Species Profiles for Pacific Island Agroforestry
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Canarium indicum var. *indicum* and *C. harveyi* (canarium nut)

Burseraceae (torchwood family)

canarium nut (English), galip nut (Papua New Guinea: pidgin), *nangai* (Vanuatu), *ngali*, *ngali* nut (Solomon Islands)

Lex A. J. Thomson and Barry Evans

IN BRIEF

Distribution Native to eastern Indonesia, Papua New Guinea, Solomon Islands, and Vanuatu.

Size Typically 20–30 m (66–100 ft) tall with canopy diameter of 15–20 m (50–66 ft) at maturity.

Habitat Lowland, subhumid to humid tropics, very warm temperatures throughout the year, elevation 0–600 m (0–2000 ft), annual rainfall 1800–4000 mm (70–160 in).

Vegetation Widely planted around villages and settlements.

Soils Favors medium to heavy-textured soils of moderate to high fertility.

Growth rate Slow during the first year, 0.6–2 m (2–6.6 ft), but rapid thereafter, often 2.5–3 m/yr (8–10 ft/yr) for the next 5–6 years.

Main agroforestry uses Homegarden, windbreak, mixed woodlot.

Main products Nuts, timber, traditional medicine.

Yields Estimated at up to 4–7 mt kernel-in-testa/ha/yr (1.8–3.1 t kernel-in-testa/ac/yr).

Intercropping Interplanting with crops that can provide rapid returns, such as root crops, banana, papaya, kava, etc., is recommended.

Invasive Potential Minor potential to become invasive.

PHOTO: B. EVANS

Typical canarium nut tree shape and form when grown in the open, Vanuatu.

INTRODUCTION

Canarium nut (*Canarium indicum* var. *indicum*) is a large tree that grows to 40 m (130 ft) in height and 30 m (100 ft) in canopy diameter, with a trunk diameter of 1–1.5 m (3.3–5 ft) at breast height (dbh). It is native to humid, lowland zones of eastern Indonesia, Papua New Guinea, the Solomon Islands, and Vanuatu, where it favours medium to heavy-textured soils of moderate to high fertility, with free to slightly impeded drainage and neutral pH. Canarium nut is mainly found in lowland rainforest, secondary forest, old garden areas, and it is widely planted around villages and settlements. Traditionally, nut trees are selected, tended, or cultivated in or around coastal village sites. It has been and continues to be a very important food tree in Melanesia and was an important component in one of the world's first known permanent agricultural/arboricultural systems.

Canarium nut has long been regarded as a species well suited to community forestry and mixed arboricultural systems. The species is capable of rapid growth, with kernel-in-testa yields of up to 4–7 mt/ha/yr (1.8–3.1 t/ac/yr) expected from mature plantations. It has potential for inclusion in various agroforestry practices, including homegardens, windbreaks, perimeter plantings, and silvopastoral systems.

The species has a great, as yet largely untapped, economic potential for commercial development and export, mainly because of its abundance and non-perishable nut-in-shell. However, the present resource base of canarium nut in native forests is widely scattered, poorly known and documented, and includes a wide diversity of nut morphotypes and sizes. The latter complicates processing and marketing, and nuts from trees with lower kernel-in-shell ratios add to transportation and overall production costs. A concerted replanting effort, with superior nut types, is considered necessary in order to develop a future nut export industry.

Collection and utilization of nuts from native forests is more intensive in times of high market demand and in years when planted stands have lower yields. Nuts from native forests will also be useful in maintaining and building up the export industry, prior to planted stands becoming mature and achieving maximum production.

The species has no major drawbacks that mitigate against its wider planting in Melanesia and other parts of the Pacific. It has only minor potential to become an environmental weed.

Canarium nut has been cultivated in Melanesia for thousands of years and is an extremely important tree in traditional, customary life. Stories, songs, and dances relating to the tree have been recorded, and in parts of the Solomon Islands the traditional calendar is based around the trees' flowering and fruiting cycle. The trees are frequently planted as tribal boundaries and commemorative markers, and rights to harvest individual trees are traded within and among clans. Canarium nut groves are often the only evidence left of pre-Christian inland villages and their associated taboo sites.

DISTRIBUTION

Native range

Canarium nut is native to eastern Indonesia, Papua New Guinea, the Solomon Islands, and Vanuatu; it is widespread and common in the latter two countries. It is mainly found in the lowland humid zones.

Current distribution

The species has been introduced into Fiji, where it is cultivated for its edible nuts and is possibly semi-naturalized. It is uncommon in cultivation in Samoa, where it is known locally as *lama palagi*. Some small plantations have been planted in far north Queensland, Australia, using seed from PNG.

BOTANICAL DESCRIPTION

Preferred scientific name

Canarium indicum L.

Family

Burseraceae (torchwood family)

Non-preferred scientific names

Synonyms include *C. amboinense* Hochr., *C. commune* L., *C. mehenbethene* Gaertn., *C. moluccanum* Blume, and *C. zephyrinum* Rumphius

The existing taxonomy of *Canarium* is based almost exclusively upon the gross morphology of dried herbaria material. This taxonomy, particularly that of the cultivated taxa, is inaccurate, and is likely to be significantly changed once the taxa are subjected to thorough DNA analysis.

Common names

canarium nut (English)
galip nut (pidgin, Papua New Guinea)
nangai (Vanuatu)
ngali, *ngali* nut (Solomon Islands)

The standard common name in the Pacific is canarium nut. In Papua New Guinea it is known widely in pidgin as galip nut, but also referred to as *lawele* (New Britain) and *hinuei* (New Ireland). In the Solomon Islands, it is mainly known by the Kwara'ae name of *ngali* or *ngali* nut. Other local names include *angari* (Santa Ana), *ngari* (Kausage/Simbo and Varisi), *ngoeta* (Marovo), *nolepo* (Garciosa Bay), *nyia nyinge* (Ayiwo), *okete* (Roviana), *sela* (Guadalcanal) and *voi'a* (Vaiakau). In Vanuatu the local Bislama name for *Canarium* species (including canarium nut) is *nangai*. Other recorded local names in Vanuatu include *bunnige*, *punnige* and varieties *nige kava* and *nige karia* (Epi Island/Moriu) *nanae*, *vanae* (Santo Island/Sarete Village), *nangae* (Santo Island/Narango Village), *nangrau* (Aneityum Island/Anelghowat Village), *negerdove* (Loh Island/Lungharagi Village), *ngaetua* (Maewo Island/Naone Village), *ngapor*, *ngaqov* (Gaua, Banks Group/Lambot, and Namasari Villages), *ngeta*, *ngev tentel* (Vanua Lava, Banks Group/Mosina Village), *ngna*, *nangan*, *nanga* (Santo Island/Hog Harbour), and *vungaingai*, *vungigae* (Malo Island/Naviaru Village).

Size

Canarium nut is a large tree that can attain 40 m (130 ft) in height, 30 m (100 ft) in crown diameter, and 1–1.5 m dbh (3.3–5 ft). Most mature trees are 20–30 m (66–100 ft) tall and 15–20 m (50–66 ft) across with a dbh of 50–100 cm (20–40 in).

Form

The form typically is a reasonably well formed tree with short–medium length bole to about half the tree height, with heavy lateral branches and a dense canopy. The trunk is commonly buttressed, with steep or even buttresses up to 1.5 m (5 ft) high.

Flowers

The flowers are arranged in terminal panicles, 15–40 cm (6–16 in) long, with stipules at the base and bracts of flowers, the latter soon deciduous. Flowers are small, ca. 1 cm (0.4 in) across, and yellowish white. Perianth parts, sepals and petals, are arranged in threes, densely and finely hairy on the outside. In PNG and the Solomon Islands, the species is dioecious, with separate male and female flowers being borne on different trees. In Vanuatu trees may also bear either hermaphrodite flowers (sexually-functionally male and female) plus female flowers; or hermaphrodite flowers plus male flowers. The proportion of hermaphrodite and unisexual flowers varies considerably from one tree to another, but unproductive non-fruiting "male" trees are very rare in Vanuatu.

Flowering appears to be initiated by changes in day length. Accordingly, the onset of flowering depends on latitude, such that at about 3–4°S it starts in about April, while at 11°S its starts around September. In Vanuatu cyclones in the previous year can lead to earlier flowering in the following year, e.g., starting in July–August. In the Solomon Islands canarium nut trees generally flower at the beginning of the year during the wet season.

Under good conditions trees commence flowering about 5–7 years after planting.

Leaves

The leaves are bright to dark green, imparpinnate with (3–) 6–8 (–10) pairs of leaflets on a rachis to 30 cm (12 in) long. Individual leaflets are oblong-obovate to oblong-lanceolate, and typically 7–28 cm long by 3.5–11 cm wide (2.7–11 in long by 1.4–4.3 in wide). Stipules are persistent, ovate with toothed or notched margins, large and conspicuous (typically 1.5–6 x 1.3–4 cm [0.6–2.4 x 0.5–1.6 in], but up to 10 x 5 cm [4 x 2 in]) and located at the junction of the petiole and branch.

Fruits of canarium nut. PHOTO: C. ELEVITCH

Fruit

Fruits are borne on erect or slightly drooping stems, which are held clear of the canopy. The fruit is an ovoid to obovoid drupe, 3–6 x 2–4 cm (1.2–2.4 x 0.8–1.6 in) and generally green when unripe, turning deep dark green to black when ripe. In PNG the fruiting season, which lasts about 3 months, is reported to be fairly constant from year to year (May–July). In the Solomon Islands fruits start to mature in August, with production peaking between September and October. Trees in the Western Province fruit a little earlier than those in more eastern provinces. In Vanuatu the normal fruiting season is between October and January with a peak in November. Fruiting commences at about 7 years after planting.

Nut terminology (after Evans 1996)

Fruit	The outer skin (exocarp) and flesh (mesocarp), the nut-in-shell and kernel-in-testa
Nut-in-shell (NIS)	The shell (endocarp) and kernel-in-testa
Kernel-in-testa (KIT)	The edible kernel (seed) and testa
Testa	Skin surrounding the kernel
K:N ratio	Ratio of nut-in-shell that is kernel-in-testa
Kernel oil	The oil pressed from the kernel
Kernel cake	The residue after oil extraction

Seeds

The nut-in-shell (NIS) is three- to six-sided or rounded with one (or sometimes two or three) kernels. Nut properties vary considerably, e.g., NIS range of 28–62 mm long by 20–35 mm wide (1.1–2.4 in long by 0.8–1.4 in wide), with a fresh weight of 8–20 g (0.3–0.7 oz) in the Solomon Islands. The same figures for NIS of selected nut trees in Vanuatu were 36–56 mm long by 23–34 mm wide (1.4–2.2 in long by 1–1.3 in wide), with a fresh weight of 9–18 g (0.3–0.6 oz).

The fleshy mesocarp of the fruit is an important food for many animals, in particular flying foxes and pigeons, who act as seed dispersal agents.

Similar species

Canarium nut is closely related to three species in the taxonomic group vulgare, namely *C. vulgare* (from Indonesia) and *C. ovatum* and *C. luzonicum* (from Philippines). However, only *C. vulgare* shares a common distribution in eastern Indonesia and western New Guinea. Canarium nut can be distinguished in the field by the number of paired leaflets (six to eight) and its large stipule with toothed margin found at the conjunction of the petiole and branch. In *C. vulgare* the stipule margin is smooth. In *C. harveyi* and *C. salomonense*, two other edible species that have overlapping distributions, the stipules are smaller and located on the petiole, and there are fewer pairs (two to four) of leaflets.

Look-a-likes *C. harveyi* (left) and *C. indicum* (right). *C. indicum* has much larger stipules (the leafy appendages at the leaf bases), with toothed margins. PHOTOS: C. ELEVITCH

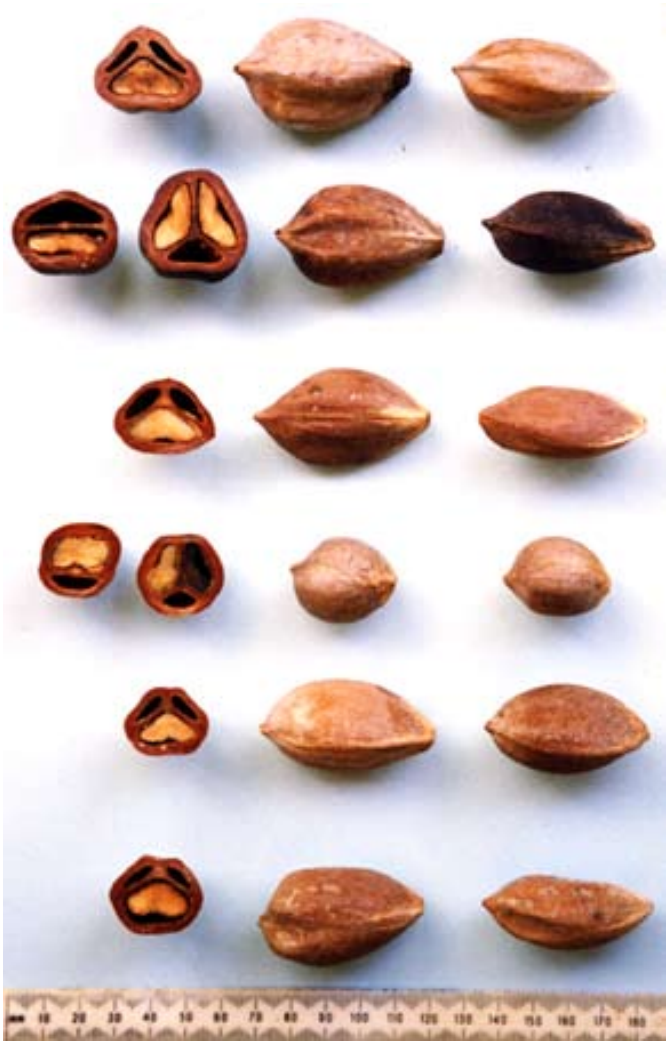
GENETICS

Variability of species

Intensive selection in the Solomon Islands and Vanuatu has produced selections with potentially valuable economic characteristics, such as thin shells and large kernels. In Vanuatu there are at least five "folk" varieties of canarium nut, which vary in shape, size, fruit color at maturation, and flesh (mesocarp) color and texture.

Known varieties

In addition to numerous local selections, two varieties of canarium nut have been formally recognized, namely the



Nuts-in-shell, Vanuatu. In natural populations there is tremendous variation in size and shape of nuts, as well as quality of the edible kernel. PHOTO: B. EVANS

type variety *indicum* and another variety *platycerioideum*. The latter, uncommon, variety occurs in West Papua (Indonesia) and has larger leaves and fruits.

ASSOCIATED PLANT SPECIES

Canarium nut is reasonably widespread throughout its native range in lowland rainforest, secondary forest, and old garden areas and is widely planted around villages and settlements. Traditionally, nut trees are selected, tended, or cultivated in or around coastal village sites. Only very rarely are the cultivated edible species found growing wild in the bush. Most so-called "wild" trees in the inland bush are remnant trees from past village sites.

Associated species commonly found in native habitat

Associated native species include *Barringtonia* species (*B. edulis* and *B. procera*), *Artocarpus altilis*, *Cocos nucifera*, *Dendrocnide latifolia*, *Dracontomelon vitiense*, *Ficus* spp., *Flueggea flexuosa*, *Hibiscus tiliaceus*, *Inocarpus fagifer*, *Macaranga* spp., *Metroxylon* spp., and *Pometia pinnata*.

Species commonly associated as aboriginal introduction in Pacific Islands

Commonly associated aboriginal introductions include *Citrus* species, *Musa* species, *Spondias dulcis*, and *Syzygium malaccense.*

Species commonly associated in modern times or as recent introduction

Commonly associated more recent introductions include *Mangifera indica* and *Theobroma cacao.*

ENVIRONMENTAL PREFERENCES AND TOLERANCES

Climate

The species is found in the lowland, subhumid to humid tropics. Temperatures are very warm to hot throughout the year. Tropical cyclones occur at periodic intervals throughout canarium nut's range in SE Solomon Islands and Vanuatu, mainly during the months of November through to March. The entire range is frost free.

Elevation range

0–600 m (0–2000 ft). The elevation range is usually from near sea level to 250 m (820 ft), but the tree may be planted up 600 m (2000 ft), with an extreme recorded elevation of 1850 m (6070 ft).

Mean annual rainfall

1800–4000 mm (70–160 in), although usually 2500–3500 mm (100–140 in).

Rainfall pattern

Canarium nut prefers climates with summer or uniform rainfall patterns.

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

0–1 month

Mean annual temperature

25–28°C (77–82°F)

Mean maximum temperature of hottest month

29–32°C (84–90°F)

Mean minimum temperature of coldest month

17–24°C (63–75°F)

Minimum temperature tolerated

Likely to be sensitive to temperatures below 5–7°C (41–45°F).

Soils

Canarium nut generally occurs on medium to heavy-textured soils, of moderate to high fertility, with free to slightly impeded drainage and neutral pH.

Soil texture

It prefers medium and heavy soils loams, sandy clay loams, clays, clay loams, and sandy clays.

Soil drainage

The tree tolerates soils with free or impeded drainage.

Soil acidity

It prefers neutral to alkaline soils (pH 6.1–7.4).

Special soil tolerances

Canarium nut does not tolerate shallow, infertile, or saline soils.

Tolerances

Drought

Likely to be only tolerant of short droughts of less than 3–4 months duration.

Full sun

Mature trees produce maximum nut yields when grown in close to full sunlight.

Shade

Can tolerate 25–70% shade. Young plants are sensitive to full sun and ought to be planted under shade (at least 50% shade). After 3–4 years the level of shade may be progressively reduced, through thinning or ring-barking unwanted overstory plants.

Fire

Likely to be intolerant of fire due to volatile resin in bark.

Waterlogging

The species is not well adapted to waterlogged conditions, but may tolerate impeded drainage for several months.

Salt spray

The species sometimes grows within a short distance of the sea and is likely adapted to light salt spray.

Wind

The trees have overall good tolerance of both steady and strong winds. During cyclones some large branches may be broken off and most other branches pruned of excessive woody twigs, but such damage is not highly detrimental. Trees damaged by cyclonic winds typically respond by producing early and vigorous floral growth from broken branches.

Maturing fruit and female flowers on the same branch of a cyclone damaged Nangai tree (MS111, *C. indicum*) in Narango village, South Santo, 24 September 1999. Trees damaged by cyclonic winds respond by producing early and vigorous floral growth from their broken-off branches. PHOTO: B. EVANS

Abilities

Self-prune

Trees display intermediate self-pruning ability.

Pollard

Trees regrow well following removal of large branches either during harvesting of nuts or breakage during cyclones.

GROWTH AND DEVELOPMENT

Plants grow relatively slowly during the first year, e.g., 0.6–2 m (2–6.6 ft), but thereafter grow rapidly under suitable conditions, e.g., 2.5–3 m/yr (8–10 ft/yr) for the next 5–6 years. After 5 years trees may attain a mean dominant height of 14 m (46 ft) and dbh of 15 cm (6 in). Height and dbh increase rapidly up to at least 15–20 years of age.

Flowering and fruiting

Trees begin to flower and fruit more heavily and regularly from about age 7–8 years.

Rooting habit

The tree has a deep taproot (Chaplin 1988).

Reaction to competition

Mikania and *Merremia* vines can stunt growth when seedlings are first planted out in open spaces, but mature trees are among the tallest in Melanesian forests so are able to compete well.

PROPAGATION

The species is readily propagated from seed, either as nursery-raised seedlings or by direct-seeding into the field. Limited success with grafting (cleft and splice) as well as air-layering has been reported (Evans 2004).

Seed collection

Fruits should only be collected from healthy, high-yielding trees with good nut characteristics including high kernel/nut ratios, large and preferably single-seeded nut-in-shell, thin shells, and sweet-tasting kernels. Collection time varies by location (country/latitude) and from year to year, but usually collection can be carried out in the second half of the year. Fruits turn deep dark green to black when ripe.

Seed processing

Propagation is from seeds (nut-in-shell) extracted from freshly collected mature fruits. There are about 50–200 seeds (nut-in-shell) per kg (23–91 seeds/lb). The outer fleshy mesocarp is removed by wetting and/or rotting.

Seed

Canarium seed is recalcitrant, which means it does not retain viability when dried or stored for extended periods. Seeds should be sown as soon as possible after collection. If seeds need to stored for a few weeks, then the outer flesh should be removed and the nut-in-shell stored in a shaded, cool (e.g., 15–25°C [59–77°F]), dry place, secure from rodents and other pests.

Pre-planting treatments

Seeds should be soaked in fresh water for 24 hours prior to sowing. Discard any nuts that float or that do not sink completely to the bottom.

Growing area

The seed (nut-in-shell) may be sown in the nursery or directly sown into the final field position. Seedling germination should be undertaken in a rat-proof, shaded area (25–50% sunlight) with pots watered regularly until at least first-true-leaf emergence.

For direct sowing, three or four seeds should be sown the final location. A small triangular plastic tree guard can provide a well protected and good microclimate for germination and help to mark the planting site.

Germination

Seed should be sown 1 cm (0.4 in) deep on their sides directly into large pots or polybags, e.g., 20–30 cm (8–12 in) deep and 10–20 cm (4–8 in) diameter. Some seeds can be simultaneously sown into germination trays for transplanting into those pots where seeds fail to germinate.

Media

The growing medium should be a well drained soil or potting mix: sand or sandy loam mixed with well composted organic matter is ideal.

Time to outplanting

Plants grow very rapidly in the nursery and are ready for field planting about 3 months after germination. However, during dry periods plants should be kept in the nursery until the start of the next wet season. Seedlings should be hardened prior to outplanting, e.g., by placing them in higher light levels (e.g., 50% sunlight) for 1–2 months prior to planting.

Approximate size at time of outplanting

Plants should be about 25–30 cm (10–12 in) tall at outplanting. Smaller seedlings about 20–25 cm (8–10 in)

high may also be used.

Other comments on propagation

It is also possible to carefully uproot and transplant wildlings (naturally germinated seeds, usually from under superior mother trees). The best success with wildlings is obtained with smaller, younger plants and during wet, overcast weather.

Guidelines for outplanting

Some leaves of the seedlings may be cut off or cut in half immediately prior to planting to reduce evapotranspiration. This may reduce the stress of outplanting.

Seedlings survive and grow best under intermediate light levels (e.g., 25–50% full sunlight). They may be planted in secondary or primary forest that is progressively thinned to allow more light to reach the seedlings.

In more open situations young plants are prone to sunburn. Some overstory cover should be established prior to outplanting of seedlings. This may be quickly achieved by planting four or five poles or live posts of species such as *Hibiscus tiliaceus*, *Gliricidia sepium*, and *Pterocarpus indicus* around each planting hole. This should preferably be done at least 6 months prior to planting of *Canarium*.

Seedlings should be planted into well prepared holes in which topsoil and/or organic matter is incorporated. In more open situations it may be useful to provide some temporary shade, using leafy branches, coconut or fern fronds. In the absence of follow-up rains, artificial watering may increase survival (e.g., 10 l [11 qt] per plant every 2 weeks would be beneficial).

Seedlings should be weeded regularly as needed. This may be as often as every month in better-lit situations and where vines such as *Merremia* and *Mikania* are present. Cut weeds and other vegetation should be mulched back around the seedling, leaving a gap of about 10 cm (4 in) from the trunk. Mulching conserves moisture, lowers soil temperature, provides nutrients, and helps prevent weed germination. With good aftercare and maintenance, high seedling survival will be obtained, usually over 90–95%.

DISADVANTAGES

The main disadvantages are:

- Difficulty in obtaining superior germplasm, a problem that is exacerbated by canarium nut's recalcitrant seeds that make international transfer of seed more problematic.
- Long time between planting and first returns from nuts, e.g., 7–8 years.
- Lack of on-farm storage technologies that would allow nuts-in-shell to be locally cracked and permit the high-value, low-volume kernels-in-testa to be more readily transported to central processing units.

Potential for invasiveness

Canarium nut has minor potential to become an invasive species. It may have naturalized along roadsides in Fiji.

Diseases and pests

The species does not appear to be highly susceptible or damaged by any particular pest or disease. Recorded insect pests include *Amblypelta cocophaga*, *Coccus hesperidum* and *C. longulus*, *Ectatorhinus magicus*, *Pinnaspis buxi*, and *Pseudococcus solomonensis*. Fungal diseases include *Coleophoma* sp., *Phellinus noxius*, *Phyllachora canarii*, and *Skierka canarii*.

AGROFORESTRY/ENVIRONMENTAL PRACTICES

Crop shade

Mature trees cast a heavy, wide shade and are only suitable for providing crop shade to the most shade-tolerant crops, such as cocoa.

Alley cropping

The species is not especially amenable to inclusion in alley cropping systems due to its shade requirement in the first few years.

Homegardens

Canarium nut is a good candidate for inclusion in aboriculture systems and tree homegardens, e.g., at the rate of one to three trees per garden. The trees provide nuts for local consumption from an early age, coupled with reasonably good stability during strong winds and cyclones.

Improved fallows

Not very well suited to inclusion in improved fallows, due to the long period between planting and fruiting and the high value of trees once they come into nut production (which would preclude their cutting to allow light for agricultural crops).

Boundary markers

Good boundary marker due to high value (i.e., likely to be "valued" on both sides for nuts) and longevity.

Windbreaks

An excellent species for inclusion in the upper story layer in windbreaks.

Silvopasture

Likely to have some potential for growing in silvopastoral systems, providing shade for livestock, and recycling nutrients from deeper soil layers, but trees would need to be grown at wide spacing, e.g., 10–25 per ha (4–10 trees/ac) to allow enough light for pasture to grow beyond the edge of the canopy.

Woodlot

A good species for inclusion in mixed- or single-species woodlots for provision of timber and/or nuts.

Native animal/bird food

Birds and bats consume the fleshy mesocarp of fruits.

Ornamental

An attractive, long-lived tree well suited to ornamental and amenity plantings, especially for shade.

USES AND PRODUCTS

Canarium nut is one of the Melanesia's most useful multipurpose trees, providing food (nuts), timber, and oil. The nuts constitute an important seasonal food and appear to have been important in the diet of New Guineans for at least 6000 years. Considerable selection by local peoples of individual trees with desired fruit characters has taken place in the Solomon Islands and Vanuatu. These selections have been made on the basis of kernel size and taste, ease of opening, thin pericarp, oil content, and, rarely, taste of the flesh and productivity. In the Solomon Islands, canarium nut is considered by villagers to be the most important fruit- or nut-producing species in five of six provinces surveyed, namely, Makira, Malaita, Isabel, Choiseul, and Western. It is also considered to be one of the most important timber species, providing cash income in Makira and Malaita Provinces, and to a lesser extent in Choiseul Province. It is also the major indigenous tree species that villagers plant, tend, or transplant in the Solomon Islands. Other traditional uses include production of wood for canoes and wooden articles such as custom bowls, collection of a resin for light, or used as canoe caulk and various uses in traditional medicines, mainly involving preparations from the bark. Nowadays, within its natural range, canarium nut is commonly cultivated for its edible nuts. The nuts are of considerable sustenance and commercial importance, including sale in local markets, processing, and export.

Fruit

The mesocarp (outer fleshy skin) of some cultivars is edible.

Nut/seed

The kernels are an important seasonal food in Melanesia. They are nutritious and have a high protein content (8–14%). They are consumed either fresh or roasted or smoked. They may be eaten as a snack food or incorporated into various cooked dishes.

Medicinal

In the Western Province of the Solomon Islands, a preparation is made from the bark for the treatment of chest pains.

Flavoring/spice

The crushed kernel of canarium nut can be used as a topping on ice cream.

Timber

The wood is suitable for light construction (in low-decay situations), moldings, veneer, and numerous interior purposes. The wood of *C. indicum* is fine textured and pink-brown. It has a medium density of 430–560 kg/m^3 (27–35 lb/ft^3) and is non-durable when exposed to weather. The wood of *C. harveyi* may have potential as veneer, as its figure and color can be very decorative.

Fuelwood

Suitable for fuelwood and sometimes burned.

Craft wood/tools

Traditionally used to make bowls and other wood articles.

Canoe/boat/raft making

The wood is traditionally used in canoe manufacture.

Resin/gum/glue/latex

Resin oozes from wounds on the trunk caused by a variety of natural factors such as pests/diseases, damage during cyclones, etc. In Melanesia this resin was formerly collected for use as canoe caulk.

Tannin/dye

The soot from burning resin was formerly used as a ceremonial black face paint in Melanesia.

Cosmetic/soap/perfume

An oil extracted from the kernel has various local uses. It may be substituted for coconut oil and has potential in

skin-care products.

Illumination/torches

In Melanesia the resin was formerly collected and burned for light.

Ceremonial/religious importance

Burning resin is aromatic and was used in traditional ceremonies and churches.

COMMERCIAL PRODUCTS

Canarium nut can make a substantial contribution to local food and wood supplies, and, importantly, to sustainable rural incomes through the high export market potential of its nuts. The main commercial product of canarium nut is the nut kernel for human consumption, and in Melanesia commercial interest in canarium nuts is high. Marketing operations range from private and community-based production, processing, and marketing of kernel oil for cosmetic and medicinal use, to government-backed nationwide purchasing of kernels for sale as confections and oil. In Vanuatu there are two commercial companies purchasing nuts. The buying price is about US$0.25–0.50/kg (US$0.11–0.22/lb) of nut-in-shell or US$4–5/kg (US$1.82–2.27/lb) for kernel-in-testa. In Port Vila, the dried, roasted, honey-coated kernels are retailed in plastic bags and glass jars for the equivalent of more than US$16/kg (US$7.27/lb). Another company exports dry whole and half kernels in bulk to France for secondary processing and sale in the luxury confectionery and pâtisserie market. Consumer demand for all of the products is high, and supply, both quantity and reliability, is constricting marketing efforts. Fresh canarium nut kernels-in-testa are sold in local markets in Vanuatu in bundles or skewered on sticks (palm frond spines) for the equivalent of US$10–17/kg (US$4.55–7.73/lb).

In the Solomon Islands, canarium nut is considered by villagers to be the most important fruit/nut producing species in five of six provinces surveyed: Makira, Malaita, Isabel, Choiseul, and Western.

A secondary and much less important commercial product is sawn timber, mainly for local use in house construction and furniture. However, in parts of the Solomon Islands it is considered to be one of the most important timber species, providing cash income in Makira and Malaita Provinces, and to a lesser extent in Choiseul Province.

Because of the potential of canarium nut as a high-value export crop for nuts (for confections) and/or oil extraction, some research is being done on its taxonomy, production, and marketing. Additional research needs include selection, evaluation, and improvement of promising varieties for timber production, investigation of silvicultural aspects, phenological studies, and vegetative propagation.

Spacing

Nuts

The suggested spacing is 9–10 x 9–10 m (30–33 x 30–33 ft), i.e., 100–123 trees/ha (40–50 trees/ac). The area required for commercial production is likely to be at least 1 hectare (2.5 acre) for an individual grower. A well managed and consolidated plantation area of 100 ha (250 ac) (made up of one, several, or many growers), could provide about 500 mt (550 t) of KIT per year and support commercial processing and export.

Nuts and timber

The suggested initial spacing for joint production of nuts and timber is close within rows (about 2 m [6.6 ft]) and wide between rows (9–10 m [30–33 ft]), i.e., 500–555 trees/ha (200–220 trees/ac), thinned down to a final spacing of about 100–150 trees/ha (40–60 trees/ac) by removal of poorer formed individuals in one or two operations at age

The food composition per 100 g of raw *Canarium indicum* nut

Water (g)	35.4	Protein (g)	8.2	Fat (g)	45.9	Sugar (g)	0.2
Starch (g)	0.3	Ash (g)	2.6	Fiber	10.6	β-car. eq. (µg)	165
Retinol (µg)		Thiamin (mg)	0.13	Riboflavin (mg)	0.06	Niacin (mg)	1.7
Vit. C (mg)	8	Na (mg)	18	K (mg)	627	Ca (mg)	44
Fe (mg)	3.5	Mg (mg)	284	Zn (mg)	2.4	Cu (mg)	1.6
Mn (mg)	1.1	Edible portion*	13%	Energy	439 kcal/1838 kJ		

* The inedible material is the hard shell of the nut
Source: English et al. 1996

3–6 years.

Some advantages of *C. indicum* for nut production over the other main edible *Canarium* species, *C. harveyi,* in Melanesia are as follows:

- The nuts of *C. indicum* are suitable for drying and exporting, whereas the dried kernels of *C. harveyi* are considered to have a somewhat unpleasant turpentine taste (Evans 1999).
- The recorded average annual yield of NIS per tree is much greater for *C. indicum* (113 kg [250 lb]) than the observed yields for *C. harveyi* (Evans 1999a).
- *C. indicum* is far more widespread than *C. harveyi* in both the Solomon Islands and Vanuatu, and it appears to possess great ecological adaptability.
- Excessive consumption of fresh nuts of *C. harveyi* can cause nausea and vomiting.

Management objectives

Nuts

Pruning is best carried out in conjunction with harvesting of fruits on reproductively mature trees. Fruit set will be lessened the year following by heavy pruning, but pruning of half the trees in any given year may be done to induce a more uniform annual production of nuts from a given plantation or group of trees.

Nuts/Timber

The aim of management is to maximize nut production while concentrating wood increment on a straight, lower bole (i.e., butt log of 6 m [20 ft]).

Design considerations

For commercial production of nuts it is recommended that plantings be located near major marketplaces or processing centers within 20–50 km (12–30 mi) by road.

Yields

High yields of nuts from 1 ha (2.5 ac) of canarium nut plantation at a spacing of 206–625 trees/ha (83–253 trees/ac) are estimated to commence in the seventh year at about 750 kg (1650 lb) kernel-in-testa (KIT). Yields are expected to rise sharply to about 4–7 mt KIT/ha/yr (1.8–3.1 t KIT/yr) at age 10–15 years.

On-farm processing methods required to access market

Compared with manual cracking, mechanical cracking of nuts can considerably improve efficiency of cracking, but too wide a range of nut sizes can lower the percentage of whole kernels obtained by mechanical/electrical crackers. Unfortunately there is a lack of on-farm storage technologies which would allow nuts-in-shell to be cracked in villages or on-farm and permit the high-value, low-volume kernels-in-testa to be later transported to central processing units. Kernels-in-testa need to be kept dry, cool, and airtight to avoid oxidation and rancidity.

On-farm processing methods

Drying, smoking, or roasting nuts enables them to be stored for periods of about 3–12 months, depending upon the quality of the nuts and storage containers and conditions. Roasting would preferably be done at a central unit, with suitable equipment, trained personnel, and good quality control.

Markets

Nuts

The size of the international market for canarium nuts is large. Canarium nuts, like *Terminalia catappa* nuts, have the potential to behave as under-supplied niche commodities with a highly inelastic demand commanding a price equivalent to macadamia nuts (currently >US$10/kg [US$4.55/lb] wholesale), providing packaging and quality are similar. High-value niche markets could be secured and enhanced by organic certification, promotion of canarium nut as an exotic commodity, and direct, internet-based marketing. Marketing opportunities and constraints for Pacific tree nuts will depend on quality control, packaging, continuity of supply, and targeting marketing toward specific groups, such as tourists.

Timber

Markets for timber of planted canarium nut timber will be mainly the local timber markets for general-purpose timber and will vary considerably in volume. Through selection and breeding it may be possible to eventually develop individuals which produce not only good quality nuts but also decorative timber (with attractive figure and color), which might command a high price for furniture manufacture.

Canarium harveyi

Introduction

In the Santa Cruz Islands (Solomon Islands) and Banks Group (Vanuatu) the kernels of *C. harveyi* are an important food crop (Evans 1999a). Fresh nuts are seasonally important foods and preserved through smoking to provide food throughout the year. Many different superior nut forms have been produced during thousands of years of domestication, and var. *nova-hebridiense* is believed to have arisen as a result of human selection. The species is a less important food source in other parts of its range, such as Fiji and Tonga, where wild types with smaller nuts predominate. In these areas it is considered a useful timber tree.

Native range and current distribution

Canarium harveyi is native to the Solomon Islands, Vanuatu, Fiji, Tonga, and Niue. Var. *nova-hebridiense* appears to be the product of long-term selection and is native to the Santa Cruz Islands (in SE Solomon Islands) and in the adjacent Banks Group in northern Vanuatu. Var. *harveyi* is found throughout the rest of the native range, including central and southern Vanuatu, while var. *scandens* (from Fiji) probably does not warrant varietal rank. In Tonga it is found in forests and garden areas on all island groups (Yuncker 1955). In Niue, trees of the type variety are reported to be moderately common but scattered on the Lower Terrace and in more open secondary forest further inland. In Fiji the elevation range is from near sea level to 600 m (1970 ft) (Smith 1985). The species is not known to have been planted as an exotic.

An 8-year-old *C. harveyi* tree. PHOTO: C. ELEVITCH

BOTANICAL SUMMARY

Preferred scientific name *Canarium harveyi* Seem.

Family Burseraceae, torchwood family

Non-preferred scientific names

Canarium sapidum Hems.

Common names

canarium nut (English)
'ai (Tonga)
ai (Niue)
kaunicina, *kaunigai* (Fiji)
nangai, *nangae* (Vanuatu)
Santa Cruz ngali nut (Solomon Islands)

In Vanuatu the local Bislama name for *Canarium* species (including *C. harveyi*) is *nangai* or *nangae*. Other recorded local names in Vanuatu for *C. harveyi* include *angai, gamagamba, hamkamba, nanae, nergervot, negertowo, ngatimbi, ngai, nge dun, ngev mum, nangai hos, nagrau, nengai, nenge, ningi, vanae*, and *vosai facau* (Siwatibau et al. 1998). On Mota Lava (Banks Group) it is known as *nange d* (Evans 1999a).

In the Solomon Islands, *C. harveyi* is known locally by the names Santa Cruz *ngali nut* (Solomon Islands Pidgin), *nyinga* (Ayiwo, Ree Is., Santa Cruz), and *nolepo* (Graciosa Bay, Nendo, Santa Cruz) (Evans 1999a).

In Fiji the species is mainly referred to as *kaunicina* and *kaunigai*, with other local names including *dawadawa* (Gau) and *yaga* (Fulaga, Lau) (Smith 1985). Local names recorded for *C. harveyi* in Fiji by Thaman et al. (2000) were *kaunicina*, *kaunigai*, *kai ni cina* (Nausori, Viti Levu), and *yagai* (Karoko, Vanua Levu; Naiiviivi, Qamea). In Tonga and Niue the species is referred to as *'ai* and *ai*, respectively (Tupoulahi-Fusimalohi 1999, Sykes 1970).

Characteristics

Canarium harveyi is a medium-sized tree, 10–22 m (33–72 ft) tall with a dbh up to about 1 m (3.3 m). The trunk may occasionally be buttressed, with reasonably equal plank-like or branched buttresses. Trees are characterized by a dense canopy, with a short deciduous phase at fruit maturity (Solomons) or during the dry season (Tonga). The bark is light grey and generally smooth (Evans 1999a).

The leaves are bright to dark green, pinnate with two to four pairs of leaflets and often with one terminal leaflet. Stipules are arranged in pairs on the petiole (5–20 mm [0.2–0.8 in] from the base). They are relatively small compared with *C. indicum* (5–10 x 6–10 mm [0.2–0.4 x 0.24–0.4 in]), auricle shaped, with entire or toothed margins. They soon fall off, leaving distinctive twin scars.

Fruits of domesticated trees are oval-shaped drupes 6–9 cm (2.4–3.6 in) long by 4–5 cm (1.6–2 in) wide, green when immature, turning deep purple or black at full maturity. Wild trees have smaller fruits, about 4 cm (1.6 in) long by 2.8 cm (1.1 in) wide in Niue (Sykes 1970). Fruit production varies considerably between trees and ages. Production varies from numerous fruiting spikes loaded with up to 40 fruits to few fruiting spikes with only two to six fruits (Walter and Sam 1996).

Top: The number of paired leaflets for *C. harveyi* is usually two to four, compared with six to eight for *C. indicum*. This *C. harveyi* tree in Tonga has three-paired leaflets. Bottom: *C. harveyi* flowers. PHOTOS: C. ELEVITCH

Ripe *C. harveyi* fruits are 3–6 cm (1.2–2.4 in) long and 2–4 cm (0.8–1.6 in) wide. PHOTO: B. EVANS

The nut-in-shell (NIS) is ellipsoid to oval-shaped, two- to three-sided in cross section, with one kernel or seed (or sometimes two or very rarely three) per NIS. The sterile cells are almost totally or strongly reduced. The kernel-in-testa (KIT) is an edible nut, ovate with longitudinal grooves, consisting of two intimately entwined cotyledons enclosed in a protective testa (Evans 1999a). The average NIS varies from 42 mm (1.7 in) long by 29 mm (1.1 in) wide in Vanuatu to 61 mm (2.4 in) long by 33 mm (1.3 in) wide in the Solomon Islands (Walter and Sam 1996, Evans 1991). More complete botanical descriptions are available in Smith (1985, vars. *harveyi* and *scandens*) and Evans (1999a, var. *nova-hebridiense*).

ENVIRONMENTAL PREFERENCES

Climate

The species is found in the lowland, subhumid to hu-

mid tropics. The mean annual rainfall is 1800–4000 mm (70–160 in) distributed rather uniformly or with a summer maximum. Temperatures are very warm to hot throughout the year. The mean annual temperature is around 23–28°C (73–82°F), the mean maximum temperature for the hottest month is 27–32°C (81–90°F), and the mean minimum temperature of the coldest month is 15–24°C (59–75°F). The absolute minimum temperature is 8–19°C (46–66°F). Tropical cyclones occur at periodic intervals throughout its range in Vanuatu, Fiji, Tonga, and Niue, mainly during the months of November to March.

Soils

It generally occurs on medium- to heavy-textured soils with free to slightly impeded drainage and neutral pH.

Vegetation types

C. harveyi is reasonably widespread throughout its native range in lowland rainforest, secondary forest, old garden areas, and it is widely planted around villages and settlements. Traditionally, nut trees are selected, tended, or cultivated in or around coastal village sites (Evans 1999). Only very rarely are the cultivated edible types found growing wild in the bush. Most "wild" trees in the inland bush, are remnant trees from past village sites (Evans 1999).

PROPAGATION

Canarium harveyi is propagated from seed that is recalcitrant and should be sown as soon as possible after collection. Seedlings grow quickly in the nursery and are ready for planting after 3–5 months (see propagation section for *C. indicum* for further information).

MANAGEMENT

Trees may be heavily pruned during fruit collection. This results in a low fruit set the following year, followed by a very heavy crop the year after. Accordingly trees can be differentially managed through pruning to produce a more uniform yield of nuts each year from a given plantation or group of trees.

USES

Land use, environmental, and service aspects

This tree is a frequent component of the middle canopy in multistory food garden systems in Santa Cruz (Evans 1999a). It is also an important shade tree in Vanuatu and useful for coastal protection (Sam et al. 1999).

Products

In both the Solomon Islands and Vanuatu the timber is used for canoe construction, custom and food bowls, and for firewood (Evans 1999a, Siwatibau et al. 1998). It is recorded as a timber tree in Fiji (Smith 1985)

Local consumption of nuts is the most important use for *C. harveyi* trees, and the species is an important food source in the Santa Cruz Islands (SE Solomon Islands) and in the Banks Group in northern Vanuatu. In Niue the nuts are regarded as the best quality among the native trees (Sykes 1970).

Fresh fruits or nuts are opened using a stone, and the kernel is eaten fresh. Kernels may also be preserved by slow and continuous drying and smoking in baskets or storing them on racks hung over kitchen fires (Henderson and Hancock 1988, Walter and Sam 1996). This enables kernels to be stored and edible for up to 12 months (Evans 1999a). In Vanuatu the oily nuts are often sprinkled on tuber pudding (Walter and Sam 1996).

The nut-in-shell (NIS) characteristics of *C. harveyi* in the Solomon Islands are generally superior to *C. indicum*, but certain *C. indicum* trees have similar kernel-to-nut ratios to the average for *C. harveyi* (Evans 1999a), and this trait is likely to be improved in an appropriately designed breeding program. Generally the nuts of *C. harveyi* are easier to split by hand than those of *C. indicum*.

In former times and infrequently the oily kernels were used as primitive candles, and the oleoresin is occasionally used as lighting oil and incense (Evans 1999a, Siwatibau et al. 1998). The species is recorded as being used in traditional medicine on Malekula and Ambrym (Siwatibau et al. 1998). The nut shells are highly flammable and occasionally used as cooking fuel.

COMMERCIAL POTENTIAL

The commercial potential of *C. harveyi* is considered to be less than that of *C. indicum* for a number of key reasons:

- the kernels have a somewhat unpleasant turpentine taste, especially when dried, which can cause nausea if too many are eaten
- nut-in-shell yield appears to be less than that measured for *C. indicum* (Chaplin and Poa 1988)
- the trees, especially the highly cultivated var. *novahebridiense*, are less widespread, appear less adaptable, and are more prone to pests and disease.

INTERPLANTING/FARM APPLICATIONS

An advantage of growing canarium nut in a polyculture (together with other food and timber trees) is that consequences of canarium nut failure in a particular year can be minimized through production and sale of products from other species. Furthermore, there is a long waiting period (at least 7 years) before canarium plantations begin to provide commercial returns. Therefore, interplanting of crops that can provide more rapid returns such as root crops, banana, papaya, kava, *Barringtonia procera*, and *Terminalia catappa* may be necessary for cash-strapped farmers. It is recommended that a moderately shade-tolerant, nitrogen-fixing shrub legume, such as *Flemingia*, be interplanted to help maintain soil nitrogen levels.

Example interplanting system

In Melanesian tree gardens canarium nut trees, which often have tall, straight boles making them difficult to climb, are frequently planted alongside smaller "living ladder" trees such as *Barringtonia* spp. and *Inocarpus fagifer*. These allow easier access to the canopy for early harvesting (before dispersal by fruit bats and pigeons) and for pruning. The living ladder trees are planted 1–2 m (3.3–6.6 ft) away from the canarium nut trees.

GERMPLASM RESOURCES

The Pacific Basin Agricultural Research Center has a research collection of many *Canarium* species, including *C. indicum* and *C. harveyi*.

Pacific Basin Agricultural Research Center
P.O. Box 4459
Hilo, Hawaii 96720
Tel: 808-959-4301; Fax: 808-959-5470
Web: http://pbarc.ars.usda.gov/pages/research/tpgrmu/canarium.shtml

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Canarium indicum var. *indicum* and *C. harveyi* (canarium nut)

Authors: Lex A.J. Thomson[1] and Barry Evans[2]

1. South Pacific Regional Initiative of Forest Genetic Resources (SPRIG) Project, SPC Forestry Program, Suva, Fiji (current contact info: IPGRI, Via dei Tre Denari 472/a, 00057 Maccarese (Fiumicino), Rome, Italy; E-mail: L.Thomson@cgiar.org).
2. SPRIG Marketing Specialist, 30 Berry St, Sherwood, QLD 4075, Australia; E-mail: barryevans@bigpond.com.

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