Species Profiles for Pacific Island Agroforestry
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Pandanus tectorius (pandanus)

Pandanaceae (screwpine family)

***ajbwirōk*, *anewetāk* (Pingelap Atoll, Pohnpei), *binu* (Kapingamarangi Atoll, Pohnpei); *bōb* (Marshall Islands); *choy, fach, far* (Yap); *deipw, fach, far* (Chuuk); *deipw, kipar* (Pohnpei); *épo* (Nauru); *fa*, *fafa*, *laufala*, *falahola*, *kukuvalu*, *lou'akau* (Tonga); *fala*, *lau fala* (Samoa, Tuvalu); *hala* (Nukuoro Atoll, Pohnpei); *hala*, *pū hala* (Hawai'i); *kafu* (Guam); *mweng* (Kosrae); *ongor* (Palau); *pandanas* (Vanuatu: Bislama); *pandanus*, *vacouet* (French); pandanus, screw pine (English); *te kaina* (Kiribati); *vadra*, *voivoi* (Fiji)**

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PHOTO: C. ELEVITCH

Pandanus growing along the southern coast of 'Upolu, Samoa.

IN BRIEF

Distribution Native throughout the Pacific islands and parts of Southeast Asia and northern Australia.

Size Reaches 4–14 m (13–46 ft) in height, with about the same canopy diameter.

Habitat Usually elevations of sea level to 20 m (66 ft), but can grow at elevations of 600 m (1970 ft) or higher.

Vegetation Associated with species of coastal forests.

Soils Adapted to a very wide range of light to heavy soil types.

Growth rate Stem growth is slow to moderate, 2–80 cm [0.8–31 in] per year.

Main agroforestry uses Coastal protection, windbreak, homegardens.

Main uses Food, weaving, thatch.

Yields 10–300 leaves per tree per year or 8–12 fruits.

Intercropping Often planted in and around mixed agroforests in the Pacific.

Invasive potential Naturally spreads into coastal plant communities. Since it is native to Pacific islands, the tree is not considered to be invasive.

INTRODUCTION

Pandanus (*P. tectorius*) is a large shrub or small tree of immense cultural, health, and economic importance in the Pacific, second only to coconut on atolls. A highly variable species complex, it grows wild mainly in semi-natural vegetation in littoral habitats throughout the tropical and subtropical Pacific, where it can withstand drought, strong winds, and salt spray. It propagates readily from seed, but it is also widely propagated from branch cuttings by local people for farms and homegardens. It grows fairly quickly, and all parts are used, from the nutritious fruits of edible varieties, to the poles and branches in construction, to the leaves for weaving and garlands. The plant is prominent in Pacific culture and tradition, including local medicine. Hundreds of cultivated varieties, collectively recognized in the Pacific but specific to numerous independent cultural traditions, are known by their local names and characteristics of fruits, branches, and leaves. At present, there is evidence that this diversity is declining, with certain varieties becoming difficult to find. The reasons include less replanting, deforestation, fire, flagging interest by the new generation, and rapid population growth leading to urbanization. Planting pandanus should be promoted in both rural and urban areas. For example, small shrubby varieties could be planted along boundaries or borders. Plantings should be encouraged in protected areas and in well maintained public areas. For example, in Hawai'i plantings of pandanus on hotel grounds were utilized and greatly appreciated by local weavers, due to good access and ease of harvesting. Special attempts should be made to collect and replant endangered varieties that are valued for their edible fruits and other uses.

DISTRIBUTION

Native range

Pandanus tectorius naturally occurs in strandline and near-coastal forests in Southeast Asia, including the Philippines and Indonesia, extending eastward through Papua New Guinea and northern Australia, and throughout the Pacific islands, including Melanesia (Solomon Islands, Vanuatu, New Caledonia, and Fiji), Micronesia (Palau, Northern Marianas, Guam, Federated States of Micronesia, Marshall Islands, Kiribati, Tuvalu, and Nauru), and Polynesia (Wallis and Futuna, Tokelau, Samoa, American Samoa, Tonga, Niue, Cook Islands, French Polynesia, and Hawai'i).

Current distribution

Many traditionally recognized and named varieties have originated through selection and vegetative propagation of wild plants in Melanesia, Micronesia, and Polynesia. These have sometimes been widely planted as aboriginal introductions to many islands. Additionally, new variants may be selected from seedling progeny or mutations in cultivated varieties.

BOTANICAL DESCRIPTION

Preferred scientific name

Pandanus tectorius Parkinson

Family

Pandanaceae (screwpine family)

Non-preferred scientific names

In this treatment, *P. tectorius* is recognized as a highly variable species complex that is widespread on strandline and coastal forest communities throughout the tropical and subtropical Pacific Ocean. Numerous, often minor, morphological variants of pandanus have been recognized and formally described as species, mainly by St. John. Some of the more widely used and important synonyms encompassing entities within the *P. tectorius* complex include *P. pedunculatus* R. Br., *P. pyriformis* (Martelli) St. John, and *P. spurius* Miquel. The concept of variety is useful to designate socio-economically important, and/or striking and unusual forms.

Common names

ajbwirōk, *anewetāk* (Pingelap Atoll, Pohnpei)
binu (Kapingamarangi Atoll, Pohnpei)
bōb (Marshall Islands)
choy, fach, far (Yap)
deipw, fach, far (Chuuk)
deipw, kipar (Pohnpei)
épo (Nauru)
fa, *fafa*, *laufala*, *falahola*, *kukuvalu*, *lou'akau* (Tonga)
fala, *lau fala* (Samoa, Tuvalu)
hala (Nukuoro Atoll, Pohnpei)
hala, *pū hala* (Hawai'i)
kafu (Guam)
mweng (Kosrae)
ongor (Palau)
pandanas (Vanuatu: Bislama)
pandanus, *vacouet* (French)
pandanus, screw pine (English)
te kaina (Kiribati)
vadra, *voivoi* (Fiji)

In the atoll island countries of the central and northern

Pacific, several hundred traditional varieties (many used by people for food) are recognized and given individual names in the local languages and maintained largely through vegetative propagation.

Size and form

Pandanus tectorius is a stout, branching, often multi-stemmed, large shrub or small tree (2–) 4–14 (–18) m ([6.6–]13–46[–59] ft) in height, with about the same canopy spread. Plants of most varieties have numerous aerial and prop roots and thick, forking, often spiny trunks. Wild seedling-derived plants often have a single bole or trunk for 4–8 m (13–26 ft) before forking. Maximum stem diameter is 12–25 cm (4.7–10 in).

Flowers

The species is dioecious—there are separate male and female plants. Flowers are borne in heads at the shoot apex. Male flowers are fragrant, tiny, white, pendant, arranged in racemes or branched in clusters, with large white showy bracts. Male flowers only last for about a day, with the inflorescence decaying within 3–4 days (Brink and Jansen 2003). Female flowers are pineapple-like.

Leaves

There is considerable variation in leaf shape and size, both on and among trees. Leaves are spirally-arranged in three rows and clustered at branch apices, dark green, 1–3 m (3.3–10 ft) long by 11–16 cm (4.3–6.3 in) wide, V- to Y-shaped in section, with spiny/prickly margins and midribs. Marginal prickles are usually 0.8–2.5 mm (0.03–0.1 in) long. A few traditionally recognized and named varieties have leaves with smooth margins, e.g., 'Tutu'ila' in Tonga, 'Nei Naobua' in Kiribati, 'Lau fala' in Samoa, and at least one variegated form in Fiji.

In fully expanded leaves, the midrib is bent, and the up-




Top left: Male inflorescence. PHOTO: C. ELEVITCH **Top right: Female inflorescence.** PHOTO: C. ELEVITCH **Bottom: Fruit heads comprise an aggregate of many tightly bunched wedge-shaped phalanges or drupes; these are also called "keys," as removing one will allow the rest to come apart easily.** PHOTOS: L. THOMSON

per third (or so) of the leaf hangs down, giving pandanus plants their characteristic drooping appearance.

Fruit

The multiple fruit head displays considerable plant-to-plant variation in morphology, size, and color, and many of the traditionally named varieties (females) are recognized by their particular combination of fruit head characteristics (Hiyane 1971).

The shape of the fruit head may be ovoid, ellipsoid, subglobose or globose, with overall dimensions of 8–30 cm (3–12 in) long by 4–20 cm (1.6–8 in) diameter. Fruit heads are made up many (38–200) tightly bunched, wedge-shaped fleshy phalanges or drupes (also referred to as keys).

Individual phalanges are narrowly oblong to ovoid and 2.5–11 cm (1–4.3 in) long by 1.5–6.7 cm (0.6–2.6 in) wide (at widest point). The endocarp (internal tissue surrounding the seeds) is dark reddish-brown, hard/bony, and 15–35 mm (0.6–1.4 in) long. The mesocarp comprises apical and basal sections. The apical mesocarp formed in the apex of each carpel comprises an elongated cavern with aerenchyma of a few longitudinal fibers and white membranes. The basal mesocarp is fibrous and fleshy, about 10–30 mm (0.4–1.2 in) long. This is the portion of the fruit that is chewed and eaten in edible varieties. At maturity the color of the basal section of the phalanges varies from pale yellow to dark yellow, orange, and orange/red. For intact fruiting heads the visible apical portion of the phalange is typically green with brown markings at maturity, turning yellow with age, after falling. In some varieties the apical portion may be colored dark orange at maturity, e.g., 'Fala'hola' in Tonga.

Phalange split lengthwise to reveal a seed (cut in half). PHOTO: L. THOMSON

The apical profile of individual phalanges ranges from truncate and sub-truncate to convex. There are 1–15 carpels per phalange, and these are arranged either radially or in parallel rows. The central apical sinuses range from 1–28 mm (0.04–1.1 in) deep.

Seeds

The seeds are obovoid, ellipsoid, or oblong; 6–20 mm (0.25–0.8 in) long; red-brown and whitish/gelatinous inside. The small (10 mm [0.4 in] long) white seeds of pandanus found in some varieties have a coconut-like taste.

Phalanges are widely dispersed by ocean currents and can float for many months, during which time the seeds maintain viability.

Bark

The bark is grayish- or reddish-brown, smooth/flaky, with characteristic undulating leaf scars and rows of prickles.

Rooting habit

The root system of pandanus plants is dominated by thick, slightly spreading prop roots originating from the lower part (1–1.5 m [3.3–5 ft]) of the trunk. The prop roots penetrate and are mainly concentrated in the surface soil layers. In some plants, there may be a few aerial roots hanging vertically from branches.

Similar or look-a-like species

***Pandanus odoratissimus* L.f.** is another highly variable *Pandanus* species that is taxonomically very close to *P. tectorius*. It is widely distributed along Indo-Malayan coasts from India and Sri Lanka throughout Southeast Asia to Taiwan, the Ryukyu Islands, and western parts of Micronesia. The main morphological difference is considered to be the larger white or very pale leaf spines in *P. odoratissimus*, compared with smaller greenish spines in *P. tectorius*. The two species are thought to hybridize readily where they co-occur and are possibly better treated as subspecies of *P. tectorius*.

The following *Pandanus* species occur naturally and/or are

Left: Characteristic ring pattern on bark left after older leaves fall off. PHOTO: L. THOMSON **Right: Prop roots descending into a thin substrate over lava rock, 'Upolu, Samoa.** PHOTO: C. ELEVITCH

cultivated in near-coastal locations in the Pacific islands and are sometimes confused with the *P. tectorius* complex.

***Pandanus dubius* Sprengler** grows in coastal forests, including beaches and rocky shores in Southeast Asia and the Western Pacific region, including Palau, Northern Marianas, Guam (local name pahong), Kiribati (local name tekaureiko), Federated States of Micronesia (local names mweng kaki, kipar-n-ai), Papua New Guinea, Solomon Islands, Vanuatu, and Rotuma. It is occasionally cultivated for its edible seeds and thick leaves for basket making and floor mats. It is distinguished from *P. tectorius* by its long penducles, 60–80 cm (24–32 in) in length, and large, white, edible, and tasty rounded seeds (1–1.5 cm [0.4–0.6 in] in diameter) situated at the base of the phalange. Its trunk is covered with sharp prickles (lenticels), and the roots are covered in vertical rows of lenticels.

***Pandanus whitmeeanus* Martelli** is a female clone that probably originated in Vanuatu. It is now widely cultivated near sea level in swampy, grassy areas in Fiji, Wallis and Futuna, Samoa, Tonga, and the Cook Islands for its leaves, which are used to make fine mats and handicrafts. It is distinguished from *P. tectorius* by the position of its stigma, which is oblique to vertical on the distal, outer face of the phalange apex, compared with apical on carpel summit in *P. tectorius*. The multiple fruit heads are subglobose to ellipsoid, up to 25 cm long by 22 cm diameter (10 x 9 in), and the basal section of the phalange is bright red when mature.

GENETICS

Variability of species

Pandanus tectorius is a geographically widespread and an exceptionally morphologically variable species or species complex. Female plants within a geographically localized population, such as on the same stretch of beach, may exhibit distinctively different fruit characteristics (fruit shape and size, number of phalanges per fruit, phalange shape, color, size, texture, nutrient content, carpel number, shape and appearance, edibility, taste, seed shape, etc.). Such variants have sometimes been described as different species, but in a biological sense they are part of the same interbreeding population and, furthermore, it is not possible

to designate male plants to such "species." Morphological variation is also evident in plant form, trunk, and branch thickness, presence and number of prop and aerial roots, leaf characteristics and spiral arrangement, and extent of spines on different plant parts. Varieties may represent geographic races or provenances, morphologically distinctive individuals, vegetatively propagated clones, polyploids, and interspecific hybrids. Variation within populations is generated through recombination during sexual reproduction and long-distance dispersal by ocean currents of buoyant phalanges. The mating system is expected to be highly outcrossing (due to separate male and female plants) or facultative apomictic (in the absence of male plants) (Brink and Jansen 2003). Variation in economically important characters is also maintained through people vegetatively propagating individual plants with preferred traits. For weaving, plants with strong, flexible, non-spiny leaves are preferred, while for human consumption, female plants with sweet, soft-textured fruits, low in oxalates, and with small keys that fit better in the mouth for chewing are favored.

Known varieties

Hundreds of traditional varieties of *Pandanus tectorius* have been recognized, named, and propagated by local people in different parts of the Pacific islands. An individual plant may have originally been identified as having value for a particular use, such as fruits for human consumption or leaves for weaving fine mats, and then vegetatively propagated and widely planted. An important botanical variety for weaving is *P. tectorius* var. *laevis* (synonyms include *P. spurious* Miquel, *P. laevis* Kunth, and *P. inermis* Reinw.). This variety has spineless (or near spineless), fragile leaves and is known as 'Kie' in Tonga, 'Lau Fala' in Samoa, and 'Lau Hala Kilipaki' in Hawai'i. Useful varieties or clones may be propagated vegetatively and cultivated on many islands in different countries, either under the same or similar name, or a completely different name. For example, on Kiribati the traditionally recognized variety 'Antinakarewe' or 'Teantinakarewe' is prized for its flavorsome, edible fruits and is cultivated under the same name on many islands, including Abiang, Butaritari, and Tarawa, but has a different name elsewhere in Kiribati. Within this variety, there may be two types distinguished on the basis of key/phalange size and bunch size; the form with big keys is very similar or the same as the variety 'Ļōjokdād' in the Marshall Islands (Englberger 2004). More frequently, traditionally named varieties have limited distributions, for example, on one or just a few neighboring islands. In Kiribati, there may be up to 200 different traditionally recognized, named and cultivated varieties of pandanus, many of which may be exclusive to a village or family, although only 16 names are apparently widely recognized on Tarawa. Some botanists have named morphologically distinctive varieties (or morphotypes) of *P. tectorius* as separate species, but these may be extremes of a continuum or else only identifiable as female plants and thus do not fit into the accepted biological definition of species.

Culturally important related species in the genus

Some entities within the *P. tectorius* complex may prove to be taxonomically and biologically valid species, and culturally important in the areas in which they occur. An example might be *P. odoratissimus* L.f., which naturally intergrades with *P. tectorius* in Southeast Asia/western Pacific rim, presumably through interspecific hybridization.

ASSOCIATED PLANT SPECIES

Pandanus is common in littoral habitats throughout the Pacific (Melanesia, Micronesia, and Polynesia), including on atolls. In all parts of its natural range, pandanus is a frequent component of strandline and coastal vegetation, including grassy or swampy woodlands, secondary forests, and scrub thickets developed on makatea (raised fossilized coralline limestone terraces). It commonly occurs on the margins of mangroves and swamps. Pandanus also occurs as an understory tree in plantations and forests on atolls and larger islands (either planted or naturalized).

Associated species of native habitats

In strandline communities, associated species include creepers such as *Ipomoea pes-caprae*, *Canavalia sericea*, and *Vigna marina*. Other coastal thickets and forest associates include *Acacia simplex*, *Amaroria soulameoides*, *Tournefortia argentea*, *Barringtonia asiatica*, *Bruguiera gymnorrhiza*, *Calophyllum inophyllum, Casuarina equisetifolia*, *Cerbera manghas*, *Chrysobalanus icaco*, *Cocos nucifera*, *Cordia subcordata*, *Excoecaria agallocha*, *Guettarda speciosa*, *Hernandia nymphaeifolia*, *Hibiscus tiliaceus*, *Intsia bijuga*, *Morinda citrifolia*, *Podocarpus neriifolius*, *Santalum insulare*, *Scaevola taccada*, *Schleinitzia insularum*, *Terminalia catappa*, *T. littoralis*, *Thespesia populnea*, and *Vitex trifoliata.* Peat swamp associates include *Sphagnum cuspidatum* and various sedges.

Species commonly associated as aboriginal introductions in Pacific islands

Pandanus is frequently planted or protected in garden areas and homegardens, sometimes in monocultural patches or as border plantings. Associated species include *Artocarpus altilis*, *Colocasia*, *Citrus* spp., *Polyscias* spp., and a host of other food crops, fruit trees, and ornamentals.

Species commonly associated in modern times

It is planted in homegardens with many different recent introductions, including ornamentals, fruit and nut trees, and timber trees (e.g., *Swietenia macrophylla* and *Agathis robusta* in Tonga).

ENVIRONMENTAL PREFERENCES AND TOLERANCES

Climate

Pandanus grows in maritime (usually less than 20 m [66 ft] above sea level), tropical, humid and subhumid climates. The species is very well adapted to exposure to strong, often salt-laden winds, including buffeting from moderate to severe tropical cyclones, over a large part of its range.

Rainfall varies considerably across its range, both in amount and seasonal distribution. Rainfall may be distributed more or less uniformly throughout the year, bimodally, or with a peak over 4–6 months at any time of the year, usually during the hottest period. Pandanus mainly occurs in localities with 1500–4000 mm (60–160 in) annual rainfall, and with no or a short dry season (i.e., no or a few months receiving <40 mm [1.6 in] on average). In near-equatorial Pacific regions there is considerable year-to-year variation in annual rainfall, such that plants may have to tolerate extended dry periods of up to 6 months.

In its native habitats, temperatures are warm to hot throughout the year and show little variation, both seasonally and diurnally.

Elevation range

0–20 m (0–66 ft). It may be cultivated at higher elevations, e.g., up to about 600 m (1970 ft) in Hawai'i (Little and Skolmen 1989).

Mean annual rainfall

1500–4000 mm (60–160 in)

Rainfall pattern

Pandanus is adapted to climates with summer, bimodal, and uniform rainfall patterns.

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

Long-term average rainfall data suggest that across its range there is a short (less than 3 months) or no dry season. However, in some locations, especially in the central or equatorial Pacific, there may be a dry season of up to 6 months, or longer, in some years.

Mean annual temperature

24–28°C (75–82°F)

Mean maximum temperature of hottest month

28–36°C (82–97°F)

Mean minimum temperature of coldest month

17–25°C (63–77°F)

Minimum temperature tolerated

12°C (54°F) (absolute minimum temperature recorded in its native range)

Left: Typical littoral forest community including beach heliotrope (*Tournefortia argentea*) and beach she-oak (*Casuarina equisetifolia*), Houma, Tongatapu, Tonga. PHOTO: L. THOMSON **Right: Pandanus often grows on shorelines exposed to salt spray and wind, 'Upolu, Samoa.** PHOTO: C. ELEVITCH

Soils

Pandanus naturally occurs on various coastal soils, especially sandy and rocky beaches, including raised coralline terraces and recent basalt (lava flows). It is adapted to an extraordinarily wide range of light to heavy-textured soil types, including brackish/saline soils, light-colored, infertile coralline atoll sands, alkaline sands, thin soils over limestone, and peaty swamps.

Soil texture

The tree grows in light to heavy soils (sands, sandy loams, loams, sandy clay loams, clay loams, sandy clays, and clays).

Soil drainage

Pandanus grows in soils with free or impeded drainage, including seasonally waterlogged soils.

Soil acidity

It grows in acid to alkaline soils (pH 6–10).

Special soil tolerances

The tree grows in shallow, saline, sodic, and nutrient-poor soils, as well as peat swamps.

Tolerances

Drought

The species is tolerant of moderately long droughts, e.g., 3–6 months or more, which are experienced infrequently in the central Pacific (and which are masked by long-term climatic averages). It also frequently occurs on thin soils of low moisture-holding capacity, which also indicates good drought tolerance. During very dry periods it will usually continue to bear fruit, albeit smaller and fewer in number, and it is considered more drought tolerant than coconut in atoll environments (Stone et al. 2000).

Full sun

The species is very well adapted to growing in full sunlight, and it predominantly occurs in open, exposed sites.

Shade

Pandanus also grows well at intermediate levels of shade (e.g., 30–50% shade). The range of shade tolerated is 0–70%. At higher shade levels plants cease flowering and fruiting.

Fire

Pandanus naturally occurs in grasslands that are regularly burned. Older plants are tolerant of low- to medium-intensity fires but are killed by high-intensity fires. Moderately intense fires mainly kill juvenile plants less than 0.5 m (20 in) tall and 5 cm (2 in) stem diameter. Low- to moderate-intensity fires may be important for long-term maintenance of pandanus populations, as pandanus is more fire-tolerant than many of its larger, and competing, woody associates.

Frost

Its frost tolerance is unknown but likely to be limited, with plants expected to be damaged by low temperatures (e.g., <10°C [50°F]) and killed at temperatures approaching freezing.

Waterlogging

The species generally tolerates waterlogging well and is often found in swampy localities with impeded drainage. However, in Kiribati, it is recommended that planting in swampy areas be avoided in order for pandanus plants to be healthy and give high fruit yields. Pandanus is likely to tolerate waterlogging for at least 6 months and possibly indefinitely in suitable soil types, such as peat. It occurs on the margins of saltwater mangroves, and it evidently tolerates periodic saltwater inundation during unusually high tides and storm surges.

Salt spray

The species is exceptionally tolerant of salt winds, with plants often colonizing the most exposed seaside locations.

Wind

Pandanus is tolerant of strong, steady winds, such as southeast trade winds, and is capable of surviving gale force storm winds associated with category 1–2 tropical cyclones. Cyclone damage includes bent leaves, fruits broken off, broken branches, and broken stems. During the most severe cyclones (category 3–5), about 10% of larger individuals (>6 m [20 ft] tall) in more exposed sites may be broken and die. Stem breakage typically occurs just above the prop roots.

Abilities

Regenerate rapidly

Under suitable conditions, the plants will regenerate fairly rapidly from seed in fallen fruit segments.

Self-prune

Pandanus plants display a form of self-pruning. In older plants (>30 years of age), the rate of branching is equaled or exceeded by the rate of branch death, such that the total number of branches stays about the same or declines.

Left: Trees grow in very harsh, windy conditions such as here on east coast of ʻEua, Tonga. Right: Pandanus colonizing limestone pillar in Haʻapai, Tonga. PHOTOS: L. THOMSON

Coppice

The coppicing ability of pandanus has not been well investigated. However, plants in which the main stem is broken by cyclones fail to regrow. Accordingly, single-stemmed plants are likely to have limited or no coppicing ability. Multi-stemmed, shrubby individuals, propagated from cuttings, may have some limited coppice regrowth ability, especially if some live stems are retained.

Pollard

In general, pandanus plants do not respond well to pollarding, with limited regrowth occurring after branch cutting.

GROWTH AND DEVELOPMENT

Growth rate

Growth and development varies with sex of plant (male or female), variety, and types of planting stock (seedling or branch cutting).

For seedling plants, there is a 4–9 year semi-prostrate juvenile phase, followed by an erect trunk growth phase of 5–12 years, and then a sexual/flowering phase of 40 or more years. Male plants are usually more branched, up to about 30 branches (maximum 60), than females, up to about 15 branches (maximum 30). The rate of stem growth varies from very slow to moderate (2–80 cm [0.8–31 in] per year). Branch diameter is usually reduced by 10–30% at each branching, and branching ceases when branch diameter is less than about 3.5 cm (1.4 in) in males and 4.5 cm (1.8 in) in females. The life span of established pandanus plants is typically about 50–80 years (but longevity may be much greater, as long as 100–150 years in some environments). The productive fruiting life of vegetatively propagated plants may be only 20–25 years. Senescence is associated with a gradual decline in branch diameter, leaf size, and number of live branches. Branch death is due to the death of the apical meristem, mainly due to insect damage or breakage.

Plants developed from branch cuttings usually grow much faster in earlier years than seedling-derived plants, e.g., elongating about 50–80 cm (20–31 in) per year, and branch from a lower height.

Flowering and fruiting

First flowering in seedling-derived plants commences at about 15 years, while plants derived from branch cuttings typically flower in (2–) 3–4 (–6) years. Seasonality of flowering varies greatly among countries/localities, and among varieties. In Fiji, male plants usually flower once per year (March–May), although flowering plants may be found at any time of the year. Female plants flower heavily every second year; anthesis and fertilization typically occur in March–May, with fruits reaching maturity about a year later, during the following February–April period. In northern Australia, the main fruiting season is April–August. In Kiribati, Marshall Islands, and the Federated States of Micronesia, there are two main fruiting seasons, around December–March and later in July–September. Varieties vary in seasonality, some known to come early or late in the season. Plants may fruit occasionally during the off-seasons throughout the year. In female plants, the period from flower initiation to fruit maturation is about 2 years.

Reaction to competition

Pandanus plants react fairly well to root zone competition from grasses, sedges and woody plants, but growth is slowed and flowering ceases if plants are overtopped and become shaded.

PROPAGATION

The tree is mainly grown from branch cuttings, as plants derived from seeds do not usually reproduce the same qualities of the parental plant. Numerous cultivated traditional varieties (or clones) exist on atolls; most have been selected for their superior edible fruit qualities and are propagated from cuttings. The wild varieties reproduce from seed in their native habitats and are preferred for timber due to their longer, straighter boles.

Propagation by branch cuttings

Propagule collection

Branch cutting material is carefully selected; typically, shorter laterals including one or more aerial or prop roots are chosen. The length of cuttings is about 30–40 cm (12–16 in).

Where early fruiting is desired, the practice in Kiribati is to select branches already with fruits for cuttings. Prior to planting, the existing flowers/fruit are removed.

Propagule processing

The leaf area is reduced by about 70% by cutting and trimming the leaves.

Branch cuttings for propagation; note aerial roots are still attached and leaves are trimmed. PHOTO: L. THOMSON

Propagule storage

It is preferable to plant cuttings immediately or shortly after collection. If being transported to another locality, they may be kept in shaded, cool conditions in sealed, moistened plastic bags for several days.

Pre-planting treatments

None.

Growing area

During the wet season, cuttings may be planted out into their final position in the field, usually in full sun (or up to about 25–30% shade). In Kiribati, depending on type of cutting material and other factors, one or more of the following practices may be adopted to increase rooting and improve survival and growth:

- Planted cuttings in a swamp taro pit until roots develop.
- Plant cuttings late in the afternoon on rainy days (and during the new moon phase).
- Water cuttings daily during prolonged dry spells and during dry season.
- Include organic matter (especially coconut husks) and rusty cans in the planting hole.
- Mulch with dried leaves of pandanus, coconut, and breadfruit.

High survival and rooting of cuttings is likely to be achieved in shade houses with low to intermediate shade levels (up to 50%) and enhanced with misting and/or regular watering.

Media

A sand bed is recommended. On atolls, excavated taro pits are often used.

Time to outplanting

Cuttings rooted in the nursery or a taro pit are transplanted once they have developed several roots.

Approximate size

Rooted branch cuttings are usually about 40–60 cm (16–24 in) long at the time of field planting.

Guidelines for outplanting

The survival of branch cuttings may vary greatly depending on the material used, the variety, handling prior to planting and planting location. Cuttings with several pre-existing aerial roots will usually give high survival, and the presence of pre-existing aerial roots is essential when planting directly into more exposed, beach-side localities.

Propagation by seed

Seed collection

Collect intact phalanges (keys). Larger fruits may contain some seedless keys. The average number of seeds per phalange is about two (with a maximum number of eight).

Seed processing

To speed germination, keys may be soaked in cool tap water for 5 days, changing the water daily. Viable keys will float.

Seed storage

Seeds are probably recalcitrant, meaning that they lose viability if dried. However, because seeds are thought to remain viable after floating on ocean currents for some time, storage of clean keys for weeks or months may be possible.

Pre-planting propagule treatments

Phalanges may be mashed against screens to remove the

Left: Propagation of pandanus seedlings in Forestry Division Nursery, Vava'u, Tonga. Right: Volunteer seedling ready for transplanting. PHOTOS: L. THOMSON

soft pulp and extract the seeds, although this is not necessary.

Growing area

Phalanges may be sown directly into their final location or propagated in full sun (or part shade) in a nursery. Direct sowing is a less expensive method and would generally be preferred, except where seed is in short supply or planting sites are weedy and/or subject to disturbance or burning.

Germination

One source recommends planting phalanges at a depth of two times their diameter (NTBG 1996), and another recommends removing the fleshy part of the key, laying it on the planting medium, and burying it half-way (Bornhorst 2005). Seedlings usually germinate within 4–10 weeks when intact phalanges are planted in moist soil/sand. Up to eight shoots (individual seedlings) may emerge from a single phalange, and many or all may survive, aided by the initially semi-prostrate growth habit, which reduces crowding.

Media/containers

A well drained, sandy, or coralline medium is recommended. Larger sized plastic bags, e.g., 15–20 cm (6–8 in) diameter, are preferable.

Time to outplanting

The nursery duration period is not especially critical for pandanus seedlings. It is recommended that plants be field planted when they are about 4–12 months old.

Approximate size at time of outplanting

The approximate height at outplanting is 30–40 cm (12–16 in).

Guidelines for outplanting

Seedling survival will normally be very high, except for mortality arising from extreme events such as erosion by tidal surge for beachside plantings, or wildfire.

In atoll environments the following factors are considered important for healthy growth and fruit yields of pandanus:

- Avoid planting in swampy areas.
- Provide windbreaks during establishment phase.
- Roots of other plants close to the base of the plant should be cut to increase yields.
- Apply ash from cooking fires (at rate of one coconut shell-full) around base of mature specimens.

Pandanus planted in understory of mixed garden, American Samoa. PHOTO: C. ELEVITCH

DISADVANTAGES

It may be hard to obtain planting stock of preferred varieties of pandanus in significant quantities. To obtain edible fruits, vegetative propagation is necessary. Also, cuttings are best taken only after the fruits of a tree have been harvested. There may be a lag of several to many years before planting stock can be bulked up for large-scale plantings. A further drawback is the difficulty of moving preferred varieties between islands and countries, due to the technical difficulties of either producing apomitic seed and/or the logistical and quarantine issues associated with moving planting stock in the form of large branch cuttings. Breeding for improved sex-specific traits, such as edible or perfumed fruits, is problematic in a dioecious species, with separate male and female plants.

Potential for invasiveness

This species naturally colonizes and spreads into beach and littoral plant communities throughout much of the Pacific islands (where it is highly valued for providing diverse products and services). It has a low potential for invasiveness beyond its natural habitats. Non-preferred genotypes, such as those resulting from volunteer seedlings, are sometimes considered weeds and cut down.

Diseases and pests

The most important pests in the central Pacific are sap sucking mealybugs that may weaken plants. Rats and hermit crabs may feed on green and ripe fruits. In general, pandanus appears to suffer only minor damage from pests and diseases. There is a serious scale affecting pandanus forests in Hana and the entire east Maui region in Hawai'i; this pest was first noticed in the early 1990s and is spread-

In many areas, pandanus forms dense stands, such as here in Kaneohe, Hawai'i. PHOTO: C. ELEVITCH

ing along the coast. Leaves are yellowing and trees are now in very poor health.

Recorded arthropod pests include *Aspidiotus destructor* (coconut scale), *Aspidiotus nerii* (oleander scale), *Graeffea crouanii* (coconut phasmid), *Oryctes rhinoceros* (coconut rhinoceros beetle), *Pinnaspis strachani* (hibiscus snow scale), *Pseudococcus giffardi*, and *Pseudococcus perforatus* (mealybugs).

In northern New South Wales (Australia) dieback of *Pandanus* species is caused by an infestation of the pandanus planthopper (*Jamella australiae*). The insects produce a sticky substance called honeydew, which encourages mold growth. This makes leaves drop and kills the tree's growing points, eventually causing death of the tree. In its native habitats in North Queensland, *Jamella* is controlled by natural predators, including wasps.

Recorded fungal species on pandanus include *Asteromella* sp., *Coniothyrium pandani*, *Dothidella pandani*, *Glomerella* sp., *Lembosia pandani*, *Macrophoma pandani*, *Melanconium pandani*, *Melanconium* sp., *Meliola juttingii*, *Microcyclus pandani*, *Oxydothis pandani*, *Phomatospora cylindrotheca*, *Phomatospora pandani*, and *Volutellaria fuliginea*. Recorded nematodes include *Helicotylenchus dihystera. Erwinia carotovora* subsp. *carotovora* has been recorded as a bacterial disease of *Pandanus*.

Host to crop pests/pathogens

Pandanus is a host for several insect pests of coconut (see above).

Other disadvantages or design considerations

Members of the *kochi* group of *Aedes* (*Finlaya*) mosquito species breed almost exclusively in leaf axils, such as those of aroid root crops, including taro, and Pandanaceae (Taylor 1998).

AGROFORESTRY/ENVIRONMENTAL PRACTICES

The plants provide a wide range of environmental services, including control of coastal erosion; windbreak, including protection of food crops from salt spray; improvement of soil fertility and organic matter levels; shade for humans; and shelter and nesting sites for birds.

Mulch/organic matter

On atoll islands of Micronesia all parts of pandanus may be used for production of compost, as well as in mulching and raising fertility and organic matter levels in sandy, coralline soils. In Kiribati pandanus leaves are used for mulching in giant swamp taro pits.

Soil stabilization

When grown on the seaward slopes and crests of frontal dunes, pandanus helps to bind the sand and prevent wind erosion.

Crop shade/overstory

Pandanus is rarely used as crop shade as the crown is low, interfering with tending of crops, and the asymmetrical branch habit results in variable, often heavy, shade levels.

Alley cropping

Due to its size and habit, the species has good potential for inclusion in alley cropping systems, especially in near-coastal sites where it can act as a low to mid-level windbreak.

Homegardens

Pandanus is commonly planted in homegardens in coastal areas, because of its ornamental appeal, hardiness, and ability to provide a wide range of products, including leaf material for weaving into everyday products, edible fruits, flowers for perfume, and traditional medicines.

Living fences

Pandanus is commonly planted along fence lines and as a boundary marker, especially in near-coastal sites with sandy soils.

Windbreaks

When established at close spacing on or near the crests of beach frontal dunes, pandanus plants function as a windbreak, protecting less tolerant dune plants from the dam-

Left: House thatched with pandanus in Butaritari, Kiribati. PHOTO: R. THAMAN **Right: A boundary hedge of pandanus together with sago palm (*Metroxylon warburgii*), 'Upolu, Samoa, which serves as a cultural resource for craft materials.** PHOTO: C. ELEVITCH

aging effects of salt-laden winds. Pandanus is often planted as a windbreak in atolls to protect crops from salt spray.

Silvopasture

Pandanus is recorded as providing fodder for animals such as pigs and horses.

Woodlot

The plant is sometimes grown in block configurations for production of leaves for weaving. When these plantations have matured and are no longer producing high yields of easily harvested leaves, they can be harvested for timber.

Native animal/bird food

The fruits are eaten and dispersed by crabs, birds, and fruit bats.

Wildlife habitat

Pandanus provides nest sites for birds, especially in atolls.

Bee Forage

Honeybees have been observed foraging on female flowers and fruits.

Fish/marine food chain

Pandanus undoubtedly provides benefits for marine ecosystems and food chains, through its role in beach protection and stabilization.

Coastal protection

The tree is tolerant of foliar salt spray, sand blasting, exposure to strong winds, and high levels of solar radiation. It is considered to be a secondary sand dune colonizing plant and is a useful species for planting on exposed frontal dunes that have already been partly stabilized against wind erosion.

Ornamental

Pandanus is widely planted as an ornamental in homegardens, especially as a boundary along front fences in Pacific islands. Both female and male plants have ornamental

STORIES AND LORE

Pandanus is one of the Pacific's must useful plants and is featured prominently in Micronesian and Polynesian creation mythology, cosmogony, proverbs, riddles, songs, chants, and sayings (e.g., Grimble 1933-34, Thaman and Whistler 1996, Meilleur et al. 1997, Natake and Kairo 2002, Kayser 2002). For example, one legend in Kiribati tells of a man from Makin Atoll who awoke from death and asked that the 'Tearabukitaba' variety of pandanus be planted (Englberger 2004). A legend from the Marshall Islands describes how two people from Bikini Atoll stole the fruit of the variety 'Robijen', and how they went to Kwajalein Atoll and stole pandanus fruit of the 'Anberia' variety (Downing et al. 1992). Another legend tells of a traditional leader's young infant, who was washed away to another island by a big wave; parts of the legend mention pandanus, including a game using pandanus sticks and the woven mat used for burial woven from pandanus leaves. These stories emphasize the cultural importance of pandanus and illustrate the specific use of variety names.

potential. Variegated cultivars are being increasingly planted in Fiji and elsewhere.

USES AND PRODUCTS

Different parts of the pandanus plant are used to provide a myriad of end products throughout the Pacific islands, especially on atolls. The trunk and large branches are commonly used for building materials in house construction, and for ladders. They are also used to make headrests/hard pillows, vases, and fish traps, as sources of glue or caulking for canoes, to extract cream from grated coconuts, and as an aid in making string. Trunks and branches may be burnt for fuelwood or used to make compost. Prop or aerial roots are used in fabrication of house walls, and as supports, basket handles, paintbrushes, and skipping ropes. They are also used to produce dyes and in production of traditional medicines.

The leaves of selected varieties are treated by soaking in the sea and/or boiling or heating and dying and are then used to make mats, baskets (including for ladies and to keep valuables), hats, fans, pillows, canoe sails (formerly), toys, and other plaited wares. The leaves are also used for thatching (both walls and roofs), and for making compost, including special composting baskets woven around the base of giant swamp taro, cigarette wrappers, balls for children's games, and ornaments. They are used for traditional medicines and as a cooking aid in some recipes. The young leaves are used in traditional medicine and for lancing boils, making fans, decoration, and pig feed.

Throughout the atoll island countries of the central/northern Pacific, the fleshy keys of the fruits of many traditionally selected, named, and cultivated varieties are consumed fresh or made into various preserved foods. The fruits are also consumed in Solomon Islands and Papua New Guinea. In Polynesia the fragrant, ornamental fruits of different varieties are strung into leis or garlands and used to make perfume. The fibrous, dried, mature drupes are used as paint brushes for painting tapa, for fuel, compost, and as fishing line floats. In Kiribati the fruit may also be used as bait for catching lobster. The fragrant male flowers are used to scent coconut oil, perfume tapa cloth, and make garlands.

Left: A village leader in Mand Village, Pohnpei, displays an open bunch of the cultivar 'Aspwihrek', prized among Pingelapese for its edible fruit. PHOTO: A. LEVENDUSKY. **Right: A key of the edible cultivar 'Enewedak' is happily held by a boy in the Pingelapese village of Mand, Pohnpei.** PHOTO: L. ENGLBERGER

Staple food

Pandanus fruits are a staple food in parts of Micronesia including the Marshall Islands, Federated States of Micronesia, and Kiribati providing up to 50% of energy intake (Miller et al. 1956, Englberger et al. 2003). They are also widely consumed on Tokelau and Tuvalu (Englberger 2003). In some places the consumption of pandanus has decreased in recent decades due to the availability of imported foods; e.g., pandanus was formerly a major staple food in Nauru (Kayser 2002). In Micronesia adults may commonly consume 20 fresh keys or about 1 kg (2.2 lb) of fruit per day. The fruit pulp is preserved in several different ways. A paste, which is compared to dates in taste, texture, and appearance, is made by boiling and baking the keys, followed by extracting, processing, and drying the pulp. Cultivars with large amounts of pulp are preferred, and the taste differs among cultivars. On average, 100 g pandanus paste provides 321 kilocalories, 2.2 g protein, 134 mg calcium, 108 mg phosphorus, 5.7 mg iron, 0.04 mg thiamin, 2 mg vitamin C (Murai et al. 1958, Miller et al. 1956, Dignan et al. 1994) and from 390 to 724 µg/100 g beta-carotene (a carotenoid that is a precursor to vitamin A), depending on variety and coloration (Englberger et al. 2006a and 2006b). Fresh pandanus is an important source of vitamin C. Preserved pandanus pulp mixed with coconut cream makes a tasty, sweet food item. Pandanus can also be made into flour that is consumed in different ways, usually prepared as a drink.

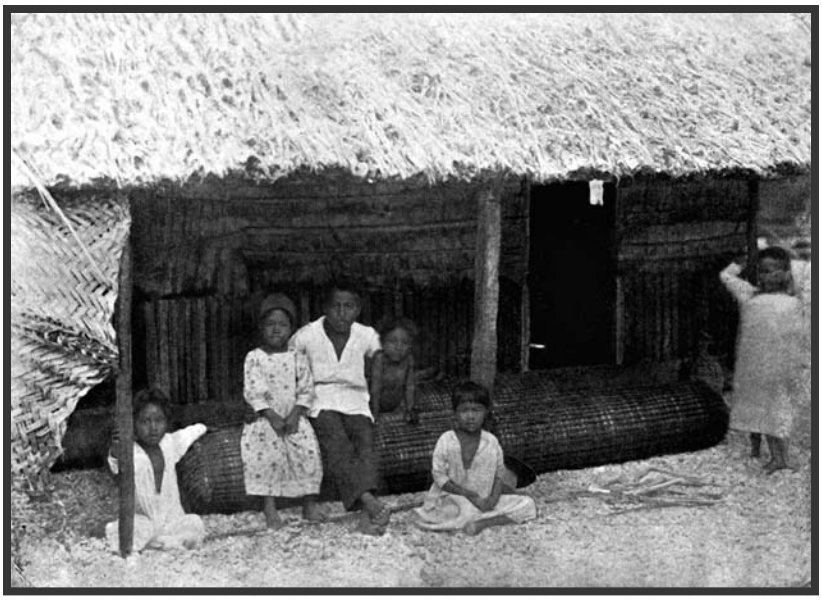
Keys of the edible cultivar 'Enewedak'. PHOTO: L. ENGLBERGER

Fruit

The keys of selected edible cultivated varieties, those with low amounts of calcium oxalate crystals, are consumed raw or cooked. Juice and jam may also be prepared from the fruit. In parts of Micronesia, chewing pandanus keys is usually done outside of meal times and is a pleasurable, highly social activity. Adults may typically consume 20–50 keys daily during the main fruiting seasons (Englberger et al. 2003).

A 100 g portion of edible pericarp is mainly comprised of water (80 g) and carbohydrates (17 g). There are also significant levels of beta-carotene (19 to 19,000 µg) and vitamin C (5 mg), and small amounts of protein (1.3 mg), fat (0.7 mg), and fiber (3.5 g) (Dignan et al. 2004, Englberger et al. 2003, Englberger et al. 2006a and 2006b). The edible flesh of deeper yellow- and orange-colored varieties

Left: Drying pandanus fruit paste in the sun, Kiribati. PHOTO: L. THOMSON **Right: Roll of preserved fruit paste , as traditionally packaged in pandanus leaves, Marshall Islands.** PHOTO: L. ENGLBERGER



This photograph, taken around 1897, shows the huge size of preserved pandanus rolls as presented to the chiefs in the Marshall Islands. SOURCE: KRAEMER 1906

contain higher provitamin A carotenoid levels. The fruit of these varieties has considerable potential for alleviating vitamin A deficiency in Micronesia (Englberger et al. 2003). As carotenoid-rich food may protect against diabetes, heart disease, and cancer, the consumption of pandanus may also alleviate these serious emerging problems of the Pacific. Pandanus fruit is also a useful source of vitamin C (ascorbic acid), thiamine, riboflavin, and niacin (vitamin B-3) (Murai et al. 1958, Miller et al. 1956).

The fruit of wild forms of pandanus contains oxalate crystals that irritate the mouth unless broken down by cooking. The ripe fruit of wild forms may be consumed following cooking and straining the pericarp, but they are not especially palatable or sweet.

Nut/seed

The small seeds of a few varieties of *P. tectorius* are eaten. A similar species, *P. dubius*, has larger seeds that are eaten.

Beverage/drink/tea

Juice pressed from the fruits is sweet and slightly acid with a pungent flavor (Miller et al. 1956). It is being produced commercially in the Marshall Islands.

Medicinal

Pandanus is a very important medicinal plant, with certain varieties sometimes preferred for particular treatments. Leaves, especially the basal white section of young leaves, and roots are used. In Kiribati, pandanus leaves are used in treatments for cold/flu, hepatitis, dysuria, asthma, boils, and cancer, while the roots are used in a decoction to treat hemorrhoids. In Hawai'i the main parts used in making traditional medicines are the fruits, male flowers, and aerial roots (Meilleur et al. 1997). These are used individually or in combination with other ingredients to treat a wide range of illnesses, including digestive and respiratory disorders. The root is used in Palau to make a drink that alleviates stomach cramps, and the leaves are used to alleviate vomiting (Del Rosario and Esguerra 2003). The root is also known for its use in traditional medicine in Pohnpei (Adam et al. 2003).

Animal fodder

Leaves, particularly young leaves, are recorded as providing fodder for domestic animals such as pigs and horses.

Masticant/stimulant

Male pandanus flowers have been credited with aphrodisiac properties in Marshall Islands.

Beautiful/fragrant flowers

The highly fragrant male flowers are widely used for decoration.

Timber

The stems are used in house construction and also for making ladders, especially on atoll islands. Male trees have hard, solid trunks with a yellow interior containing dark brown fiber bundles. The male wood is very strong, but brittle, meaning that it can suddenly break under a heavy load. It is also a difficult wood to split. Trunks of female trees are hard on the outside, but soft, pithy, or juicy in the interior (Little and Skolmen 1989). Slats made from the clean, dried aerial/prop roots are used for walls of houses and food cupboards.

Fuelwood

In the northern Pacific, the discarded, dried keys are highly prized as fuelwood for cooking because they are slow burning and therefore preferred for barbecues. The trunk and branches are occasionally used as fuelwood where other fuelwood is scarce, such as on atolls.

Craft wood/tools

The wood has many craft uses, such as headrests/pillows, vases, and as an aid for string making and extracting coconut cream. It was formerly used to make weapons (lances and batons). When the flesh is removed from the inner end of a dried key, fibrous bristles are exposed. The bristle

Harvesting of leaves for thatch on building structures. Misi-misi variety, Wainidoi, Fiji. PHOTO: L. THOMSON

end can be used as a brush for decorating tapa, with the hard, woody outer end acting as a handle. Fish traps are made out of the aerial roots in Kiribati.

Canoe/boat/raft making

The trunk of one variety in the Marshall Islands is used to make the masts of traditional canoes. In Hawai'i pandanus leaves were the traditionally main material for making canoe sails (Meilleur et al. 1997).

Fiber/weaving/clothing

In many Pacific countries pandanus leaves are used to weave traditional items of attire, including mats for wearing around the waist in Tonga, as well as hats and various types of baskets.

Rope/cordage/string

The roots are made into skipping ropes and basket handles. String or cordage is made from the cleaned and dried prop roots.

Wrapping/parcelization

The leaves are used to wrap tobacco/cigarettes in Micronesia.

Thatch/roofing/mats

Pandanus leaves are used to weave traditional floor mats in many Pacific countries, as well as in the construction of traditional houses (thatch for walls and roofing). A roof made from pandanus leaves is said to last about 15 years, while one of coconut leaves may last only 3 years (Little and Skolmen 1989).

Resin/gum/glue/latex

The trunk is a source of glue or caulking for canoes.

Body ornamentation/garlands

Leaves, often neatly cut, fragrant fruits, and flowers are used in making garlands or leis.

Tannin/dye

A black dye used in weaving is prepared from the roots in Kiribati. Charcoal from pandanus was used in various mixtures to dye and waterproof canoes; the beaten aerial root tips were used to apply the mixtures.

Top: Thatch wall. Bottom: House side panel made of pandanus slats. PHOTOS: L. THOMSON

Left: Colorful phalanges are often used in personal adornment, such as here in Cook Islands. PHOTO: L. THOMSON **Top right: A local expert teaches pandanus leaf weaving, Kealakekua, Hawai'i.** PHOTO: C. ELEVITCH **Bottom right: Children in the Pingelapese village of Mand in Pohnpei enjoy the shade of a pandanus tree bearing edible fruit.** PHOTO: L. ENGLBERGER

Cosmetic/soap/perfume

Male flowers picked from uncultivated pandanus are used alone or in combination with other flowers to perfume coconut oil in Polynesia. An exquisite, uniquely Pacific perfume is made from the aromatic fruits of selected traditional cultivated varieties in the Cook Islands. In South and Southeast Asia, the male flowers and preparations derived from them are used to scent clothes and incorporated into cosmetics, soaps, hair oils, and incense sticks. In Hawai'i, the male flowers were used to scent tapa.

Ceremonial/religious importance

Pandanus is sometimes considered to have supernatural and magical properties in parts of Micronesia and Hawai'i. In Kiribati it may be used as a ceremonial food, while in Indonesia the male flowers are used in ceremonies.

Other

In Kiribati and the Marshall Islands the leaves are formed into a ball for use in a kicking game. The trunks of female trees are hard on the outside but soft or juicy in the interior. The female trunks have been used as water pipes after removing the soft interior (Little and Skolmen 1989).

URBAN AND COMMUNITY FORESTRY

Pandanus has a striking appearance and is very suitable for planting in urban areas. As an ornamental, pandanus is as characteristic of the lowland tropics as coconut but does not have coconut's dangerous large falling fruits and fronds. The tree is salt, wind, and drought tolerant, and requires little care.

Size in an urban environment

Pandanus typically reaches 6–9 m (20–30 ft) in height with a similar canopy spread in urban areas. The rigid prop roots may extend out 1 m (3.3 ft) or more from the main trunk, and aerial roots off branches often dangle from further out.

Rate of growth in a landscape

The growth of seedlings is slow to moderate, 2–80 cm/yr (1–32 in/yr) in height. Trees grown from branch cuttings grow faster, about 50–80 cm/yr (20–32 in/yr).

Root system

The subterranean root system is concentrated in the surface soil layers. Apart from the aerial and prop roots, the tree's root system is unlikely to interfere with maintenance or recreational activities, lawns, or structures such as sidewalks or foundations.

Products commonly used in a Pacific island household

The pliable, strong, durable leaves are used throughout the Pacific for plaited mats, baskets, and other domestic wares. The ripe and fragrant fruit segments are used for personal adornment (e.g., in leis) and are consumed as a staple food in certain areas. Plant parts were used medicinally for thrush and other childhood diseases, chest pain, and difficult childbirth (Krauss 2001) (see "Medicinal" above).

Light requirements

Plants grow well in full sun and also will thrive in 30–50% shade.

Water/soil requirements

It grows best in well drained soils; however, it can tolerate a wide variety of substrates, including coral sand, young lava flows, and peaty swamps. Pandanus can grow in areas with up to 6 months of drought, although it typically grows in

Left: Variegated plant, Hoʻomaluhia Botanical Garden, Kaneohe, Hawaiʻi. Right: Growing in mixed garden together with citrus and breadfruit (*Artocarpus altilis*) at 460 m (1500 ft) elevation, Kona, Hawaiʻi. PHOTOS: C. ELEVITCH

areas with less than 3 months of dry weather. It thrives in areas where groundwater is near to the surface.

Life span

The tree typically lives 20–80 years and can live over 100 years. Individual trees selected for desirable qualities can be vegetatively propagated to extend their lives indefinitely. In some atoll environments the productive fruiting life of cultivars may be only 20–25 years, and regular replanting is needed to maintain good yields of larger fruits.

Varieties favored for use in homegardens or public areas

Numerous local varieties are found throughout the Pacific, where they are propagated from stem cuttings in order to keep them true to type. A sought-after variety for weaving is *P. tectorius* var. *laevis*, which has leaves that are free of prickles along the edges and midrib. Possibly hundreds of locally named varieties have been selected for edible fruits. For ornamental use, striking variegated cultivated forms exist, such as 'Baptistii', which has 1–4 white or yellow stripes a long the middle of the leaves, and 'Veitchii', which has lengthwise stripes along the edges of the leaves.

Seasonality of leaf flush, flowering, fruiting

Vegetative growth occurs year-round. It is likely that male trees flower once a year, while female trees flower heavily every second year. However, both male and female plants may be flowering during the off-season any time of year. It takes fruits several months to ripen.

Exceptional ornamental values

Pandanus presents a bold image in the landscape with its spirally arranged leaves, prop roots, widely forking branches, and smooth trunk and branches. The bark is covered with leaf scars that give a ring-like pattern. The tree is often used singly or in small groups as an accent tree in lawns or mixed gardens. Both female and male flowers are visually striking, and the male flowers are very fragrant.

Use as living fence, hedge or visual/noise barrier

Grown close together, young plants form a barrier of intertwined, prickly leaves. As the trees grow older and trunks form, the usually prickly prop roots can take over as a form of physical barrier in a dense planting.

Birds/wildlife

Pandanus is used as a nesting tree for certain birds, including seabirds such as noddy terns.

Different fruit types. Top: 'Antinakarewe' (Kiribati). Middle: Unnamed variety (Kiribati). Bottom: 'Fala'hola' (Tonga).
PHOTOS: L. THOMSON

Fruit color variations recognized by Hawaiian lei makers (adapted from MacDonald and Weissich 2003)

- hala—the common yellow to red fruit segments
- hala ʻikoi—lemon color at base, bright orange in outer half
- hala lihilihiʻula—bright yellow at base, changing to bright orange-red on the outer part of the fruit segment
- hala melemele—bright yellow fruit segments
- hala pia—small, canary-yellow fruit segments prized for leis and medicinal purposes
- hala ʻula—Entire fruit segments red-orange

Maintenance requirements

The tree requires little maintenance aside from removing the fallen leaves and fruits. Although the tree grows on nutrient-poor soils, moderate fertilizer or compost applications are beneficial. Surface mulching around the tree adds nutrients to the soil while helping to retain soil moisture and reducing erosion. Pandanus tends to regrow poorly or not regrow at all after heavy pruning. However, for larger trees with many branches, a small number of branches may be pruned off without undue harm to the tree.

Special considerations regarding leaf, branch, and fruit drop

Year-round drop of the long, prickly leaves can be a nuisance in public areas or gardens and will require regular clean-up in frequented locations. The large fruit segments fall from female trees and can be unsightly. If not removed, the scattered fruit segments will attract fruit flies and rats.

Nuisance issues

Dead leaves that accumulate in the branch crowns can be used by rats to build nests.

Hazards

The prickly leaves and aerial roots could be a hazard in public areas where people might rub against them.

Common pest problems

Mealybugs and scale insects are minor, occasional pests, both of which can be controlled with insecticidal soap or oil. Other pests include ants and whiteflies.

Other comments about this species in urban environments

Trees can be grown in containers in smaller garden areas or on terraces, although their usually spiny leaves make this problematic in small spaces.

COMMERCIAL PRODUCTS

The main commercial products from pandanus are woven products, often of high value; e.g., individual mats may be worth more than US$500 in Tonga, Fiji, and Hawaiʻi. In Tonga mats made from thin strips of leaves with intricate designs (fala) are important gifts and indicators of wealth. Simpler designs using wider strips (lotaha and papa) are used as everyday floor mats. Taʻovala mats are worn around the waist (Evans 2003). In the Haʻapai group, 80% of women are involved in handicraft production, mainly using pandanus and some paper mulberry (*Broussonetia papyrifera*). Most traditional handicrafts made from pandanus are produced for home use, as gifts, or are informally exchanged for other products, including other handicrafts. Because the commodities are locally produced, non-perishable, and can be processed a number of ways, there is a wide range of opportunities for producers and processors to enter into the handicraft marketing chain at any stage. Pandanus is an important income generating plant in Haʻapai (Thaman et al. 1997, Tupoulahi-Fusimalohi 1999), and the islands are well known as a producer of all types of mats known as fakahaʻapai and salusalu (Ika 1996). In Tonga, producers and sellers report that prices of pandanus products are relatively stable, indicating that supply is matching demand.

In the atoll islands of the central Pacific, the fruits are often sold fresh in local markets, and preserved food items are occasionally sold.

Spacing

In Tonga most farmers grow some pandanus (Evans 2003). Pandanus may be either grown in lines, especially borders, with 3–5 m (10–16 ft) between plants, or less commonly in block plantings at a spacing of about 5 x 5 m (16 x 16 ft). Plantations usually consist of a rather small number of plants, e.g., 20–100, as most of the leaves are used for weaving by family members and/or the limited land is needed for cultivating food crops.

Management objectives

Plantations need to be kept well weeded both for maintaining good growth and for access purposes when harvesting leaves or fruits.

PROCESSING LEAVES FOR WEAVING

Plant from which leaves have been harvested. Paongo variety (syn. *P. whitmeeanus*), Vava'u, Tonga. PHOTO: L. THOMSON

Drying leaves. Ha'apai, Tonga. PHOTO: L. THOMSON

Soaking leaves in sea water. Kie variety (syn. *P. spurious*), Ha'apai, Tonga. PHOTO: L. THOMSON

Weaving of mat, Butaritari, Kiribati. PHOTO: L. THOMSON

Advantages and disadvantages of growing in polycultures

Pandanus is well suited to growing in polycultures, because of its low stature and tolerance of variable light levels. It has excellent windbreak function in more exposed sites near the coast.

Yields

The main products from pandanus (depending on variety) are:

Leaves (for mats, handicrafts, traditional huts)

Harvesting of leaves usually begins at about 3 years of age. Leaves can be harvested every 3 months for a period of 5–10 years, but leaf size and accessibility for harvesting diminishes over time. Outside the Pacific islands, leaves have reportedly been harvested from much older specimens, e.g., 50–60-year-old trees. Published information on yields is limited. Mature, healthy plants in full production are likely to yield about 10–90 leaves per year on less fertile sites and 150–300 leaves per year on optimal sites.

Stems (for building/construction)

Larger stems for building poles and construction take about 15–20 years to develop.

Fruits (for human consumption and perfume)

Sexually mature plants produce about 8–12 fruits per plant every second year. The total weight of individual fruits for edible varieties varies from about 7 to 15 kg (15–33 lb). There are typically 35–80 phalanges per fruit in edible varieties, and the weight of the edible portion is from 30–75 (–100) g (1–2.7 [3.6] oz) per phalange.

Male flowers (for garlands)

Sexually mature plants typically produce 10–40 male flower spikes (about 1.5–5 kg [3.3–11 lb]) per plant each year. The potential yield of these products on a per-hectare basis depends on planting density. Density in native stands varies widely; typical planting density for final crop spacing is about 100–500 stems per ha (40–200 stems/ac).

On-farm processing

Pandanus leaves need to be dried and wrapped into bundles prior to sale in local markets. Certain varieties may need to be bleached in seawater, e.g., the kie variety (syn. *P. spurious*), for production of fine white mats in Tonga.

Markets

There is strong local and overseas demand (including by tourists) for woven pandanus handicraft products from the Pacific islands. These include beautifully crafted and expensive items such as fine white mats and hats from the Cook Islands and Tonga, respectively. Preserved pandanus paste (mokwan and te tuae) is marketed in the Marshall Islands and Kiribati, presented both in the traditional manner (wrapped in pandanus and tied tightly with coconut cord) and in plastic.

INTERPLANTING/FARM APPLICATIONS

Example system 1 (Thaman 1978)

Location

Tonga

Description

Pandanus trees, mainly the variety 'Paongo' for weaving, are planted along roadside borders of yam (*Dioscorea alata*) gardens. These are often cooperative or communal yam gardens, known as toutu'u ufi. These gardens are planted in yams, then interplanted with giant swamp taro (*Cyrtosperma chamissonis*), plantains (*Musa* spp., often including 'Maia Maoli/Popoulu', Pacific plantain), and sometimes taro (*Colocasia esculenta*). In the past, bunching onion, corn, and even cabbage were also planted among the yam mounds. Pandanus is grown along the fence line and serves not only as a boundary marker and living fence but also as an important cultural resource. After the yams are harvested, possible succeeding crops include cocoyam (*Xanthosoma* spp.), sweetpotato, and cassava. Sometimes paper mulberry is planted after the yam or succeeding crop.

Example system 2

Location

Kiribati

Description

In Kiribati edible pandanus is often seen planted around giant swamp taro pits. Other trees planted or protected nearby include coconut, breadfruit, and papaya. There are also trees that are important as sources of leaf mulch, such as beach heliotrope (*Tournefortia argentea*), *Guettarda speciosa*, and beach hibiscus (*Hibiscus tiliaceus*). In addition to being used as mulch, the leaves of pandanus are woven into baskets around the bases of the largest ceremonial giant swamp taro plants into which fertilizer is placed.

PUBLIC ASSISTANCE AND AGROFORESTRY EXTENSION

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

GENETIC RESOURCES WHERE COLLECTIONS EXIST

In Kiribati, the Division of Agriculture (Ministry of Environment, Lands and Agricultural Development), with support from SPC/FAO/SPRIG/USP, has established a field gene bank of traditional *Pandanus tectorius* varieties. The gene bank is located in Bikenibeu South, South Tarawa, and included more than 60 varieties in 2003. It is strongly recommended that other Pacific island nations undertake similar programs to conserve pandanus diversity and the underlying cultural knowledge that has fostered and maintained this diversity. The National Tropical Botanical Garden maintains a modest collection of *Pandanus* species and cultivars at its Allerton and McBryde Gardens on Kaua'i, Hawai'i. A small genebank of nine varieties of pandanus from Pohnpei atolls have been planted at the Pilot Farm collection in Pohnpei, FSM. A list of morphological descriptors has been developed by the SPRIG project.

INTERNET

Access to selected papers and color photographs: <http://www.islandfood.org>.

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Top: Boundary planting of pandanus around mixed agroforest, Tongatapu, Tonga. PHOTO: C. ELEVITCH **Bottom: Woven basket of pandanus leaves in which fertilizer and mulch is placed around the bases of the largest ceremonial giant swamp taro plants.** PHOTO: R. THAMAN

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traditional tree initiative

Species Profiles for Pacific Island Agroforestry (www.traditionaltree.org)

Pandanus tectorius (pandanus)

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