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Acacia koa (koa) and *Acacia koaia* (koai‘a)

Fabaceae (legume family)

koa (*Acacia koa*)
koai‘a, koai‘e (*Acacia koaia*)

Craig R. Elevitch, Kim M. Wilkinson, and J. B. Friday

IN BRIEF

Distribution Endemic to the major Hawaiian islands of Hawai‘i, Moloka‘i, Maui, Lāna‘i, O‘ahu, and Kaua‘i.

Size Typically attains heights of 15–25 m (50–80 ft) with a canopy spread of 6–12 m (20–40 ft).

Habitat Native to a wide elevation range of 100–2300 m (330–7500 ft) (recommended for planting only above 610 m [2000 ft]), with annual rainfall of 850–5000 mm (34–200 in).

Vegetation Associated with dozens of other native species.

Soils Requires well drained soils. Koa stands on shallow soils are not as productive as those on deep soils and may be short-lived.

Growth rate Can grow faster than 1.5 m (5 ft) per year in height for the first 5 years in favorable environments.

Main agroforestry uses Wildlife habitat, silvopastoral systems, ornamental.

Main products Timber.

Yields Projected yields of 90–180 m^3/ha (6.5–13 mbf/acre) may be possible in pure stands in 30–50 years; much less in open-grown stands in pastures or in mixed stands in natural forests.

Intercropping Difficult to integrate with annual crops due to koa’s aggressive surface root system that competes with crops, while also susceptible to damage by human, animal, and machine traffic.

Invasive potential Poses a small risk of being invasive if introduced outside of Hawai‘i.

PHOTO: C. ELEVITCH

Large koa trees such as this in South Kona, Hawai‘i, have mostly disappeared due to logging and land clearing.

INTRODUCTION

Acacia koa, known worldwide as koa, is the largest native tree of the Hawaiian Islands. It can reach heights in excess of 35 m (115 ft), although more commonly trees reach about 15 m (50 ft) in height at maturity. Koa is very important to the ecology, economy, and culture of Hawai'i. Koa trees in natural ecosystems provide habitat for many birds, insects, and plants, some endangered. As a nitrogen-fixing species, koa plays an important role in forest fertility. A key traditional use of koa logs by early Hawaiians was to build canoes. The resurgence of interest in Hawaiian voyaging and racing vessels using traditional materials has led to a greater public awareness of the scarcity of trees suitable for "canoe koa" and the importance of renewing this depleted resource.

Commercially, koa is Hawai'i's premier timber, and currently one of the most expensive woods in the world. It is utilized for furniture, veneer, and crafts. Most commercial koa is harvested from remnant individuals or stands in pasture land. Efforts in the private and public sectors are being made to re-establish koa, either through fostering natural regeneration (through the removal of livestock and occasionally scarifying the ground to expose buried koa seeds), or by planting seedlings. There are many unknowns regarding the cultivation and management of koa for commercial timber. Private landholders sometimes choose to plant koa for the ecosystem and heritage value, while recognizing that as a financial investment the outcome of koa reforestation is highly uncertain.

Koa trees once thrived in areas as low as 90 m (300 ft) in elevation. However, pests and diseases currently limit koa's optimal range to elevations above 610 m (2000 ft). Hawai'i's highly variable climate means that matching an appropriate seed source to the site conditions is important to foster a viable koa planting. Koa is a large, fast-growing tree with an aggressive root system. As such, its uses for interplanting with crops are limited. It is recommended that crops be planted no closer than 10–12 m (33–40 ft) to mature trees. However, many kinds of herbaceous plants can thrive in the dappled shade cast by koa.

The proliferation of this species is desirable within Hawai'i. However, as a fast-growing nitrogen-fixing tree with long-lived seeds and the ability to regenerate after fire, koa may have potential as a problematic invasive species outside its native range.

DISTRIBUTION

Native range

Koa is endemic to all major Hawaiian Islands (Hawai'i, Moloka'i, Maui, Lāna'i, O'ahu, Kaua'i), at 100–2300 m (300–7500 ft) elevation.

Current distribution

Scattered remnants of koa forests are still found on the main Hawaiian Islands, mostly in upland areas. The healthiest and largest populations grow at elevations of 900–1800 m (2950–5900 ft). New plantings are taking place in agricultural and former pasture areas, primarily above 610 m (2000 ft).

BOTANICAL DESCRIPTION

Preferred scientific name

Acacia koa Gray

Family

Fabaceae (legume family)

Subfamily

Mimosoideae

Non-preferred scientific names

Acacia hawaiiensis (Rock) Degener & I. Degener
A. heterophylla Willd. var. *latifolia* Benth.
A. kauaiensis Hillebr.
Acacia koaia is a closely related species previously classified as a subspecies of *A. koa* (Wagner et al. 1999)

Current remnant areas of koa (after Whitesell 1990).

Common names

koa (worldwide)

GENERAL DESCRIPTION

Size

Koa can grow to over 35 m (115 ft) in height but more commonly reaches heights of 15–25 m (50–80 ft) with a canopy spread of 6–12 m (20–40 ft). Some populations are much smaller, with a shrub-like form.

Form

The form of trees is highly variable, ranging from an upright, single trunk to low and sprawling with multiple trunks.

Flowers

Pale yellow, borne in axillary racemes with spherical heads about 8.5 mm (0.33 in) in diameter. Flowering peaks in mid to late winter. Flowers are produced throughout the year, starting when the tree is 2–3 years of age.

Leaves

Young seedlings have bipinnately compound true leaves with 12–24 pairs of leaflets. Mature trees have no true leaves, but only sickle-shaped phyllodes (flattened leaf stalks) 7–25 cm (2.8–10 in) long and 0.5–2.5 cm (0.2–1 in) wide.

Seeds

Seeds are contained within a pod (legume) 15–20 cm (6–8 in) long, containing 6–12 seeds.

Rooting habit

Koa has an extensive, shallow, and lateral-spreading root system that can often be seen on the soil surface, just under the leaf mulch. Roots can sucker, particularly when they are damaged or the tree experiences stress.

How to distinguish from similar species/look-alikes

Sickle-shaped phyllodes ("leaves") at maturity distinguish it from "haole koa" (*Leucaena leucocephala*); larger stature, larger phyllodes, and paler yellow and larger flowers distinguish it from Formosan koa (*Acacia confusa*); longer sickle-shaped phyllodes distinguish it from Australian blackwood (*Acacia melanoxylon*), which is also usually a much straighter-stemmed tree; and its much larger stature and larger phyllodes distinguish it from its close rela-

Left [scale: ⅓ size]: Young koa trees have true leaves (on left). At about 6–9 months of age, trees begin producing flattened, elongated leaf stems called phyllodes (on right) instead of true leaves. Right: Flowering branch tip. PHOTOS: C. ELEVITCH

Root suckering (on left) occurs frequently when a tree is severely stressed (on right) or when surface roots are damaged. PHOTO: C. ELEVITCH

tive koai'a (*Acacia koaia*). The rare koai'a is a shorter tree with a bushy, often gnarled habit, primarily of drier areas of Kaua'i, Moloka'i, Lāna'i, Maui, and Hawai'i (see koai'a section below).

GENETICS

Variability of species

Koa is a highly variable species in tree form, wood quality, and environmental tolerances. Populations on the island of Hawai'i tend to be larger trees with broad (2.5 cm [1 in]) phyllodes and long, straight boles, whereas populations on other islands tend to be shorter trees with narrower and more curved phyllodes. Wood colors vary from blonde to red to deep brown, sometimes showing curl or fiddleback. Growth rates, leaf shape, and bole form have been shown to be highly heritable (Sun 1996). Different populations also vary in water use efficiency, environmental tolerances, and resistance to disease (Daehler et al. 1999, Ares et al. 2000, Shi 2003). Although there are no completed studies on wood quality, anecdotal evidence suggests that populations in some areas tend to have better quality wood than populations in other areas and that wood quality, especially curl, is inherited.

Known varieties

Distinct varieties of koa occur on Hawai'i island (*A. koa* var. *latifolia*) and on Kaua'i (*A. koa* var. *kauaiensis*) (Wagner et al. 1999). *Acacia koa* var. *koa* occurs on all the main islands. Koa trees with characteristics in between *Acacia koa* and *A. koaia* (koai'a) occur on Kaua'i (Wagner et al. 1999). Isozyme studies have shown differences between Hawai'i island populations of koa and the populations of the other Hawaiian islands (Conkle 1996).

ASSOCIATED PLANT SPECIES

Koa is the second most important and widespread tree in Hawaiian forests after 'ōhi'a lehua (*Metrosideros polymorpha*). While koa may occasionally occur in pure stands, usually the species is found in mixed forests where 'ōhi'a lehua predominates. On mesic sites, the koa canopy may also be shared with a'e (*Sapindus saponaria*) and naio (*Myoporum sandwicense*). A wide variety of native understory trees are found in koa forests, including naio, 'ōlapa (*Cheirodendron trigynum*), kāwa'u (*Ilex anomala*), kōlea (*Myrsine lessertiana*), kōpiko (*Psychotria* spp.), 'iliahi (*Santalum* spp., sandalwood), olopua (*Nestegis sandwicensis*), and pilo (*Coprosma* spp.). In wetter sites, tree ferns (*Cibotium* spp.) may be prominent in the understory, while other species of ferns such as palapalai (*Microlepia strigosa*) and *Dryopteris wallichiana* cover the ground. The native Hawaiian raspberry or 'ākala (*Rubus hawaiensis*) and the shrub māmaki (*Pipturus albidus*) are also common in the understory of koa forests. At higher elevations the forest gradually becomes dominated by māmane (*Sophora chrysophylla*) (Mueller-Dombois and Fosberg 1998). Today, many koa forests consist of scattered old trees in rangelands dominated by kikuyu grass (*Pennisetum clandestinum*).

'Ōhi'a lehua, the most common native Hawaiian tree, is almost always found growing with koa. PHOTO: C. ELEVITCH

Koa forests are invaded by many non-native or alien species. On the wet sides of the islands at lower elevations, strawberry guava (*Psidium cattleianum*) is the worst invader. Christmas berry (*Schinus terebinthifolius*) invades dry-side forests. Various species of raspberries (*Rubus* spp.) pose problems in montane forests. The climbing vine banana poka (*Passiflora tarminiana*, syn. *P. mollissima*) posed a severe threat to the koa forests until a few years ago when a successful biocontrol was established (Trujillo et al. 2001). In many koa forests, a dense carpet of the alien meadow ricegrass (*Ehrharta stipoides*) prevents regeneration of native species.

ENVIRONMENTAL PREFERENCES AND TOLERANCES

Environmental tolerances of koa vary by population. Such variation is one reason that seedlings used in reforestation should come from seeds collected from sites near or similar to the planting site. An inherent advantage of relying on natural regeneration is that the genetic stock will already be adapted to the planting site.

Climate

Elevation range

100–2300 m (330–7500 ft). Recommended for planting only above 610 m (2000 ft).

Mean annual rainfall

850–5000 mm (34–200 in)

Rainfall pattern

Koa tolerates a wide range of rainfall patterns including summer, winter, and uniform.

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

0–5 months

Mean annual temperature

9–21°C (48–70°F)

Mean maximum temperature of hottest month

14–26°C (57–79°F)

Mean minimum temperature of coldest month

2–16°C (36–61°F)

Minimum temperature tolerated

–4°C (25°F). Koa seedlings may be killed by frost (Scowcroft and Jeffrey 1999).

Soils

Soil texture

Koa prefers loams, sandy clay loams, clays, clay loams, and sandy clays. Koa forests naturally occur on both light, ash-derived soils and on highly weathered clays on the older islands. Organic soils on lava rock (Tropofolists) are common in many koa regions.

Soil drainage

Koa must have freely draining soils.

Soil acidity

Acid to neutral soils are acceptable, pH 4.0–7.4.

Special soil tolerances

Koa can grow well in infertile soils. However, it does not tolerate shallow or saline soils.

Tolerances

Drought

Koa can tolerate drought for 3–5 months, depending on

After an overnight frost, young seedlings may be killed by overly rapid thawing caused by direct sunlight. Here sun screens are placed to shield seedlings from early morning sunlight, giving seedlings time to slowly warm up. Hakalau National Wildlife Refuge, Hawai'i. PHOTO: C. ELEVITCH

Pink nodules on the root system of a koa seedling, indicating active nitrogen fixation. PHOTO: J. B. FRIDAY

soil, competition from weeds, relative humidity, winds, and other factors.

Full sun

Koa is a pioneer species that thrives in full sun.

Shade

Intolerant of shade, the tree grows well only in the sun.

Fire

Koa can re-sprout from the base or roots after fire, but the above-ground parts are not resistant to fire.

Frost

Modest frosts are tolerated by mature trees but can kill young seedlings.

Wind

Although koa can survive steady winds, it will have poor form and slow growth and is therefore not considered highly wind tolerant.

Abilities

Fix nitrogen

Koa is a nitrogen-fixing legume and when successfully inoculated with the appropriate rhizobia bacteria at an early age can grow rapidly without nitrogen fertilizers.

Regenerate rapidly

It establishes quickly in open, favorable environments.

Self-prune

Grown close together, koa readily sheds its lower branches. Pruning is not recommended.

GROWTH AND DEVELOPMENT

Growth rate

Koa is a fast-growing tree. In favorable environments, koa can grow faster than 1.5 m/yr (5 ft/yr) in height for the first 5 years or so. Growth slows thereafter. Stem diameter growth rates depend on stand density (how many trees per hectare or acre). Open-grown trees in fields or pastures may increase up to 3 cm (1.2 in) in stem diameter per year for 10 years on sites with deep soil and adequate rainfall, and well managed plantation trees average 1.7–2.4 cm/yr (0.7–0.9 in/yr) on good sites with enough water and deep soil. Outstanding plantation trees have reached diameters of over 40 cm (16 in) and heights of 15 m (50 ft) in 12 years (Shi 2003). Dominant forest trees may grow 1.7 cm (0.7 in) in diameter per year for up to 25 years, and average trees in a healthy stand on a good site may grow from 0.7 to 1 cm (0.3-0.4 in) in diameter per year. In poor environments with shallow soils, low rainfall, or high elevations above 1525 m (5000 ft), average diameter growth is more typically 0.3–0.5 cm/yr (0.1–0.2 in/yr). In dense, unthinned stands or in stands that thin themselves naturally but only slowly, diameter growth all but ceases.

Flowering and fruiting

Flowering occurs year-round in many areas and is strongly seasonal in other areas. Flowering occurs most heavily from January to March, with seed ripening in August, September, and October, and may start in trees as young as 3 years old.

Reaction to competition

Young seedlings are intolerant of grass competition. Dense grass may also limit natural regeneration. Competition among koa trees in a dense stand is a limiting factor for older saplings (Grace 1995). In very dense stands, most individual trees are hardly growing at all, although a few may be able to emerge from the canopy and overtop their peers.

Diseases, pests, and predators

The major pests affecting koa are fungi (*Fusarium* spp., especially *F. oxysporum* and *F. solani,* and *Calonectria* spp.) and twig borers (*Xylosandrus compactus* and *Xyloborus* spp.). Twig borers damage branches and may kill young seedlings. Livestock readily consume small seedlings and can also quickly cause catastrophic damage to young trees by eating the leaves, stripping the bark, and trampling the extensive surface root systems. Seed predators include seed weevils (*Araecerus levipennis* and *Stator* spp.) and the koa seedworm (*Cryptophlebia illepida*) (Stein 1983). The koa




Top left and right: Damage caused by twig borer. PHOTOS: C. ELEVITCH **Bottom left: Rust on phyllodes.** PHOTO: S. NELSON **Bottom right: Mistletoe (*Korthalsella* spp.).** PHOTO: J. B. FRIDAY

moth (*Scotorythra paludicola*) may cause defoliation and in some cases may kill trees outright (Stein and Scowcroft 1985). Rusts (*Endoraecium* spp. and *Atelocauda* spp.) are common on phyllodes but are usually not serious problems. Koa is sometimes infected with *Armillaria* root rot fungi or mistletoes (*Korthalsella* spp.); older trees are attacked by a number of wood-rotting fungi (Gardner 1996). Banana poka (*Passiflora tarminiana*), a vigorous climbing vine, has overgrown and suppressed stands of koa, particularly on the islands of Hawai'i and Kaua'i, but the recent introduction of biological control agents seems to have lessened the impact of the weed (Trujillo et al. 2001).

PROPAGATION

The only propagation method currently in wide use is from seed. Success of vegetative propagation methods such as air-layers, rooted cuttings, and tissue culture has been limited (Skolmen 1986a, Skolmen and Mapes 1978, Shi 2003). Growing koa seedlings is very similar to many other nitrogen-fixing tree species, requiring pregermination treatment to break through the hard, impermeable seed coat, inoculation with an appropriate rhizobia bacteria, and special nutrient requirements. Koa is susceptible to root-knot nematodes, especially when grown in grassy areas at low elevations.

Propagation by seed

Seed collection

Koa trees are highly variable in size, form, and site performance. Hawai'i's many microclimates mean that local populations are often best adapted to the particular site conditions. For this reason, a quality seed source should be

found from a similar environment as close to the planting site as possible. When no natural stands of koa are found nearby, seeds should be collected from areas with similar environments (rainfall, drought period length, pest populations, soil conditions, etc.). Seeds should be collected from straight, healthy, fast-growing individuals, as both form and vigor are strongly inherited (Sun 1996, Sun et al. 1996, Shi 2003). If seedlings are purchased, the buyer should make sure the nursery grower took care in seed collection. It is simplest to collect seeds from short, branchy trees, but doing this ensures that the seedlings will also be short and branchy rather than tall and straight.

For areas without natural koa populations, growers should select seed from known superior populations or provenances, being careful not to introduce diseases (see box on koa wilt.) Koa seed collected from superior trees has been shown to grow up to three times as fast as koa seed collected from slow-growing trees (Sun et al. 1996). Research is still underway to select koa strains that are both fast-growing and disease resistant.

Koa seed pods contain 6–12 seeds. Pods are ready to pick when their color has turned from green to brown or black, and when the seeds inside are dark brown and filled out rather than green, flat, or small. Seeds can also be collected from the ground, although it would be prudent to surface sterilize (e.g., with a weak bleach solution) such seeds if collected in areas prone to koa wilt. Koa can bear seed any time of year, although for some populations seed availability is highly seasonal. The heaviest period for seed maturation is usually August–September.

Seed processing

Pods are dried in the sun until they can be opened easily. Seeds are extracted by hand or by machine threshing. Once extracted from the pods, seeds may be dried more if necessary (ideal moisture content for storage is 6–8%). Koa seed size is highly variable, a kilogram of seed containing 5500–16,500 seeds (2500–7500 seeds/lb). Dried seeds should be stored in an airtight container away from direct sunlight. Properly dried seeds can store at least 12–24 months at room temperature, many years longer in cooler conditions. Germination is usually 70% or higher, but can be lower depending on weather conditions during ripening.

Pre-planting seed treatments

Koa seeds have a hard seed coat that is normally impenetrable to water. To hasten germination, the hard outer layer of the seed needs to be broken ("scarified") to allow water to contact the germ so the seed can sprout.

Two common methods are used to scarify koa seeds:

1. Mechanical scarification involves nicking the seedcoat on an edge away from the point of attachment to the pod. Nail clippers work best, although a knife, file, or even sandpaper may also be used for this purpose. The nick should be shallow, just deep enough to allow water to penetrate. Manual scarification is labor intensive, but very reliable once the technique is learned.
2. Hot water treatment can be used for large seed lots. Near-boiling water (90°C, 195°F) is poured over the seeds in a volume ratio of at least five parts water to one part seed. Seeds are then soaked in the hot water

Left: Breaking seed coat dormancy through scarification is important to ensure fast and uniform germination; the nicking method is shown here. Right: Seedlings that were not inoculated with rhizobia (on left) were pale and less vigorous than their same-age, inoculated counterparts (on right). PHOTOS: C. ELEVITCH

COMMON PLANTING PITFALLS AND REMEDIES

- Overwatering and overfertilization cause stress which often exhibits itself as yellowing of the leaves. Decreasing irrigation and eliminating nitrogen fertilizer can reverse the problem.
- Weed whacking the bark at the base of the tree can ruin the tree in a fraction of a second. It's best to control weeds only by hand cutting and mulching near the tree.
- Piling mulch against the trunk can cause rotting. Leave a few inches breathing room.
- Planting a seedling too deep will cause the part of the stem that is underground to rot, and the tree will effectively be girdled. Seedlings should be planted with the top of the planting medium even with the soil surface.
- Without adequate soil contact, newly planted seedlings can be severely set back or die of water stress within a few days of planting. When planting seedlings, especially those grown in forestry tubes, the soil should be firmed right up against the seedling's root system.
- Failure to inoculate seedlings with rhizobia bacteria in the nursery will result in trees that are not vigorous. Trees should be inoculated in the nursery within 4 weeks of germination.
- Root-bound seedlings that have become stunted in their containers will never return to being vigorous, healthy trees. Seedlings should always be planted when they are ready, and seedlings that are root-bound discarded.
- Growing in lawns stresses young koa and koai'a trees. Grass competes with the trees for water and nutrients, and trees are likely to be injured when cutting the lawn. Grass should be kept away from trees, ideally at a radius equal to the height of the tree or more, although many kinds of herbaceous plants can be grown underneath koa.
- Windy or shady conditions are not conducive to rapid growth. Trees should be protected from wind and given full sun most of the day.
- Grazing animals such as cattle, goats, sheep, and pigs can ruin a field of young seedlings in a matter of minutes or hours. These animals should be kept away from koa seedlings for the first few years, and preferably for the life of the trees. Horses have been grazed successfully under koa in some instances but have destroyed plantations in other situations. Pigs do not usually browse seedlings but will uproot new plantings and rub against seedlings, damaging the bark.
- When planting dense stands of koa, failure to thin out trees on time will cause growth to stagnate. Stands should be thinned at the first sign of loss of vigor.

for 1–3 minutes, followed immediately by a cooling in tepid water. The hot water weakens the seed coat, allowing water to penetrate.

Whichever of these methods is used, it is best to start with a small trial to make sure the seeds germinate and are not harmed. To start the germination process and to test if scarification was successful, scarified seeds should be soaked in cool water overnight to allow water to be absorbed into the seed before planting. Scarified seeds swell with water, while seeds that remain unscarified will not take on water. Healthy, successfully scarified seeds germinate in 2–7 days.

Growing area

Koa is relatively easy to grow in the nursery. In most environments of Hawai'i, koa seedlings can be grown outdoors in an uncovered growing area and no special greenhouse area is needed. If available, some cover (greenhouse or temporary cover) is ideal for the first 2 weeks after germination to protect sprouts from hard rains and seed-eating birds. Rodents also eat koa seeds and should be excluded from the nursery area. Root-training forestry containers are best for koa. Tubes or open-ended suspended pots available from forestry suppliers are usually used. These containers have ribbing on the inside walls to train the roots to grow straight down without spiraling or wrapping around each other. Containers can be filled with any kind of commercial well drained potting media. Potting media should also be inoculated with mycorrhizal fungi, available from commercial suppliers and garden centers.

Seedling establishment phase

Seeds are planted into forestry containers that have been pre-filled with media. Shallowly cover the seed with potting media, followed by a thin mulch layer, such as finely sifted black cinder or #2 poultry grit (available from feed stores and farm supply centers). Seeds should be buried about as deep as they are wide, and no deeper. Water with a fine-headed sprayer to keep the medium moist. Full sun is best. Daily watering is usually necessary, by hand or with an automated system.

Scarified seeds will germinate in 2–7 days. After 1–2 weeks of growth, seedlings should be inoculated with rhizobia

Damage with a power weed cutter happens in an instant and seedlings usually never recover. PHOTO: C. ELEVITCH

bacteria selected for this species (available from commercial suppliers or from nodules collected from the roots of healthy forest trees). Strains of rhizobia selected by researchers are best for optimum nodulation and nitrogen fixation.

Active growth phase

As the seedlings develop, they should be watered as needed and never allowed to dry out. Watering in the morning is typical for nurseries that grow koa. Hot, dry days may necessitate a second watering in the early afternoon. Late afternoon and evening watering is not recommended, as it can lead to disease problems such as sooty mold. After about 6 weeks, seedlings should be double-spaced in their trays to ensure that each seedling receives full sunlight and to facilitate strong stem development. Depending on seed lot, about 10% of the seedlings will be stunted or poorly formed, and these should be culled. The remaining seedlings should be monitored for pests, but predators are generally not problematic once the seedlings are taller than 8 cm (3 in). If any weeds enter the soil-free media, they should be removed. No fertilizer application is necessary if seedlings were inoculated with rhizobia bacteria and mycorrhizal fungi. No pruning should be done. After 10–16 weeks, seedlings may be hardened for a few weeks by gradually reducing watering frequency to introduce seedlings to temporary, moderate water stress. The target size ranges from 15–30 cm (6–12 in), depending on the container size. When seedlings have reached target size, they may be delivered to the planting site.

Plantation establishment

Site preparation is a crucial part of koa establishment. The area must be fenced to exclude any grazing animals (domesticated or feral), and competitive vegetation should be removed from around the planting holes. As discussed above, genetic quality is a crucial aspect of koa growth and the seed source must be carefully considered and matched for the outplanting site. Koa planted at low elevations often succumbs to introduced pests or diseases such as black twig borer or fungi such as *Fusarium* spp. For areas with a pronounced dry season, outplanting is typically scheduled at the onset of the rainy season. For areas that receive sufficient rainfall throughout the year, the spring (March or April) is an optimal time for outplanting.

At planting time, seedlings should be carefully removed from their containers and planted at the correct depth, with the ground even with the root collar. Soil should be firmed around the tree. Watering for the first few weeks after planting may be necessary if rainfall is insufficient. If possible, a weed barrier/mulch around the tree (kept several inches from the trunk) can aid in koa establishment. Koa is a hardy pioneer species, and survival is usually over 90% after outplanting on well prepared sites.

Spacing

Spacing for koa timber production is a much-debated topic, and no firm guidelines have been established. Mature, pure stands in plantations might support 100 trees/ha (40 trees/acre, equivalent to 10 x 10 m [33 x 33 ft] spacing). Plantations should be initially planted at a much denser spacing of 2 x 3 or 3 x 3 m (6.6 x 10 or 10 x 10 ft) to promote upright form and self-pruning of lower branches. Drawbacks to denser plantations are that they require earlier thinnings to maintain rapid tree growth and require a greater initial investment in seedlings. Mixed plantings of koa and slower-growing native trees such as ʻōhiʻa lehua and naio may promote self-pruning in the koa while avoiding the need for early thinnings.

Management objectives

Koa may be managed simultaneously for timber and wildlife habitat, watershed protection, and native forest restoration. Understory plantings with economically valuable

KOA WILT

Koa wilt is a common, fatal disease of koa and koaiʻa that is of major concern to growers. Leaves in the upper crown on affected trees rapidly wilt, turn yellow, and die while still on the tree. Occasionally only one branch will be affected, while at other times the entire tree will show symptoms. Sapwood of infected branches and roots usually shows a characteristic dark staining, and the roots may be killed. The tree's bark may develop cankers as the disease progresses. Defoliation of the crown progresses downward until the entire tree is killed, and small trees may succumb to the disease in as little as a few weeks. Koa wilt has been associated with infection of the vascular fungus *Fusarium oxysporum* f. sp. *koae* (Gardner 1980), although other species of *Fusarium* may also play a role. Infection by the fungus spreads upward from the roots and blocks conducting vessels in the branches and trunks of the trees, leading to canopy loss and death.

Planted stands at elevations below 760 m (2500 ft) are the most frequently affected, although koa wilt has been observed as high as 1650 m (5400 ft) (Anderson et al. 2002). Trees less than 15 years old are most often affected. Symptoms of the disease often become more severe after a period of environmental stress, such as drought. In some planted low elevation stands, 90% of the trees have died. The disease is found on Hawaiʻi, Maui, Oʻahu, and Kauaʻi.

The koa wilt fungus is probably a recent introduction to Hawaiʻi in the past few decades, and the future effects of the disease are difficult to predict. Field control of the disease with fungicides would probably be impractical. Some families of koa have shown less susceptibility to the disease than others, and research is underway to select resistant varieties for planting in disease-prone areas (J. Brewbaker, pers. comm.). Current recommendations for the grower are to avoid planting seed or seedlings from infected areas, as the fungus is seed-borne and soil-borne. Use of seed from select trees from nearby, natural stands of koa is probably the best way to avoid the disease. Seedlings should be raised in soilless media, and soil from infected areas should not be brought to the planting site. Shoes, tires, and tools should be well cleaned after leaving an infected area to remove any infected soil. Tools such as saws and machetes used in infected stands should be sterilized before being used elsewhere. Growers who plant koa in highly disease-prone areas (lands below 760 m [2500 ft] in elevation) should be prepared for high losses. In areas with no local koa populations, planting trees from several different seed sources may increase the likelihood of finding resistant trees. The presence of the pathogen will not necessarily cause disease. However, if conditions for infection are right and the pathogen is present, disease may occur.

Left: Crown of a tree infected with koa wilt, showing leaf yellowing and loss. PHOTO: S. NELSON **Right: Koa wilt attacking an experimental plantation and cut stem of an infected tree showing staining of the sapwood and cankers on the bark.** PHOTOS: J. B. FRIDAY

Left: Muriel and Kent Lighter show trees that were planted in circles of six to eight seedlings. After 5 years there are about 400 trees/acre, and the best trees will be released by thinning out the poorer trees. PHOTO: C. ELEVITCH **Right: Koa trees self-prune when grown in dense stands.** PHOTO: J. B. FRIDAY

native plants such as palapalai (*Microlepia strigosa*, an ornamental fern used in the hula), maile (*Alyxia oliviformis*, a scented vine), māmaki (*Pipturus albidus*, a native nettle used to make a medicinal tea), and pepeiao (*Auricularia*, an edible fungus) show promise. Koa plantations allow light to penetrate the canopy and usually support a grass understory, which may be grazed occasionally by livestock if care is taken to avoid damage to the trees (see section on silvopasture, below).

Plantation design considerations

Pests and diseases generally limit commercial koa plantings to higher elevations (above 600 m, 2000 ft) and mesic to wet sites. The tree does not do well in extremely wet sites (>5000 mm [200 in] precipitation) or on shallow or poorly drained soils. In Hawai'i, koa performs better on deep ash-derived soils than on lava soils, and better on 'a'ā (rough) lava soils than soils over pāhoehoe (sheet) lava. On mesic sites koa productivity is tied to water availability. Koa is an extremely variable species and it is crucial to obtain seed from superior trees for planting stock. Since populations are adapted to local environments, it is best to use locally obtained seed when available. Young koa plantations need to be protected from weeds, livestock, fire, and wind. As koa is a nitrogen-fixer, young koa stands do not respond to nitrogen fertilization but have in some cases responded to fertilization with phosphorus. Older koa stands may benefit from complete fertilizers.

Natural regeneration

Koa is both a rapidly growing, light-demanding pioneer tree that quickly colonizes open sites, and a long-lived tree that is part of mature forests. Koa naturally regenerates from buried "seed banks," seeds that have been buried in the soil for years or even decades. These germinate when the soil is exposed to sunlight and warmth, by natural means such as fire or windthrow of large trees, or artificial means such as scarifying or scraping the surface soil with a bulldozer (Scowcroft and Nelson 1976, Scowcroft and Wood 1976). Seed banks thus exposed will germinate rapidly but may only produce a single crop of seedlings if the scarification exhausts that seed bank. If seedlings regenerated from

a seed bank are destroyed, there are often no more viable seeds left in the soil. In some cases, however, seedlings regenerated after a fire have been destroyed, but subsequent bulldozer scarification has resulted in additional regeneration. Seed banks may not exist in very old pastures or may be viable only under the canopy of scattered overstory koa trees. Koa also regenerates from root sprouts, especially where shallow roots have been damaged by livestock.

Travis Idol observes koa root sprouts springing up after removal of cattle, Mauna Loa. PHOTO: J. B. FRIDAY

Natural forest management

Naturally regenerated stands of pure koa may have as many as 20,000 seedlings/ha (8100 seedlings/ac). These grow quickly, and the young seedlings may close canopy and form a solid stand in less than 10 years. Growth of individual trees slows thereafter, as the trees compete for growing space. Such "dog-hair" thickets of koa should be thinned and the best trees selected and released from competition. Young, vigorous trees with full crowns respond best to such release, but even trees as old as 25 years with some crown loss have grown faster after thinning (P. Scowcroft, P. Baker, pers. comm.) In order to avoid generating overly dense stands, some landowners have tried partial scarification in old pastures, only scraping the soil in lines or in patches across the landscape. "Row thinning," or mechanically clearing lines in dense stands, might also help to release the remaining trees.

Pure stands of koa that have developed on lava soils in wet sites at low elevations have sometimes briefly flourished but then ceased growing altogether and died out after 20 to 25 years.

Mature native forests contain diverse tree species and may have only a few koa trees per hectare. Koa will not regenerate in forest shade or even under its own sparse canopy, nor is it able to grow up through the canopy of other trees. Once a koa tree is overtopped by another tree, its growth ceases. In natural forests with only a few very large koa per hectare, koa probably depends on large tree-fall gaps to regenerate. Stands of young koa can be seen growing up adjacent to large ancient stumps left over from logging or huge stems that were toppled by storms. Silvicultural systems for koa forest regeneration can rely on natural regeneration through the seed bank, but enough light must reach the forest floor for young koa trees to grow. Harvesting systems in dense mixed-species forests where single trees are selected and cut are likely to result in "high-grading" or the removal of the koa from the forest rather than the regeneration of a healthy koa forest. "Group selection" systems where small patches of forest are cut so that enough light reaches the forest floor for koa to grow might be a way to regenerate koa forests without causing large-scale disturbances, but guidelines for using such systems in koa forests have not yet been developed. It is not known how large a gap must be created in order to regenerate healthy koa. Koa is also susceptible to wounding, and loggers need to work carefully to avoid injuring future crop trees. Larger clearcuts will regenerate dense stands of koa, but single-species, single-age stands that might be susceptible to insects and disease need to be thinned, as described above, if timber production is desired.

Alien invasive plant species can take over koa forests and prevent the regeneration of koa. Tropical ash (*Fraxinus uhdei*) in particular thrives in the same environment as koa and outcompetes the native trees for sunlight (Ares and Fownes 2001). Banana poka (*Passiflora tarminiana*) vines can smother young koa trees, but the weed is less of a threat since the introduction of a leaf spot fungus (Trujillo et al. 2001). At elevations below 1000 m (3300 ft), strawberry guava (*Psidium cattleianum*) completely occupies the understory of many forests and prevents regeneration. Strawberry guava also rapidly colonizes any gaps created by logging. Any sustainable harvesting plan for koa forests must include a plan to deal with the invasive species that will compete with koa. Loose cattle and sheep browse young koa seedlings, and most koa logging in Hawai'i has historically not resulted in healthy regeneration because

herbivores have continually eaten the seedlings as they appear.

Yields

Koa does not yield large volumes of timber per unit area, but low volumes may be made up for by the high value of the wood. Rotation ages for koa have been estimated at 30 to 50 years (and up to 80 years for veneer quality timber), although no one has managed koa stands from regeneration through to harvest, so these estimates of rotation age may be overly optimistic. It is not known how tree age or growth rate affects wood quality. Stem diameter increment may be up 0.7–1 cm (0.3–0.4 in) at first, although the diameter increment of individual stems slows drastically once the crowns close and individual trees compete with one another. In overly dense stands, diameter growth all but ceases. Dominant trees, those whose canopies are above their neighbors, may grow more than 1.7 cm (0.7 in) in diameter per year. Silvicultural treatments, including thinning, fertilizing, and controlling competing vegetation, should allow managers to maintain tree growth at high levels for a longer period. Pure stands on deep ash-derived or ʻaʻā soils with adequate rainfall might yield 90–180 m^3/ha (6.5–13 mbf/acre), while stands developed on shallow pāhoehoe soils and in areas with little rainfall would yield substantially less. Most koa, however, has been and continues to be harvested from mixed-species native forest or from large scattered trees in pastures, both of which yield much less timber per unit area than pure stands.

DISADVANTAGES

Potential for invasiveness

Koa is not generally planted outside its native range. However, as a fast-growing nitrogen-fixing tree, the potential for invasiveness outside Hawaiʻi may be high. There are a number of traits that mitigate against its invasive potential. It would probably not invade intact forests elsewhere in the tropics because it: 1) is very shade intolerant, 2) has no known dispersal agent except wind, 3) is not itself tolerant of fire, 4) is fed on by many vertebrate and invertebrate herbivores, and 5) is susceptible to diseases common to the tropics (Scowcroft, pers. comm.). It would not survive in temperate regions due to freezing temperatures or low rainfall.

Susceptibility to pests/pathogens

Many diseases and pests affect koa, particularly at elevations below 610 m (2000 ft). In lowland areas where koa has been planted, there has been up to 80–100% mortality due to various pests and pathogens, particularly fungi. Animals such as horses, cattle, goats, and pigs are also a very common source of high seedling losses and damage to trees less than 10 years old.

Host to crop pests/pathogens

Koa hosts black twig borer (*Xylosandrus compactus*), a pest that also affects coffee, citrus, cacao, mango, macadamia, and other crop and timber trees such as mahogany and eucalyptus species.

Other disadvantages or design considerations

Koa's aggressive surface root system can compete with crops and disrupt underground utility lines. Shallow root systems are also easily damaged by machinery or foot traffic. Koa trees must be given a wide berth, a minimum of 10–12 m (33–39 ft) for mature trees.

AGROFORESTRY/ENVIRONMENTAL PRACTICES

Soil stabilization

Koa establishes quickly on degraded sites and its extensive root systems aid in soil stabilization.

Crop shade/overstory

Koa casts a light shade that is compatible with many herbaceous understory plants. However, due to koa's extensive surface root system, this tree is preferably planted on borders of other plantings, where competition and root damage to the koa trees are minimized.

Improved fallow

As a nitrogen-fixing tree, koa is a good candidate for improving fallow land.

Windbreaks

Koa tolerates wind poorly but can be planted as part of a multi-row windbreak. Because it has a very sparse crown and is easily deformed by wind, it is recommended that very wind-tolerant species be planted in rows on either side of a row of koa.

Silvopasture

Koa leaves are highly palatable to livestock, and browsing can injure and kill trees. Weaning calves or horses may be temporarily grazed under koa if there is a good grass crop; however, the animals must be closely supervised to ensure they do not damage the koa trees. Mature cows will push down small koa trees to consume their leaves. If livestock

are left too long in pastures with koa or left in during dry periods, they may strip the bark from the trees to get at its moisture. Livestock also easily damage roots of koa, especially in shallow soils. Horses have proven less damaging to koa, although some horses relish the taste of koa leaves and bark. Grazing under koa may help lessen the competition from the grass for water and nutrients and may lessen the fuel buildup and the chance of fire.

Animal fodder

Prunings have been used as cut-and-carry fodder for horses, although this might not be advisable because horses develop a taste for the leaves, twigs, and bark. Horses with a taste for koa will quickly eradicate any seedlings or saplings in areas to which they have access.

Native animal/bird food

Koa is considered to be an important habitat for insects that are food for native birds. Native (and exotic) insects feed on koa flower nectar, flower parts, foliage, cambial tissue, seeds, and probably other tissues as well.

Wildlife habitat

Many native Hawaiian birds depend on koa forests directly or indirectly for habitat. Large old trees provide important nest sites. Commonly seen birds include the red ʻapapane (*Himatione sanguinea*) and ʻiʻiwi (*Vestiaria coccinea*), the yellow ʻamakihi (*Loxops virens*), and the inquisitive ʻelepaio

Koa casts a light shade (23-year-old koa trees at Keauhou Ranch, Kaʻū, Hawaiʻi). PHOTO: J. B. FRIDAY

Dying and dead koa trees in pasture. PHOTO: C. ELEVITCH

(*Chasiempis sandwichensis*). The endangered ʻakiapōlāʻau (*Hemignathus munroi*), a species of honeycreeper, eats insects found in the bark and rotting wood of koa trees and is found in both young and old koa stands. Koa forests are also the home of the endangered Hawaiʻi ʻākepa (*Loxops coccinea*) and the Hawaiʻi creeper (*Oreomystis mana*). In 1985, the Hakalau Forest National Wildlife Refuge was established on the slopes of Mauna Kea on the island of Hawaiʻi primarily to protect habitat for native forest birds. The refuge has been reforesting former cattle pasture since then and has planted hundreds of thousands of koa seedlings.

Bee forage

Koa flowers provide pollen and nectar for bees.

Ornamental

Koa makes a spectacular ornamental, although there are pest and disease concerns below 610 m (2000 ft).

ʻAkiapolaʻau on koa branch. PHOTO: J. JEFFREY

Modern day koa racing canoe (outrigger detached on right) named Lanakila Mau O Ka Lōkahi. PHOTO: J. B. FRIDAY

USES AND PRODUCTS

Medicinal

The leaves and ashes have been used medicinally by Hawaiians (Krauss 1993).

Timber

Koa is an extremely important timber tree in Hawaiʻi. For more information, see the "Wood quality" sidebar.

Fuelwood

Formerly, before its timber value was recognized and supplies became scarce, koa was used as firewood.

Craft wood/tools

Ancient Hawaiians used koa for calabashes (ʻumeke lāʻau), canoe paddles, spears, and surfboards (Krauss 1993, Abbott 1992). Koa was not the preferred wood for calabashes to be used for food because it imparted a bitter taste. Today, koa wood is the basis of a flourishing crafts industry in Hawaiʻi.

Canoe/boat/raft

Koa was traditionally used for canoes (waʻa), from one-person fishing canoes to the huge voyaging canoes that could sail between islands and across vast expanses of ocean. In ancient times, the cutting of a forest giant with stone tools to make a canoe was an undertaking of several days for many men, involving many ceremonies and prayers. When a log was felled, it is said that the men watched for a sign from the ʻelepaio bird. If the bird landed on the log and pecked at it, the log would be abandoned. Today, large "canoe koa" have all but disappeared. A single koa log large enough for a traditional Hawaiian voyaging canoe should be 10–14 m (35–45 ft) long and 120 cm (48 in) in diameter along the entire length of the log. Shorter logs may be spliced together to make larger canoes. Smaller logs of 75–90 cm (2.5–3 ft) in diameter are used for racing or fishing canoes. Canoe carving is a living tradition in Hawaiʻi

and koa canoes are still used in races, especially on the island of Hawai'i.

Tannin/dye

Tannin from koa bark has been used to make a red dye for kapa cloth (traditional bark cloth) (Krauss 1993).

Ceremonial/religious importance

The name "koa" also means "warrior" in Hawaiian and the tree is very important in Hawaiian culture.

URBAN AND COMMUNITY FORESTRY

A treasured Hawaiian tree, koa can be grown in home and public landscapes with large open spaces. At lower elevations, or sites with limited space, koa's close relative koai'a is often a more suitable alternative.

Size in an urban environment

In a landscape koa generally grows to 6–15 m (20–50 ft) in height. When grown in the open, the canopy spread is often wide, about half the height of the tree. In other words, a large open area is required. For small areas, koai'a is an excellent alternative, with its more compact form.

Rate of growth in a landscape

Koa growth can be very rapid, greater than 3 m (10 ft) in the first year and more than 1.5 m (5 ft) for the next few years, considering the following measures are taken.

- Only healthy, rapidly growing seedlings should be planted, not root-bound trees whose growth has been slowed by the container size.
- Seedlings should have been inoculated with rhizobia bacteria within 4 weeks of germination.
- Koa should be planted well away from grassy areas, including lawns.

Left: Damage to surface roots and trunk causes undue stress. Right: In the right conditions, and with proper care, koa trees can live many years in a landscape, Volcanoes National Park, Hawai'i island. PHOTOS: C. ELEVITCH

- Grass and weeds should be suppressed within the seedling's root zone, preferably by hand-weeding and mulching.
- Foot and machine traffic near the tree should be avoided.
- Common maintenance pitfalls such as weed whacking the bark of the tree or spraying herbicide on the leaves or exposed surface roots should be strictly avoided.

Root system

The surface roots are often partially exposed, especially in rocky soils. Foot and machine traffic can easily damage the roots and cause the tree to suffer over the long term. It is best to plant the trees in marginal areas (slopes, buffer areas, etc.), where there is no traffic. When the roots are injured or the tree is cut down, some trees send up suckers from the root system within a wide ring around the tree. Although the surface roots are unlikely to lift concrete pathways or other human structures, koa's intrusive root system may be damaging to underground utilities.

Products commonly used in a Pacific island household

Wood is the primary product derived from koa trees. A mature healthy tree in a landscape can be quite valuable for its wood if allowed to grow for 30 years or longer.

Light requirements

Although small seedlings can tolerate light shade, best health and vigor is attained with full sunlight for the life of the tree.

Water/soil requirements

Koa requires freely draining soils. Standing water or waterlogging is detrimental to tree health. Overwatering should be avoided.

Expected life span in a homegarden

Since most people in Hawai'i live below the minimum recommended elevation of 610 m (2000 ft) for koa, homegarden plantings of koa are often subject to various pests and diseases that can greatly shorten their lives. It is common for koa trees to die at an age of 5–20 years, or even younger in areas where koa wilt is present. Risks can be minimized if measures are taken to support tree health (see "Rate of growth in the landscape" above).

Varieties favored for use in homegardens

It is best to plant trees grown from seeds that were collected from the nearest natural population. This gives reasonable assurance that the trees are adapted to the local climate and soils, while also conserving local native germplasm.

HAWAIIAN SAYINGS (PUKUI 1983)

E ola koa.
"Live like a koa tree."
(Live a long time, like a koa tree in the forest.)

Ka ulu koa i kai o Oneawa.
"The koa grove down at Oneawa."
(From the legend of Hi'iaka. Canoes are sometimes referred to as the koa grove at sea.)

Seasonality of leaf flush, flowering, fruiting

In many areas, koa flushes with new growth nearly year-round, slowing during dry or cool periods. Flowering takes places throughout the year in some areas and is strongly seasonal in others.

Transformation of bark from smooth to rough. PHOTO: C. ELEVITCH

Exceptional ornamental values

Silver-green foliage distinguishes koa in the landscape. Its light yellow "puff-ball" flowers (inflorescences) are borne in sprays that are modestly showy. The bark of young trees is smooth, and often covered with an attractive bright orange-red lichen (harmless to the tree). At an age of about 8–10 years, the bark becomes fissured, rough, light to dark brown, and often hosts silvery lichens (also harmless).

Use as living fence, hedge or visual/noise barrier

Koa is not suitable as a living fence, as this would require attaching fencing to the trunk, which injures the tree and greatly diminishes any future timber value (due to pieces of metal potentially left in the wood). Koa does not tolerate trimming well, which would be required for a hedge.

Birds/wildlife

Koa flowers provide pollen and nectar for various insects, including bees. In or near native forest, koa hosts numerous native Hawaiian insects and birds.

Maintenance requirements

Mulching with leafy materials such as grass clippings, hedge trimmings, chipped tree trimmings, etc. is highly recommended to suppress weeds, conserve soil moisture, and protect koa's surface roots. Because of its association with nitrogen-fixing bacteria, koa does not benefit from nitrogen fertilizer; however, applying phosphorous fertilizer can be beneficial. Pruning is not recommended, as limb cuts provide easy access to fungi and borers.

Special considerations regarding leaf, branch, and fruit drop

The tree can grow tall, so it should not be planted near overhead utility lines or structures.

Nuisance and hazards

None.

Common pest problems

Common pests include pathogenic fungi and twig borers. Avoiding overwatering and damage to roots, trunk, and branches may reduce the risk of attack by pathogenic fungi. Twig borers tend to attack seasonally, usually during dry periods, and healthy trees recover. Trees also can recover from light seasonal damage by whitefly, beetles, thrips, scale insects, Chinese rose beetle, and mites. Leafhoppers that cause defoliation and stippling of the leaves can be treated with soapy water.

Cabinet of curly koa by Marian Yasuda. PHOTO: H. LUM

Other comments about this species in urban environments

Because of koa's particular susceptibility to pests and diseases below 610 m (2000 ft) elevation, it may die prematurely. Even though most people in Hawai'i live below its recommended minimum elevation, koa's fast growth and beauty make it well worth growing in landscapes. The benefits of growing this highly valued Hawaiian tree far outweigh the risks, even if the tree only lives a few years in a particular location. Most people in Hawai'i never see koa trees, and even young koa trees planted in local communities and urban settings give people an opportunity to become familiar with one of the most important trees of the Hawaiian forest.

WOOD QUALITY

(by C. Barton Potter)

Koa wood variability

Koa is Hawai'i's premier timber tree. From area to area and tree to tree, koa wood varies mechanically in density, specific gravity, drying and machining qualities, and many other characteristics. Koa is not a particularly dense wood, with specific gravity averaging 0.55 for wood air-dried to 12% moisture content and a density of 609 kg/m^3 (38 lb/ft^3) (Skolmen 1974). Visually, the wood is strikingly variable across a spectrum of color and figure. A strong correlation exists between economic value and visual attractiveness.

A native Hawaiian timber

Koa wood is revered and valued as much for its strong association with its native Hawai'i as for its appearance. Koa's status as the largest and second most common native tree has ensured its use by people in a wide number of applications. However, many decades of land management favoring agriculture and livestock, exacerbated by the success of numerous competitive alien species, has displaced koa and hindered it from naturally regenerating in much of its native range. While logging has contributed to diminishing koa populations, the state of koa resources today is primarily due to the lack of regeneration. High-quality logs have become scarce on the market, which has elevated the value of the wood and put practical limits on wood applications. The best logs are being directed to high-yield, high-return applications such as veneers, high-end furniture, and musical instruments. Makers of products that consume large volumes of wood, such as solid koa furniture or canoes, are finding it increasingly challenging to locate affordable koa wood. A market thrives for craft items made from small-dimension wood such as branches, stumps, and cutoffs.

Chatoyance

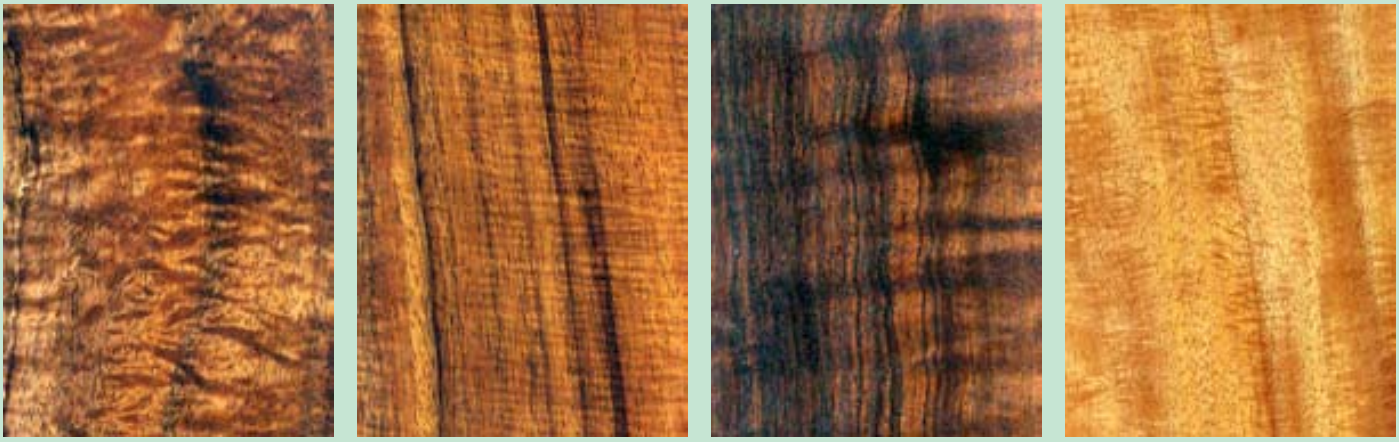
Koa wood is generally known for its red to brown color and for its light-refractive characteristics, known as chatoyance. This attribute can lend a hologram-like effect to finished wood surfaces, adding to the visual allure of koa items.

Kiln drying

Because it shrinks nearly equally in radial and tangential directions, koa can be kiln dried more easily than many other types of wood. Boards with runout (end-grain on the face of the board), pith defect, rot, and other anomalies can warp, cup, or twist if drying is too rapid. Best results are always obtained when a single species is dried at a time, allowing the kiln schedule to be tailored specifically to the wood being dried. In other words, koa wood should be dried by itself in the kiln.

Milling, cutting, and sanding

When green, koa wood cuts readily with sharp saws or chisels. This is one reason sawmillers prefer to mill logs green and bowl turners prefer to turn the wood while it is still green—both boards and roughed-out bowls are easier to season properly than whole logs. When dry, koa wood is not unusually dulling to hand tools, but it does contain tannins that under the tip of all but the sharpest of high speed tools can cause blackening or burning of the surface being cut. The tannic exudate can build up just behind the tool tip, increasing friction and drag, resulting in charring that can be hard to sand out. The sharper the tool, the less this happens; therefore, sharpness is a must when cutting with high-speed tools. The same can be said for sanding: the sandpaper must be clean and the grit sharp or a charring effect may occur that is easier to avoid than to remove by sanding a second time. Koa planes easily, although there can be problems with tearout of curly grain. Sanding versus planing is the preferred method of reducing the thickness of a board that has curly grain.



Left to right: Blister figure, curl with color banding, dark light curl, plain with light flame. PHOTOS: C. B. POTTER

COMMERCIAL PRODUCTS

Processing required

Milling is required for production of koa wood products such as lumber, veneer, molding, or flooring. Because of the high value of koa wood, small-scale milling in the field with a portable mill is often feasible and economically viable, although it typically yields a smaller percentage of usable wood than large, fixed mills.

Markets

Markets exist in Hawai'i, the mainland United States, and the Far East. Koa veneer is produced in California from wood shipped from Hawai'i. Koa stumpage (the amount paid to a landowner for the right to harvest trees) in Hawai'i was approximately $700–840/m^3 ($2500–3000/mbf) in the late 1990s and early 2000s, up from less than a tenth of that a decade previously. Finished koa lumber in Hawai'i retails at prices from $4.50 per board foot for yellow, straight-grained wood (#2 common) to $65.00 and up per board foot for finely figured, curly, dark red wood.

Furniture made from koa is the main product of Hawai'i's $30 million/year forest industry (Yanagida et al. 2004) Gradual, sustained harvest of koa helps maintain Hawai'i's local furniture and craft industry, while harvesting large quantities for export has led to rapid boom and bust cycles.

INTERPLANTING/FARM APPLICATIONS

For many reasons, koa is a difficult tree to integrate with other crops, livestock, or farm activities. However, in certain situations and with careful planning and management, it can form a component in a diverse farm system.

Despite massive planting efforts in the 1920s and 1930s, when over a million koa trees were planted in the forest reserves (Nelson 1965), there are few successful koa plantations today. None have been grown through to harvest, nor has much natural koa forest been managed for timber. Interest in koa forest management increased greatly with the skyrocketing of koa prices in the 1990s, and now many landowners are again experimenting with plantations and forest management plans.

Potential drawbacks of interplanting

Koa's aggressive surface root system is very competitive with crops. Trees become large, and must be afforded plenty of light and space. The area must be fenced to preclude losses from cattle, sheep, goats, and pigs. Due to pests and diseases, koa is generally only suitable for areas with higher elevation than where most crops are grown.

Example system 1

Location

Honokōhau, Kona, Hawai'i (1380–1830 m [4500–6000 ft]).

Description

Downed and sickly trees were harvested for their timber in a cattle pasture. After the harvest, the cattle were removed, and koa regenerated prolifically from the buried seed bank, particularly in areas where the machinery used for harvest operations disturbed the soil surface.

Yields/benefits

After koa seedlings began growing in thickly, weaning calves were introduced to thin the dense, regenerating stands during the first 2 years of establishment. The calves were carefully monitored by an experienced rancher so they did not run short of low-growing seedlings and begin consuming larger seedlings. After several years of growth, cattle and horses have been allowed into the area for brief periods to graze the undergrowth.

Spacing

The initial density of regrown koa seedlings was 1200–5000 trees/ha (500–2000 trees/acre), which will be reduced to a final density of less than 125 trees/ha (50 trees/acre).

Honokōhau koa with understory maintained for brief periods by cattle and horses. PHOTO: C. ELEVITCH


Left: Koa boundary for coffee orchard. Right: 23-year-old koa regeneration at Keauhou Ranch, Hawai'i. PHOTOS: C. ELEVITCH

Example system 2

Location

Hōlualoa, Kona, Hawai'i (640 m [2100 ft]).

Description

In a newly planted coffee plantation, koa was planted in marginal areas such as on rocky and steep slopes, and along boundaries where coffee cultivation was untenable.

Yields/benefits

The koa is a long-term timber in areas that have marginal value for crops requiring intensive cultivation.

Spacing

Single rows have a spacing of about 3 m (10 ft) between trees, with about 9 m (30 ft) spacing from coffee trees.

Example system 3

Location

Keauhou Ranch, Volcano, Hawai'i (1600 m [5250 ft]).

Description

Degraded forest with remnant large koa was logged, and residual vegetation was bulldozed to scarify the soil in 1978. Grazing animals were kept out, but no other management was done. Koa regeneration from the buried seed bank was prolific. After 23 years, a pure koa overstory of basal area 26 m^2/ha and 17 m (56 ft) height had developed, with the best trees reaching 20–30 cm (8–12 in) dbh. Nine other native tree species had established from seed spread from nearby native forest.

Spacing

Initial densities of 20,000 seedlings/ha (8100 seedlings/ac) were observed. Trees naturally thinned to 1000 stems per ha (400/acre) after 23 years. The target spacing of eventual crop trees is 10 x 10 m (33 x 33 ft), or 100 trees/ha (40 trees/acre).

Acacia koaia (koai‘a)

Koai‘a (*Acacia koaia*) is a close relative of koa that is native to the islands of Kaua‘i, Moloka‘i, Lāna‘i, Maui, and Hawai‘i. Koai‘a and koa are so closely related that there is controversy among taxonomists as to whether they are different species. For the purposes of this discussion they are treated as distinct species. Koai‘a is much more compact in size than koa, often having a bushy, gnarled, or even horizontal growth habit. Koai‘a grows well in harsher conditions than koa: dry, windy, and open. The tree’s size and tolerance for harsher conditions make it more suitable for most urban environments than koa.

Characteristics

Koai‘a is a small tree, rarely taller than 5 m (16 ft), with a domed canopy that is usually about as wide as the tree is tall when grown in the open. The phyllodes (mature “leaves”) are generally narrower, shorter, and straighter than those of koa, although there is tremendous variation. The inflorescence is similar to koa, but the seedpods are narrower with seeds longitudinally arranged instead of transversely as in koa. Seeds are similar in appearance to koa seeds, although they are considerably smaller than seeds produced by most koa trees. The wood is harder, denser, and more finely grained than koa wood.

Propagation

Koai‘a is propagated from seed, using methods identical to those used for koa.

URBAN AND COMMUNITY FORESTRY

Koai‘a makes a wonderful addition to urban and public landscapes, and should be used instead of koa where a compact tree is needed, or in harsher, drier environments than are recommended for koa.

Size in an urban environment

In a landscape koai‘a generally grows to 5 m (16 ft) tall. In the open, the canopy is often wide and domed, often with a diameter as wide or wider than the tree is tall. Some trees have a tendency to spread laterally, with a squat form and horizontal branches.

Rate of growth in a landscape

In an optimal environment koai‘a can grow rapidly for the first few years. Growth in height of 1–1.5 m (3.3–5 ft) per year for the first 2 years is common. After this, growth in

Top: Remnant koai‘a trees growing in open, dry area, North Kohala, Hawai‘i. Middle: Koai‘a leaves and flowers. Bottom: Koa seeds are arranged transversely in the seedpod (above), while koai‘a seeds are arranged longitudinally (below). This is one of the identifying traits of koai‘a. PHOTOS: C. ELEVITCH

Acacia koaia (koai‘a)

height slows down, the canopy broadens, and the stem(s) increase in diameter. Cautions for proper care of koai‘a in the landscape are the same as for koa.

Root system

As with koa, koai‘a has a strong lateral root system, which is often partially exposed on the surface, especially in rocky soils. Any kind of traffic can injure the roots and stress the plant. It is best to plant the tree in areas with limited or no traffic. Herbicide use under the tree should be avoided, as it could make direct contact with exposed roots and be taken up by the tree. Instead, mulching or a living ground cover of herbaceous plants are ideal for use under koai‘a trees.

Products commonly used in a Pacific island household

The wood is much harder than koa and was used by Hawaiians for tools, fishhooks, spears, and canoe parts. When the trees were readily available, they were used for durable fence posts. Today, the rare wood is used for gun stocks, knife handles, bowls, and artwork.

Light requirements

Full sun is best for rapid growth and plant vigor. However, trees that receive light shade during part of the day can grow well.

Water/soil requirements

As with koa, koai‘a requires freely draining soils. Standing water, waterlogging, and over-watering are also detrimental.

Expected life span in a homegarden

In optimal conditions, koai‘a trees can be expected to grow many decades. Although koai‘a is more tolerant of harsh conditions than koa, there have been reports of trees dying at an age of 10–12 years from unknown causes, and at 4 years due to koa wilt.

Varieties favored for use in homegardens

There are no varieties described. For native plants such as koai‘a, it is best to use seeds that were collected from the nearest natural population. This means that residents of Moloka‘i, Lāna‘i, Maui, and Hawai‘i should use seeds originating from natural stands on their islands.

Seasonality of leaf flush, flowering, fruiting

The tree grows continually except during dry periods. Koai‘a flowers year-round in many areas, with a peak in the fall. However, seed set is sporadic. In wetter climates, seed quality is often very poor, whereas in drier climates the seed quality can be very high.

Exceptional ornamental values

Koai‘a foliage is somewhat more gray-silver than koa, and

Left: Twelve-year-old koai‘a tree growing along path at Amy Greenwell Ethnobotanical Garden, Kealakekua, Hawai‘i. Right: When grown in a lawn, koai‘a and koa become spindly and stressed. PHOTOS: C. ELEVITCH

very attractive in the landscape. Because the tree is short, the yellow flowers are more visible that koa's and can be modestly showy. As with koa, the tree trunk is often covered with an attractive and harmless orange lichen. As the tree ages, a gnarled trunk and network of branches often becomes exposed through gaps in the canopy.

Use as living fence, hedge or visual/ noise barrier

With its short size and domed canopy, koai‘a can be used as a hedge tree. However, there are two caveats. First, koai‘a trees are highly variable in size, shape, leaf size, and color shade, etc., so a uniform hedge cannot be expected. Second, pruning is not recommended due to the risk of increasing the plant's susceptibility to insect or disease attack. This means that a koai‘a hedge should not be trimmed to a uniform shape.

Birds/wildlife

Koai‘a flowers provide pollen and nectar for various insects, including bees.

Maintenance requirements

Maintenance requirements are the same as for koa.

Special considerations regarding leaf, branch, and fruit drop

None.

Hazards and nuisance issues

None.

Common pest problems

The pests that affect koai‘a are the same as those for koa. It is said that koai‘a is less susceptible to Chinese rose beetle than koa, although it may be more prone to scale insects and mealybugs.

Top: Gnarled framework of old koai‘a tree, Pu‘u o kali, Maui. PHOTO: FOREST AND KIM STARR **Bottom: Hedge of koai‘a along property boundary, Kailua-Kona, Hawai‘i.** PHOTO: C. ELEVITCH

Other comments about this species in urban environments

Koai‘a is often a better choice than koa in landscaping due to its smaller size and tolerance for harsher, drier conditions. However, as with koa, the tree is susceptible to diseases, including koa wilt, which may shorten its life considerably. Even so, it is well worth planting this rare tree in Hawaiian landscapes.

PUBLIC ASSISTANCE AND AGROFORESTRY EXTENSION

Several government agencies offer assistance with forest establishment and conservation, including the following.

The Cooperative Extension Service (CES) of the University of Hawai'i can assist landowners with questions relating to koa. It has an excellent web site for forestry, including many valuable publications, forestry news, and an extensive list of forestry links for Hawai'i.

Extension Forester
College of Tropical Agriculture and Human Resources
University of Hawai'i at Mānoa
Komohana Agricultural Complex
875 Komohana St., Hilo, HI 96720
Tel: 808-959-9155; Fax: 808-959-3101
Web: http://www.ctahr.hawaii.edu/forestry

The Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service, provides assistance with conservation practices such as windbreaks and contour plantings. They also support various cost-share programs to increase the supply of timber products from private forest lands and to aid in the establishment of native species. The NRCS has offices throughout the USA, including Hawai'i and the American-affiliated Pacific.

NRCS State Office
P.O. Box 50004
Honolulu, HI 96850-0050
Tel: 808-541-2600
Fax: 808-541-1335 or 541-2652
Web: http://www.hi.nrcs.usda.gov

The Hawai'i Forest Industry Association (HFIA) is dedicated to responsible forest management. It offers an annual woodworking exhibition, sponsors the Hawai'i's Wood trademark, and serves as an advocate for Hawai'i's diverse forest industry—from tree planting and harvesting to creating and selling wood products.

Hawai'i Forest Industry Association (HFIA)
P. O. Box 10216
Hilo Hawai'i 96721
Street address:
162 Kino'ole Street, #101
Hilo, Hawai'i 96720-2816
Tel: 808-933-9411; Fax: 808-933-9140
E-mail: info@hawaii-forest.org
Web: http://www.hawaii-forest.org/

The Forest Stewardship Program is one of many programs offering financial assistance for landowners who are investing in forests. PHOTO: C. ELEVITCH

The University of Hawai'i College of Tropical Agriculture and Human Resources maintains a Hawai'i Forestry Extension Incentive Programs web page entitled, "Government Incentive Programs for Tree-Planting or Forest Management on Private Lands" at: http://www.ctahr.hawaii.edu/forestry/Data/incentives.html

BIBLIOGRAPHY

(☛ indicates recommended reading)

Abbott, I.A. 1992. Lā'au Hawai'i—Traditional Hawaiian Uses of Plants. Bishop Museum Press, Honolulu.

Anderson, R.C., D.E. Gardner, C.C. Daehler, and F.C. Meinzer. 2002. Dieback of *Acacia koa* in Hawai'i: ecological and pathological characteristics of affected stands. Forest Ecology and Management. 162: 273–286.

Ares, A., and J.H. Fownes. 1999. Water supply regulates structure, productivity, and water use efficiency of *Acacia koa* forest in Hawaii. Oecologica 121: 458–466.

Ares, A., and J.H. Fownes. 2001. Productivity, resource use, and competitive interactions of *Fraxinus uhdei* in Hawaii uplands. Canadian Journal of Forest Research 31: 132–142.

Ares, A., J.H. Fownes, and W. Sun. 2000. Genetic differentiation of intrinsic water-use efficiency in the Hawaiian native *Acacia koa*. International Journal of Plant Sciences 161(6): 909–915.

☛ Bornhorst, H.L. 2005. Growing Native Hawaiian Plants—A How-to Guide for the Gardener, rev. ed. The Bess Press, Honolulu.

Conkle, M.T. 1996. Isozyme studies of genetic variability. In: Ferentinos and Evans, op. cit.

Conrad, C.E., D.M. Fujii, and H. Ikawa. 1995. Seed source and performance in koa tree establishment. pp. 88–89. In: Proceedings of Hawaii Agriculture: Positioning for

Growth, April 5 and 6, 1995. Hawaii Farm Bureau Federation and University of Hawaii College of Tropical Agriculture and Human Resources, University of Hawai'i Mānoa, Honolulu.

Constantinides, M. 2003. Growth dynamics of 16 tree species on 42 long-term growth plots in Hawaii. Hawai'i Department of Land and Natural Resources, Division of Forestry and Wildlife, Honolulu. <http://www.state.hi.us/dlnr/dofaw/pubs/index.html>.

Culliney, J.L., and B.P. Koebele. 1999. A Native Hawaiian Garden: How to Grow and Care for Island Plants. University of Hawai'i Press, Honolulu.

Daehler, C.C., M. Yorkston, W. Sun, and N. Dudley. 1999. Genetic variation in morphology and growth characters of *Acacia koa* in the Hawaiian Islands. International Journal of Plant Sciences 160(4): 767–733.

Dalla Rosa, K. 1994. *Acacia koa*—Hawaii's most valued native tree (NFTA 94–08). Nitrogen Fixing Tree Association, Morrilton, Arkansas. <http://www.winrock.org/forestry/factpub/factsh/akoa.htm>.

Dudley, N., and R. Hauff. Undated. Forest Health Alert: Koa Wilt Fact Sheet. <http://www.ctahr.hawaii.edu/forestry/Data/Research/KoaWiltAlert.pdf>.

☛ Ferentinos, L., and D.O. Evans (eds.). 1997. Koa: A Decade of Growth. Proceedings of the 1996 Annual Symposium held by the Hawai'i Forest Industry Association (HFIA), November 18–19, 1996. HFIA, Hilo, Hawai'i.

Friday, J.B. 2000. *Acacia koa*. In: Global Forestry Compendium. CAB International, Oxford, UK.

Gardner, D.E. 1980. *Acacia koa* seedling wilt caused by *Fusarium oxysporum* f. sp. *koae,* f. sp. *nov.* Phytopathology 61: 1377–1381.

Gardner, D.E. 1996. *Acacia koa*: A review of its diseases and associated fungi. In: Ferentinos and Evans, op. cit., pp. 56–63. <http://www.botany.hawaii.edu/faculty/gardner/diseases/koa%20diseases%20and%20associated%20fungi/koa%20diseases%20and%20associated%20fungi.html>.

Grace, K.T. 1995. Analysis and prediction of growth, grazing impacts, and economic production of *Acacia koa*. Ph.D. dissertation. University of Hawai'i, Honolulu.

Handy, E.S.C., and E.G. Handy. 1972. Native Planters of Old Hawaii: Their Life, Lore, and Environment. Bishop Museum Press, Honolulu.

Harrington R.A., J.H. Fownes, F.C. Meinzer, and P.G. Scowcroft. 1995. Forest growth along a rainfall gradient in Hawaii: *Acacia koa* stand structure, productivity, foliar nutrients, and water- and nutrient-use efficiencies. Oecologia 102: 277–284.

Krauss, B.H. 1993. Plants in Hawaiian Culture. University of Hawai'i Press, Honolulu.

☛ Little, E.L., and R.G. Skolmen. 1989. Common Forest Trees of Hawai'i (Native and Introduced). Agriculture Handbook 679. USDA Forest Service, Washington, DC.

Loudat, T.A., and R. Kanter. 1996. The economics of commercial koa culture in Hawaii. In: Ferentinos and Evans, op. cit., pp. 124–147.

☛ Mueller-Dombois, D., and R. Fosberg. 1998. Vegetation of the Tropical Pacific Islands. Springer-Verlag, New York.

Nelson, R.E. 1965. A record of forest plantings in Hawaii. USDA Forest Service Resource Bulletin PSW-1. Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

☛ Nelson, S.C., and J.B. Friday. 2006. Koa (*Acacia koa* Gray) Pest and Disease Image Gallery. Online quick reference for Hawai'i's koa growers. University of Hawai'i at Mānoa, Honolulu. <http://www2.hawaii.edu/~snelson/koa/>.

Pukui, M.K. 1983. 'Ōlelo No'eau: Hawaiian Proverbs & Poetical Sayings. Bishop Museum Press, Honolulu.

St. John, H. 1979. Classification of *Acacia koa* and Relatives (Leguminosae). Hawaiian Plant Studies 93, Pacific Science 33(4): 357–367.

Scowcroft, P.G., and J. Jeffrey. 1999. Potential significance of frost, topographic relief, and *Acacia koa* stands to restoration of mesic Hawaiian forest on abandoned rangeland. Forest Ecology and Management 114: 447–458.

Scowcroft, P.G., and R.E. Nelson. 1976. Disturbance during logging stimulates regeneration of koa. USDA Forest Service Research Note PSW-306. USDA Forest Service, Berkeley, California.

Scowcroft, P.G., and H.B. Wood. 1976. Reproduction of *Acacia koa* after fire. Pacific Science 30(2): 177–186.

Shi, X. 2003. Genetic improvement of *Leucaena* spp. and *Acacia koa* Gray as high-value hardwoods. PhD. Dissertation. College of Tropical Agriculture and Human Resources, University of Hawai'i, Honolulu.

Skolmen, R.G. 1986a. Acacia (*Acacia koa* Gray). In: Y.P.S. Bajaj (ed.). Biotechnology in Agriculture and Forestry, Vol. I, Trees. Springer-Verlag, Berlin.

Skolmen, R.G. 1986b. Where can koa be grown. In: Proceedings, Resource Conservation and Development (RC&D) Koa Conference. RC&D with DLNR/DOFAW and USDA FS, Hilo, Hawai'i.

Skolmen, R.G. 1974. Some woods of Hawaii: properties and uses of 16 commercial species. Pacific Southwest Forest and Range Experiment Station, United States Department of Agriculture, Forest Service. Technical Report PSW 8/1974.

Skolmen, R.G., and M.O. Mapes. 1978. Aftercare procedures required for field survival of tissue culture propagated *Acacia koa*. International Plant Propagators' Society Combined Proceedings, Vol. 28.

Staples, G.W., and D.R. Herbst. 2005. A Tropical Garden Flora: Plants Cultivated in the Hawaiian Islands and other Tropical Places. Bishop Museum Press, Honolulu.

Stein, J.D. 1983. The biology, host range, parasites, and hyperparasites of koa seed insects in Hawaii: A review. Proceedings, Hawaiian Entomological Society, 24(2&3): 317–326.

Stein, J.D., and P.G. Scowcroft. 1985. Growth and refoliation of koa trees infested by the koa moth, *Scotorythra paludicola* (Lepidoptera: Geometridae). Pacific Science 38(4): 333–339.

Sun, W. 1996. Genetic Improvement of *Leucaena* and *Acacia koa.* PhD. Dissertation. College of Tropical Agriculture and Human Resources, University of Hawai'i, Honolulu.

Sun, W., J.L. Brewbaker, and M.T. Austin. 1996. Genetic variations of *Acacia koa* seed, seedling, and early growth traits. In: Ferentinos and Evans, op. cit., pp. 33–38.

Trujillo, E.E., C. Kadooka, V. Tanimoto, S. Bergfeld, G. Shishido, and G. Kawakami. 2001. Effective biomass reduction of the invasive weed species banana poka by *Septoria* leaf spot. Plant Disease 85: 357–361.

☛ Wagner W.L., D.R. Herbst, and S.H. Sohmer. 1999. Manual of the Flowering Plants of Hawai'i, rev. ed. University of Hawai'i Press, Honolulu.

Walker, R. 1986. Koa and wildlife—an enduring relationship. In: Proceedings, Resource Conservation and Development (RC&D) Koa Conference. RC&D with DLNR/DOFAW and USDA FS, Hilo, Hawai'i.

Whitesell, C.D. 1990. *Acacia koa* A. Gray. In: R.M. Burns and B. Honkala. Silvics of North America Vol. 2: Hardwoods. pp. 17-28. Agriculture Handbook 654. USDA Forest Service, Washington, DC. <http://www.na.fs.fed.us/spfo/pubs/silvics_manual/volume_2/acacia/koa.htm>.

☛ Wilkinson, K.M., and C.R. Elevitch. 2003a. Growing Koa: A Hawaiian Legacy Tree. Permanent Agriculture Resources, Holualoa, Hawai'i.

Wilkinson, K.M., and C.R. Elevitch. 2003b. Propagation protocol for production of container *Acacia koa* Gray plants. In: Native Plant Network. University of Idaho, College of Natural Resources, Forest Research Nursery, Moscow, Idaho. <http://www.nativeplantnetwork.org>.

Yanagida, J.F., J.B. Friday, P. Illukpitiya, R.J. Mamiit, and Q. Edwards. 2004. Economic value of Hawai'i's forest industry in 2001. Economic Issues 7. College of Tropical Agriculture and Human Resources, University of Hawai'i, Honolulu.

traditional tree initiative

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

Acacia koa (koa) and *Acacia koaia* (koai'a)

Authors: Craig R. Elevitch[1], Kim M. Wilkinson[2], and J. B. Friday[3]

1. Permanent Agriculture Resources, PO Box 428, Holualoa, Hawai'i 96725, USA; E-mail: cre@agroforestry.net
2. Environmental Management Specialist, PO Box 1331, Duvall, Washington 98019, E-mail: kim@kimwilkinson.com
3. Cooperative Extension Service, College of Tropical Agriculture and Human Resources, University of Hawai'i, 875 Komohana Street, Hilo, Hawai'i 96720-2757, USA; Web: http://www.ctahr.hawaii.edu/forestry

Cooperative Extension Service
College of Tropical Agriculture and Human Resources
University of Hawai'i at Mānoa

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