy slip on them.

Common pest problems

Pests or diseases rarely seriously affect kukui. There are no pests of economic importance (Siemonsma 1999).

COMMERCIAL CULTIVATION

The widespread cultivation of kukui has traditionally been for its many non-commercial uses. At one time the seed oil was used as a basis for varnishes and paint, although the oil derived from tung (*Aleurites fordii*) is superior for these uses. In more recent times, the primary commercial product derived from kukui is the oil extracted from the seed for the cosmetic industry. The oil is rich in polyunsaturated oils (linolenic, oleic, and various linoleic acids), and is said to have a high penetrability and soothing effect on dry or sunburned skin and other skin maladies such as psoriasis, acne, and eczema. Most oil produced in India, Sri Lanka, and other places is consumed locally and does not find its way into international trade.

Spacing

A suggested spacing for oil production is 200 trees/ha, which can be achieved with a spacing of about 7 x 7 m (23 x 23 ft) or 6 x 8 m (20 x 26 ft).

Management objectives and design considerations

Seeds can be harvested from the ground, although the heavy leaf mulch usually found under kukui trees hinders harvesting the fallen seeds. Picking seeds from the trees is often impractical due to the height and the difficulty of judging maturity of the ripening fruit. The propensity of kukui to grow well on steep slopes may be used to some advantage, as the large spherical fruits can roll to collection areas if designed properly.

Yields

For tropical plantations with trees spaced at 200 trees/ha (81 trees/acre), nut yields were reported as 80 kg/tree (176 lb/tree), or 16 mt/ha/yr (7.1 t/ac/yr), of which 3 mt (3.3 t) would be oil Given a spacing of 200 trees/ha and an expected yield of approximately 80 kg of seeds per tree per year, about 16 mt/ha/yr can be produced. About 20% of this yield can be extracted as oil, which is equivalent to 3.2 mt/ha (1.5 t/ac) of unrefined oil per year. The current retail value (year end 2003) of kukui nut oil is about $43/kg ($19.50/lb). This represents a considerable potential retail value per hectare for the processed oil, and an incentive to investigate value-added processing methods. The residues can be converted to alcohol. Fruit yields range between 4 and 20 mt/ha/yr (1.8–8.9 t/ac/yr) and an oil yield of 3100 kg/ha (2760 lb/ac) has been reported (suitable, with modification, for diesel uses) (Duke 1983).

On-farm processing methods

Removing the outer husk and drying to ca. 12–15% moisture should be carried out on-farm. This stabilizes the seeds (prevents fungal growth and insect infestation) and prepares them for pressing.

Markets

Kukui nut oil is marketed widely through health food stores and on the Internet. Market volumes are not known.

INTERPLANTING/FARM APPLICATIONS

Some interplanting systems include:

Example 1

Location

Keauhou, North Kona, Hawai‘i.

Description

This project is a 2.4 ha (6 ac) orchard planted in 1993. The elevation is 230 m (700 ft) and rainfall ca. 1040 mm (45 in) annually. The purpose is a visual screen.

Crop/tree interactions

The interior of the property was planted with avocados, mango, and sapodilla trees. The kukui afforded modest protection from the periodic storm winds.

Spacing/density of species

The outer boundary was planted with a double row of kukui trees 2.6 m (8 ft) apart within rows and 2.6 m (8 ft) between rows.

Example 2

Location

Located at the Moloka‘i Research and Demonstration Farm in the Ho‘olehua Ag Park, Moloka‘i, Hawai‘i. The project is planted on 0.15 ha (0.36 ac).

Description

This project is called, “A Demonstration of a Multi-Cropping System in Establishing and Producing Native Trees” (Arce 2003). Five rows of trees were planted in a north-south orientation with six kukui trees in each row. There is 4.6 m (15 ft) between rows to accommodate the tractor for mowing the area between rows. In addition to the growth rate of the kukui and other trees, the project measured the performance of understory crops such as alfalfa, ginger and anthuriums for cut flowers, kava, edible fungus, and cacao. Alfalfa was successfully grown during the early years, before the kukui trees shaded the surrounding area too much. Kukui’s natural habit of dropping its branches and many falling nuts posed a hazard to understory crops such as the flowers. Ear fungus, a popular edible fungus known in Hawaiian as *pepeiao*, was introduced to kukui logs which were set in piles between the trees. Small amounts of edible fungus were produced, which could probably be increased by improved mycoculture techniques.

Spacing

Trees were planted at 3 m (10 ft) between trees, 4.6 m (15 ft) between rows.

Kali Arce shows her kukui trees in an agroforestry demonstration project in Ho‘olehua, Moloka‘i, Hawai‘i. PHOTO: J. B. FRIDAY

PUBLIC ASSISTANCE AND AGROFORESTRY EXTENSION

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

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Traditional Tree Initiative—Species Profiles for Pacific Island Agroforestry (www.traditionaltree.org)

Aleurites moluccana (kukui)

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