Species Profiles for Pacific Island Agroforestry
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Musa species (banana and plantain)

Musaceae (banana family)

aga' **(ripe banana) (Chamorro), banana, dessert banana, plantain, cooking banana (English);** ***chotda*** **(Chamorro, Guam, Northern Marianas);** ***fa'i*** **(Samoa);** ***hopa*** **(Tonga);** ***leka, jaina*** **(Fiji);** ***mai'a*** **(Hawai'i);** ***maika, panama*** **(New Zealand: Maori);** ***meika, mei'a*** **(French Polynesia);** ***siaine*** **(introduced cultivars),** ***hopa*** **(native) (Tonga);** ***sou*** **(Solomon Islands);** ***te banana*** **(Kiribati);** ***uchu*** **(Chuuk);** ***uht*** **(Pohnpei);** ***usr*** **(Kosrae)**

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IN BRIEF

Distribution Native to the Indo-Malesian, Asian, and Australian tropics, banana and plantain are now found throughout the tropics and subtropics.

Size 2–9 m (6.6–30 ft) tall at maturity.

Habitat Widely adapted, growing at elevations of 0–920 m (0–3000 ft) or more, depending on latitude; mean annual temperatures of 26–30°C (79–86°F); annual rainfall of 2000 mm (80 in) or higher for commercial production.

Vegetation Associated with a wide range of tropical lowland forest plants, as well as numerous cultivated tropical plants.

Soils Grows in a wide range of soils, preferably well drained.

Growth rate Each stalk grows rapidly until flowering.

Main agroforestry uses Crop shade, mulch, living fence.

Main products Staple food, fodder, fiber.

Yields Up to 40,000 kg of fruit per hectare (35,000 lb/ac) annually in commercial orchards.

Intercropping Traditionally grown in mixed cropping systems throughout the Pacific.

Invasive potential Banana and plantain are not considered to be invasive.

PHOTO: C. ELEVITCH

Banana and plantain are traditionally found in Pacific island gardens such as here in Apia, Samoa, although serious pests and diseases have reduced their productivity in many areas.

INTRODUCTION

Musa, a plant genus of extraordinary significance to human societies, produces the fourth most important food in the world today (after rice, wheat, and maize), bananas and plantains. *Musa* species grow in a wide range of environments and have varied human uses, ranging from the edible bananas and plantains of the tropics to cold-hardy fiber and ornamental plants. They have been a staple of the human diet since the dawn of recorded history. These large, perennial herbs, 2–9 m (6.6–30 ft) in height, evolved in Southeast Asia, New Guinea, and the Indian subcontinent, developing in modern times secondary loci of genetic diversity in Africa, Latin America, and the Pacific. *Musa* species attained a position of central importance within Pacific societies: the plant is a source of food, beverages, fermentable sugars, medicines, flavorings, cooked foods, silage, fragrance, rope, cordage, garlands, shelter, clothing, smoking material, and numerous ceremonial and religious uses. With the exception of atoll islands, banana and plantain are ideally suited for traditional Pacific island agroforestry, for interplanting in diversified systems, and for plantation-style cultivation in full sun. Although mostly consumed locally in the Pacific region, the fruit enjoys a significant worldwide export market.

Not considered invasive, *Musa* nonetheless is a persistent plant that competes relatively well with other species within managed agroforestry settings. Many cultivars are particularly susceptible to certain pests and diseases, making monocrops or even backyard banana plantings relatively challenging and requiring high labor inputs to maintain them in healthy, productive condition.

Local or indigenous selections are generally more useful and tolerant of local conditions, and have lower input requirements (compost, fertilizer, water) to obtain satisfactory yields. However, the Pacific's indigenous banana and plantain cultivars as a whole are highly sensitive to nematode, insect, and viral infestations. Some disease-resistant hybrids have been developed in recent years.

BOTANICAL DESCRIPTION

Preferred scientific name

Musa species

There are five taxonomic sections in the genus *Musa*, two of which contain edible bananas.

Family

Musaceae (banana family)

Common names

banana, dessert banana, plantain, cooking banana (English)

Pacific islands

aga' (ripe banana) (Chamorro)
chotda (Chamorro, Guam, Northern Marianas)
fa'i (Samoa)
leka, *jaina* (Indian derivation) (Fiji)
mai'a (Hawai'i)
maika, panama (New Zealand: Maori)
meika (Cook Islands)
meika, *mei'a* (French Polynesia)
siaine (introduced cultivars), *hopa* (native) (Tonga)
sou (Solomon Islands)
te banana (Kiribati)
uchu (Chuuk)
uht (Pohnpei)
usr (Kosrae)

Fe'i banana cultivars have a host of common names in different islands.

Other regions

Banane, bananier (France)
Banane, Bananen, Bananenpisang, Bananenstaude (German)
banano (plant), *plátano, platanero* (plantain), guineo (dessert banana) (Spain, Latin America)
chotda banana (plant), *banana no tsubomi* (flower) (Japan)
djantoong (plant), *jantung pisang* (flower) (Indonesia, Malaysia)
pisang, getang (Indonesia)
saging (Philippines)
barbaro, zapolete (Mexico)

Size

Banana is a large, perennial, monocotyledonous herb 2–9 m (6.6–30 ft) in height that arises from large, subterranean rhizomes (usually called "corms").

Flowers

Upon flowering, the true stem or growing point emerges from the center of the tightly rolled bunch of leaves. This odd-looking "flower cluster" is actually an elongated, plump, purple to green "bud" (sometimes called the "bell" or "heart"), which at first displays large female flowers (whose ovaries ripen into fruit). As the "bud" elongates, it exposes semicircular layers of female flowers, then neutral flowers, and finally small, generally non-functional (with no viable pollen) male flowers. Each group of flowers is arranged radially on the stem in nodal clusters. Each flower cluster is borne on a prominence on the stem bearing

the fruit (peduncle) and covered by a bract. About 12–20 flowers are produced per cluster. Collectively, the flowering parts and fruit are referred to as the bunch. Individual clusters of fruits are known as hands, and individual fruits are known as fingers.

Leaves

The entire above-ground portion of the plant is not a true woody trunk, as in other trees, but a "false trunk" or "false stem" that consists of leaves and their fused petiole bases, referred to as a pseudostem. The pseudostem supports a canopy consisting of 6–20 (or more) leaves.

Fruit

Musa fruits are variable in size, shape, and color. They are generally elongate-cylindrical, straight to strongly curved, 3–40 cm (1.2–16 in) long, and 2–8 cm (0.8–3 in) in diameter. The fruit apex is important in variety identification; it may be tapered, rounded, or blunt. The skin is thin and tender to thick and leathery, and silver, yellow, green, or red in color. Inside the ripe fruit, the flesh ranges from starchy to sweet, and in color from white, cream, yellow, or yellow-orange to orange. Bananas also vary in peel thickness. Some varieties have a thin peel and are more susceptible to damage in transport, whereas others have a comparably thicker peel (the Fe'i variety 'Karat' and others, for example).

Seeds

Cultivated varieties are typically seedless. When seeds are present, they vary among species in shape and morphology. Seeds of *Musa balbisiana*, parent of many commercial edible banana varieties, are dark brown, ovoid, about 4 mm (0.2 in) long, with a conspicuous white, powdery endosperm.

Rooting habit

Plants have numerous (200–500) fibrous roots. In well drained, deep, and fertile soils, roots may extend 1.5 m (5 ft) deep and 4.9 m (16 ft) laterally. In dry, shallow, or rocky soils, roots of *Musa* may not compete well; otherwise, *Musa* is an average to good competitor.

GENETICS

Musa species are grouped according to "ploidy," the number of chromosome sets they contain, and the relative proportion of *Musa acuminata* (A) and *Musa balbisiana* (B) in their genome. Most familiar, seedless, cultivated varieties (cultivars) of banana are triploid hybrids (AAA, AAB, ABB). Diploids (AA, AB, BB) and tetraploids (AAAA, AAAB, AABB, ABBB) are much rarer; the latter essentially being experimental hybrids.

Emerging banana bunch of 'Pisang Awak', Nu'u Research Station, Upolu, Samoa. PHOTO: A. K. KEPLER

Differences in flesh color. The banana on the left is a seedless hybrid dessert banana 'Silk' (AAB group); the yellow-fleshed banana on the right is a Fe'i banana 'Karat'. PHOTO: L. ENGLBERGER

Fruits of cultivated *Musa* species are typically sterile or have extremely low fertility. They produce fruit pulp without pollination and fruits lacking seed (i.e., they are parthenocarpic). Although sterility and parthenocarpy are im-

portant factors that contribute to the desirability of banana fruits, sterility has impeded progress in breeding programs. Through natural somatic (vegetative) mutation, hybridization, and selection over many thousands of years, considerable genetic variability has arisen within the cultivated bananas, giving rise to more than 1000 varieties worldwide. There is a great diversity of banana varieties in the Pacific, particularly in Papua New Guinea and the Solomon Islands. There is much global concern that some varieties are becoming increasingly rare and that the important diversity of banana is being eroded.

Due to problems with male and female fertility among many of the desirable parents (e.g., the Cavendish subgroup is virtually sterile), breeding programs have only recently developed useful cultivars. Also, many natural and artificially bred hybrids are susceptible to important diseases and pests.

The edible bananas of the world belong to the Eumusa section of the genus *Musa*, except for the Fe'i group, which belong to the Australimusa section. The Fe'i bananas are characterized by erect bunches, pink-red to purple sap and deep yellow or orange colored fruit pulp.

HAWAIIAN SAYINGS (PUKUI 1983)

ʻAʻohe hua o ka maiʻa i ka lā hoʻokāhi.

"Bananas do not fruit in a single day."

(A retort to an impatient person.)

He maiʻa ke kanaka a ka lā e hua ai.

"A man is like a banana on the day it bears fruit."

(One can tell what kind of man he is by his deeds. In olden days banana stalks were often likened to men. When a man's body was removed from a grave, a banana stalk was laid in to take its place.)

He maiʻa ua paʻa i ke koʻo.

"A banana well supported by props."

(A man well supported by his followers.)

DISTRIBUTION

Native range

Musa species are native to the Indo-Malesian, Asian, and Australian tropics.

Current distribution

The distribution of *Musa* species is pantropical. They may be grown in temperate, relatively frost-free climates such as California, but generally fail to fruit due to the limitations of cool temperatures.

ASSOCIATED PLANT SPECIES

Bananas are associated with tropical lowland forest inhabitants of all types; many varieties grow wild on slopes above streams. As an aboriginal introduction to Pacific islands, the banana is still associated with many traditional cultivated plants including breadfruit (*Artocarpus altilis*), seeded breadfruit (*Artocarpus mariannensis*), taros (*Colocasia esculenta, Cyrtosperma chamissonis, Alocasia* spp., and *Xanthosoma* spp.), ti (*Cordyline fruticosa*), kukui (*Aleurites moluccana*, candlenut), pandanus (*Pandanus* spp.), noni (*Morinda citrifolia*, Indian mulberry), coffee, avocado, papaya, yam (*Dioscorea* spp.), coconut, *Piper* spp. including kava (*Piper methysticum*), sweetpotato, sugarcane (*Saccharum officinarum*), Polynesian arrowroot (*Tacca leontopetaloides*), mango (*Mangifera indica*), betel nut (*Areca catechu*), edible hibiscus (*Abelmoschus manihot*), etc., all of which are important throughout Oceania. In homegardens, bananas and plantains are grown together with all types of homegarden fruits, vegetables, and ornamentals.

ENVIRONMENTAL PREFERENCES AND TOLERANCES

Climate

Elevation range

Acceptable elevations are generally 0–920 m (0–3000 ft) or more, depending on latitude. There are reports of banana fruiting at up to 2000 m (6600 ft) in Papua New Guinea. In Kula, Maui, certain cultivars such as 'Cuban', 'Santa Catarina', 'Dwarf Chinese', and others are productive up to 1000 m (3300 ft). 'Dwarf Chinese' can produce at even higher elevations, and Hawai'i's 'Maoli ka'ualau' does well up to 1220 m (4000 ft).

Mean annual rainfall

The minimum rainfall requirements for *Musa* depend on soil type, planting location, sun exposure, and variety or species. For production of commercial cultivars (e.g., 'Giant Cavendish'), a minimum of 500 mm (20 in) per year will sustain the plants if the rainfall is evenly distributed

throughout the year and the soil is fertile. However, approximately 2000 mm (80 in) per year, more or less evenly distributed, is considered to be a minimum requirement for a successful commercial banana plantation. There is no upper rainfall limit, given well drained soil.

Rainfall pattern

Seasonal rainy periods and/or drought periods are fairly normal for most banana-growing areas. Bimodal or seasonal rainfall patterns are tolerated well by edible banana growing in forested situations and/or in fertile, deep soils. Uniform rainfall distribution throughout the year is best for commercial production of edible banana; 375,000 l/ha/week (40,000 gallons/ac/week) are required for irrigation of banana plantations in dry areas. Some dwarf *Musa* species used in ornamental landscapes are relatively drought-tolerant and can tolerate a wider range of rainfall and distribution patterns.

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

The ability of *Musa* spp. to survive for a given length of time in the absence of rainfall is dependent on the following factors:

- soil type, structure, and drainage
- shade level; transpiration requirements
- mono-cropping vs. a diversified/ agroforestry system
- pest and disease pressure
- plant nutrition and soil fertility.

Because the plants can store a significant amount of water within their pseudostems and rhizomes, they can survive extended periods of drought, although their growth will slow down or cease under such conditions. In Hawai'i's rocky volcanic soils, banana suffers significant drought stress and yield reductions after only a few weeks without rain.

Since *Musa balbisiana* is considerably more drought hardy than *M. acuminata*, increasing proportions of B in a cultivar's genome are correlated with increased drought tolerance. In other words, cooking varieties such as 'Saba' (ABB) and 'Bluggoe' ('Largo' in Hawai'i, ABB), can be grown more successfully in dry, windy areas than many other varieties. 'Sucrier' (AA), with much A in its genome, is notably difficult to grow and rarely survives with low moisture or humidity.

Typical mixed forest planting of banana, breadfruit, taro, and many other useful species. PHOTO: S. NELSON

Mean annual temperature

26–28°C (79–82°F) is optimum for shooting (vegetative growth of banana). 29–30°C (84–86°F) is optimum for fruiting.

Mean maximum temperature of hottest month

35–37°C (95–99°F)

Mean minimum temperature of coldest month

–2–30°C (28–86°F)

Minimum temperature tolerated

The minimum temperature tolerated depends upon the species. At 16°C (60°F) banana plant growth slows; at 10°C (50°F), growth stops. Chilling damage and tissue necrosis

occurs at or below 13°C (55°F). Temperatures below –2°C (28°F) may kill plants to the ground, but they can often recover through new growth from subterranean parts. Damaging low temperatures generally do not occur in the lowland tropics of the Pacific but are more likely to occur in upland areas, such as on the slopes of Hawai'i's volcanoes. For example, in Kula, Maui, at about 975 m (3200 ft), winter temperatures often fall below 10°C (50°F), causing the banana plants to virtually hibernate, without producing any more leaves until warmer conditions return. This does not harm the plant, although high elevation plants will bear up to a year later than lowland plants. In Hawai'i, the best bananas for growing at higher elevations are: 'Chinese Dwarf', 'Dwarf Cuban Red', 'Grande Naine' (a Cavendish type), and some of the native Maoli varieties.

Soils

Soil texture and drainage

Banana tolerates a wide range of soils, but well drained loams are optimal. Heavy, clayey soils are suboptimal, especially if they are low in organic matter and aeration.

Soil pH

Banana tolerates a wide range of soil acidity; pH 5.5–7.5 is optimal.

Special soil tolerances

Banana tolerates, but will not thrive in, shallow soils.

Tolerances

Drought

Musa spp. vary in drought tolerance but grow and produce best where rainfall is evenly distributed throughout the year. Because of their water-filled energy reserves, they can "tough out" long dry periods but will subsequently produce only small bunches.

Full sun

Musa spp. thrive in full sun, especially if winds are not high.

Shade

Banana and plantain can even grow well in higher shade levels, up to 80%. Fruit production will be delayed by several months if plants are excessively shaded. For commercial production of banana, full sun is usually best, and a maximum of 50% shade is recommended. Although *Musa* in general grows best in full sun, the Fe'i varieties thrive best in shady conditions during establishment. Mature plants do quite well in full sun when provided with sufficient water.

Fire

Banana plants will generally recover from fire by regrowing from corms.

Frost

Although significant plant damage can occur due to frost, banana plants generally recover from subterranean parts when warm weather returns, especially if provided winter protection in the form of mulch or complete covering.

Waterlogging

Disease-free banana plants can withstand waterlogged soil but will produce poorly. Excessive irrigation or poorly drained sites may cause banana mats to "float" upon loosely rooted corms.

Salt spray

Musa spp. are tolerant of salt spray and may even produce small bunches of fruit if grown in tidal mud flats.

Wind

Winds 40–72 km/hr (25–45 mph) can topple plants when they bear fruit. Height has a dramatic affect on wind tolerance. Tall cultivars are not recommended in areas with a high probability of hurricanes, although strong enough winds will topple any banana variety. Steady winds cause significant leaf shredding, leaf drying, distortion of the crown, or (in extreme winds), complete or partial toppling of the entire plant. Winds cause more damage if the underground corm is weakened by insect pests (banana weevil) or disease (nematodes, fungal pathogens). In windy areas, dwarf varieties are best: 'Dwarf Chinese' (AAA, 'Cavendish', etc.), 'Dwarf Cuban Red', and 'Dwarf Brazilian' ("apple," AAB, Pome) varieties such as 'Santa Catarina', 'Rio Nain', or dwarf native varieties, e.g., 'Iholena Ha'aha'a' (Hawai'i). Short cultivars such as 'Dwarf Pisang Awak' are characterized by thick, short pseudostems, compact structure, and short, broad leaves; they are excellent choices for homegardeners throughout the Pacific and elsewhere. They also have the dual advantage of being easier to harvest, with less green waste for disposal. In Kīpahulu, Maui, a popular new short-trunked variety, with an extremely heavy, solid base, is dubbed 'Hurricane'.

During or before hurricanes, some industrious Pacific islanders may choose to slash off banana pseudostems to about half their height to prevent entire plants from being blown over. In this way, the basal suckers have more of a

Strong winds can shred leaves and thereby reduce productivity. Tall cultivars are not recommended for windy areas, as their trunks tend to fold over in the middle. PHOTO: C. ELEVITCH

chance to survive after the winds have passed, and the parent may even produce a small bunch of fruit also.

Abilities

Regenerate rapidly

Banana plants are known for their ability to regenerate rapidly from corms. They quickly recover after fields are damaged by strong winds or hurricanes and will produce again in 6-9 months.

GROWTH AND DEVELOPMENT

Growth rate

Growth rate is rapid until flowering; after the flower bud shoots, vertical growth of the pseudostem ceases and no additional leaves are added.

Flowering and fruiting

Flowering and fruiting occur year-round but often fluctuates seasonally, with maximum production during summer and fall.

Potential for invasiveness

Most *Musa* species are not considered to be invasive. However, due to birds feeding on them, seeded varieties have the potential to spread and become pests.

PROPAGATION

Banana and plantain are propagated principally by vegetative division and far more rarely by seeds (usually only for banana breeding, ornamental types, and wild species). In addition, tissue culture has become standard for commercial plantations in recent years, primarily because of the advantage of starting with disease-free planting material. Edible bananas are almost always seedless (however, some, such as 'Pisang Awak', produce many seeds when growing near a fertile pollen source).

Propagation by division

Propagule collection

Division by rhizomes in banana is referred to as sucker production and collection. This is the most common method used to obtain banana planting material. Sword suckers are preferred to water suckers for planting new fields because of their superior vigor and eventual yield. Sword suckers have narrow, sword-shaped initial leaves and are attached to a healthy, fruiting mother plant. Water suckers are those young plants that no longer have a physical connection with a living mother plant. Water suckers do not have the sword-shaped initial leaves. The sword suckers (with narrow leaves) can be obtained from healthy mother plants that are devoted (either in full or in part) to the production of sword suckers. These sword suckers are not removed during the normal process of thinning out banana clumps, but are reserved for collection and subsequent planting. Suckers to be used for planting can be given extra light (by trimming overhanging leaves) and fertilizer before removing them from the mother plant to enhance their viability. Suckers are ready for removal from the mother plant when they reach a minimum of 15 cm (6 in) diameter and 50 cm (20 in) height above the soil (Stover and Simmonds 1987). The sucker is removed (cut away and out) from the mother plant using a sharp tool such as a narrow-bladed, straight-sided shovel, making sure to obtain an appreciable amount of corm with the sucker. It is not advisable to use "peepers" (suckers less than 30 cm [12 in] tall) for propagation ma-

Left: A banana "sword sucker" at the stage of development suitable for propagation (right). The sword sucker is carefully separated from the mother plant where it is attached to the underground rhizome, and usually planted directly in the field. Right: Field recently planted with banana suckers as an example of monocropping. PHOTOS: S. NELSON

terial because they are extremely slow-growing, may not survive, and if they do survive will produce small bunches the first year.

Banana suckers intended for agroforestry should be allowed to develop longer on the mother plant, reaching 2–2.5 m (6.6–8 ft) in height with 6–7 leaves, and given extra nitrogen fertilizer in the weeks before their collection and use as planting material. These plants are better able to compete in a shaded agroforestry setting.

Propagule processing

Detached suckers are inspected for disease and pest damage. If rhizomes are infested with weevils or nematodes, the affected tissue should be removed before washing and immersing the rhizomes in hot water (54°C [129°F] for 20 minutes) and/or 10% bleach solution. Roots may be entirely trimmed from rhizomes without significant detriment to the plant. Trimmed suckers sprout new roots readily if irrigation or rainfall follows planting. Suckers may be planted almost immediately or allowed to sit for a few days without loss of viability. To reduce problems with *Erwinia* soft rots (bacterial diseases), it is usually a good idea to let the cut surfaces heal over (suberize) for 2 days. Suckers may have disease or pests. Care should be taken not to transfer infested suckers that contain nematodes or other banana pathogens to a new field.

Propagule storage

Suckers remain viable for several days after collection and trimming. The sooner they are planted after collection, the better is the recovery and growth after planting.

Growing area

Suckers are planted directly into planting holes in the field for plantation or agroforestry production. For suckers intended for nurseries, a light, well drained, pathogen-free growth medium will suffice. If suckers are irrigated after planting, they can begin to form new roots within days of planting, and leaf emergence can begin within 7–10 days after planting. Expected survival, if sufficiently irrigated and with proper nutrition and absence of disease, is 90–100%.

Propagation by seeds

The inedible, ornamental *Musa* species such as 'Fuzzy Pink' or 'Pink Velvet' banana (*M. velutina*), or fiber species such as the abaca 'Manila Hemp' (*M. textilis*), are two examples of *Musa* species that are commonly grown from seed.

Ease of germination depends on species, variety, and environment. Some germinate quite readily; others are more challenging. Store seeds in a cool, dry place. Seeds do not require scarification, although soaking them in water for 24–48 hours before planting is recommended. Sow seeds in a light, well drained medium, place in full sun, and keep moist. Seeds may take several weeks to germinate.

PESTS AND DISEASES

Susceptibility to pests and diseases in the Pacific

Banana and plantain are susceptible to a wide range of pests and diseases. Some pests and diseases are highly aggressive or very contagious and easily spread, and once established they are persistent and practically impossible to eradicate.

In general, the severity and occurrence of pest outbreaks and plant damage depend upon several mitigating factors:

- environmental conditions
- specific banana variety
- specific disease or pest.

Environment

Wet, rainy environments favor fungal and bacterial diseases. Relatively dry weather or climate favors many types of insect outbreaks (e.g., mites) and banana virus diseases; however, some pests, such as scab moths, cause damage during normal weather patterns in the Pacific. Disease and pest outbreaks are more common where banana plants are grown together in large numbers (monocultures), rather than where planted in small numbers and spatially separated, as in agroforestry settings. Despite the planting method, the highly contagious nature of some diseases means that many or most plants in a region may become infected by a given pathogen. The severity of the reaction depends upon the environment.

Banana variety

Although most banana varieties are susceptible to certain severe diseases, some varieties are far more sensitive than others. For example, *Fusarium* wilt was responsible for destroying many commercial plantations of the once-popular and widely grown variety 'Gros Michel', also known as 'Bluefields'. With regard to banana bunchy top virus—which has now spread throughout SE Asia and much of the Pacific—the most susceptible varieties are in the Cavendish subgroup ('Chinese', 'Williams', 'Grand Naine', 'Valery'). Members of the Pome subgroup are more tolerant of bunchy top, i.e., 'Brazilian' types (Hawaiian "Apple"), French Polynesian 'Rio' or 'Pime', and 'Australian Improved Lady Finger'. Some varieties or types of bananas are well suited for local conditions and are tolerant of existing pest and disease populations. These are primarily the "new varieties" such as FHIA-01, FHIA-02, FHIA-03, 'Giant Kalapua', which are not quite as well received as the older types but are relatively disease resistant. Researchers worldwide are continually working to develop disease-resistant varieties.

Host to crop pests/pathogens

Several significant pests and pathogens of general agricultural concern are parasites of *Musa* spp. (e.g., sap-feeding insects and root-knot nematodes). These pests have wide host ranges and may initiate or cause significant damage to some crops (e.g., vegetables). Because *Musa* spp. attract ants, some sap-feeding insects (e.g., aphids) may be a concern for certain vegetable intercropping designs with *Musa* spp.

Insect pests of banana in the Pacific

Insect pests of banana can cause significant damage to fruits (e.g., thrips, moths/caterpillars, scales), leaves (e.g., mites, moths/caterpillars), corms, and pseudostems (e.g., weevils), and can transmit important plant pathogens (e.g., aphids transmit banana bunchy top virus). Damage due to insects can greatly reduce the marketability of banana fruits. Listed and described below are some of the most common and important insect pests of bananas in the Pacific region.

APHIDS

***Aphis gossypii* (melon aphid)**
***Pentalonia nigronervosa* (banana aphid)**

These are found wherever bananas are grown. The banana aphid is a significant pest of banana due to its ability to transmit banana bunchy top virus (BBTV). Aphid excretion of "honeydew" provides a nutritional and physical substrate for sooty mold fungi, which may diminish fruit quality and physically block photosynthesis. Banana aphid populations are often tended by ant species.

BEETLES

***Adoretus sinicus* (Chinese rose beetle)**

The Chinese rose beetle, *Adoretus sinicus*, and other rose beetles are common pests on all major banana-producing islands in Hawai'i and the Pacific. The larvae primarily dwell in the soil and leaf litter surrounding the plant crop, and the adults do the damage to banana. The adult beetle is nocturnal and feeds primarily on leaf and interveinal tissue. Chinese rose beetle damage is most easily detected on younger plants.

***Cosmopolites sordidus* (banana weevil)**

The banana root borer can be very damaging to commercial and home growers. The larvae bore into corms, suckers, and roots; extensive root destruction is possible; diminished plant growth and yield results; premature toppling of plants and plant death (of young plants) can occur. A night-feeder, the borer can be trapped by baiting the field with slices of banana pseudostem. **Management**: Peel the rhizomes free of lesions and immerse in hot water at 54˚C (129˚F) for 10 minutes; minimize plant debris around mats; remove infested stumps after harvest; apply insecticides. Also, a 10% household bleach solution treatment also is useful for disinfesting corms. Pruning the corm and lower trunk first until no "tunnels" are evident and treating with household bleach is the best for the home grower. It is very important that growers of bananas everywhere are aware of this weevil and its damage, because it is spread by people unknowingly (or carelessly) giving away suckers to home gardeners with "clean" gardens. Symptoms: banana plants fall over, even in light winds. Dirt-filled tunnels creating a labyrinth of weakened tissue in the corm and lower trunk up to about 30 cm (12 in) high.

***Trigonops* sp. (weevil)**
***Polytus mellerborgi* (banana corm weevil)**
***Odioporus longicollis* (banana pseudostem borer)**

Weevils are a major pest in SE Asia. Entire banana fields were destroyed by weevils in Okinawa in 1997 (S. Nelson, pers. comm.). **Management:** If suckers are infested with weevils, all infested material should first be trimmed with a machete. This includes trimming all roots, small suckers, and all necrotic tissues until only white, clean tissues remain. Then soak the trimmed suckers in 10% household bleach solution, let them air-dry for a few days, and plant in a new spot. Let the original field remain fallow for 1–2 years. Weevils may be trapped overnight by placing freshly cut pseudostem on the ground, with the cut surface in contact with the soil.

CATERPILLARS

***Chrysodeixis eriosoma* (green garden looper)**

The larval (caterpillar) stage feeds on banana leaves.

***Erionota thrax* (banana leafroller)**

The caterpillar stage feeds on banana leaves. **Management:** The leafroller can be controlled effectively in some locations with naturally occurring biological control insect species (e.g., parasitic wasps).

Damage from weevils in Okinawa, probably *Odioporus longicollis*. PHOTO: S. NELSON

Banana corm weevil (borer), Waipi'o Bay, Maui. PHOTO: F. G. RUST

***Spodoptera litura* (rice cutworm)**
***Eudocima* (*Othreis*) *fullonia* (Pacific fruit-piercing moth)**

The fruit-piercing moth is an important pest in localized areas. The adult moth punctures and feeds on ripening

fruit, which may result in premature ripening/fruit drop. **Management:** Natural enemies of this pest may reduce pest populations over time.

***Decadarchis flavistriata* (sugarcane bud moth)**

This is a localized insect pest (caterpillar); the caterpillar stage feeds on decaying flowers and causes fruit scarring. **Management:** De-flowering prior to bagging; use of sprays of *Bacillus thuringiensis* ("BT") products.

***Erionota thrax* (banana skipper)**

The banana skipper, *Erionata thrax,* rolls up banana leaves starting from the leaf midrib. Due to the effective biological control of the banana skipper in some locations (Hawai'i), chemical treatments are uncommon. **Management:** The banana skipper can be controlled effectively in some locations with naturally occurring biological control insect species (e.g, parasitic wasps). The best way for the homegardener to control these caterpillars, which eat extensive areas of leaves, is to recognize the damage (easy) and kill them by hand.

***Opogona sacchari* (banana moth)**

The banana moth lays eggs on senescing flowers and on decaying leaves, pseudostems or fruit. The larvae feed on detritus and decaying plant material. They are often found feeding on healthy tissue at the interface with decaying plant parts. Moth larvae can destroy several palm species in tropical areas (e.g., *Chamaedorea*, areca palms, etc.). **Management:** the removal of flowers and application of insecticidal bunch treatments prior to bagging appears to greatly reduce damage larval damage.

***Nacoleia octasema* (scab moth)**

The scab moth is a very significant pest of banana fruits in Samoa and many places in the southwest Pacific. The pest also attacks *Heliconia* in some locations, as well as *Pandanus*. Banana scab moth females lay eggs on banana flower bracts or leaves as the inflorescence emerges. Larvae hatch, enter the flower, and feed on the developing fruits within. The feeding results in rough and irregular scars (brownish-black) on fruit skin. Large infestations can scar the entire fruit and cause deformed fingers. **Management:** the best control is achieved by injecting an insecticide (as recommended by local agriculture authorities) into the flower after it emerges and before it starts bending downward. A single injection, applied about one-third of the way down from the flower tip, is sufficient to provide control. Some varieties appear to be less susceptible to scab moth damage.

Banana scab moth damage, Western Upolu, Samoa. PHOTO: A. K. KEPLER

FRUIT FLIES

***Bactrocera dorsalis* (Oriental fruit fly)**
***Ceratitis capitata* (Mediterranean fruit fly)**

Fruit flies are significant quarantine pests for some destinations. They attack ripe banana fruits.

LEAFHOPPERS

***Sophonia rufofascia* (two-spotted leafhopper)**

MEALYBUGS

***Planococcus citri* (citrus mealybug)**
***Pseudococcus jackbeardsleyi* (banana mealybug)**
***Dysmicoccus brevipes* (pineapple mealybug)**
***Dysmicoccus neobrevipes* (gray pineapple mealybug)**
***Ferrisia virgata* (striped mealybug)**
***Pseudococcus orchidicola* (orchid mealybug)**

Mealybugs feed on banana leaves and fruits, but they are not a significant economic pest of *Musa* in most locations. Some mealybugs transmit banana streak virus (BSN).

MITES

***Phytonemus pallidus* (cyclamen mite)**

Mites can build large colonies during dry weather, primarily on the undersides of *Musa* leaves. Their feeding damage can cause large, dry, brown patches of necrosis on banana leaves. Generally, they are not economic pests and transmit no other diseases.

SCALES

Scales are sap-feeding insects that attack banana leaves and fruits.

***Abgrallaspis cyanophylli* (armored scale)**
***Aonidiella aurantii* (California red scale)**
***Aonidiella inornata* (inornate scale)**
***Aspidiotus destructor* (coconut scale)**
***Chrysomphalus dictyospermi* (dictyospermum scale)**
***Coccus hesperidum* (brown soft scale)**
***Coccus viridis* (green scale)**
***Diaspis boisduvalii* (boisduval scale)**
***Eucalymnatus tessellates* (tessellated scale)**
***Hemiberlesia lataniae* (latania scale)**
***Icerya aegyptiaca* (Egyptian fluted scale)**
***Ischnaspis longirostris* (black thread scale)**
***Pinnaspis buxi* (ti scale)**
***Saissetia coffeae* (hemispherical scale)**
***Steatococcus samaraius* (steatococcus scale)**

The coconut scale (*Aspidiotus destructor*) causes a localized discoloration and yellowing of plant tissue. It is classified as an armored scale; feeds on underside of banana leaves, in circular colonies; can attach to petioles, peduncles, and fruits; and is a significant quarantine pest for banana fruits shipped from the Pacific (Hawai'i) to the U.S. mainland. **Management:** Scales are controlled with sprays of insecticidal oils in Hawai'i; scale populations decline if ants can be controlled, as ants tend these insects and feed on the honeydew produced by them.

THRIPS

Thrips can scar, stain, or deform banana fruits by feeding on the fruit skin. Thrips are small, winged insects that feed on banana flowers and/or the tender green skin of developing fruits. The two factors of feeding site and species determine the type and extent of fruit damage. Thrips outbreaks can occur during periods of dry weather. The following thrips species are important pests of *Musa* in the Pacific region.

***Chaetanaphothrips signipennis* (banana rust thrips)**

Feeding by rust thrips creates areas of reddish-brown "rust" that develop on the banana fruit, especially where two adjacent fingers touch; skin cracking can occur, leading to severe damage. The damage is caused by populations of the banana rust thrips feeding on young, developing green banana fruits. **Management:** monitor rust thrips activity; apply approved insecticides to soil, plant, and fruit; use thrips-free planting material; destroy neglected or abandoned plants or banana plantations; cover the developing bunches with perforated polyethylene sleeves.

Coconut scale colony on banana leaf. PHOTO: S. NELSON

***Elixothrips brevisetis* banana (rind thrips)**
***Hercinothrips femoralis* (banded greenhouse thrips)**
***Thrips hawaiiensis* (Hawaiian flower thrips)**

Feeding by the Hawaiian flower thrips causes "corky scab," a superficial, corky scarring of the banana fruit skin; the scab is patchy, discolored, and raised. Corky scab is caused by populations of the flower thrips (*Thrips hawaiiensis*) feeding on young, developing, green banana fruits. **Management:** Monitor the crop for flower thrips populations; spray registered insecticides; keep plants moist with overhead irrigation during dry periods.

WHITEFLIES

Whiteflies are *Musa* leaf parasites and generally do not damage banana fruits directly. They feed on the leaf undersides; they are sap-feeding insects that deposit honeydew on the surface of the banana fruits and leaves in the canopy below them. This sugary deposit on leaves and fruits can lead to the growth of sooty mold fungi, which use the honeydew as a food source. Sooty mold can lessen fruit quality

and reduce overall leaf photosynthesis. Whiteflies may be tended by ant species that feed on the honeydew and protect the insects. Whiteflies may be controlled effectively in some locations with naturally occurring biological control insect species.

***Aleurodicus dispersus* (spiraling whitefly)**

The spiraling whitefly is a sap-sucking insect causing tissue damage and discoloration; it excretes honeydew, which is a substrate for the growth of sooty mold on the surface of plant organs. **Management:** Natural enemies of the spiraling whitefly may keep this pest in check locally; foliar sprays of insecticidal oils can reduce whitefly populations.

GRASSHOPPERS

***Valanga excavate* (large short-horn grasshopper)**
***Valanga nigricornis* (Javanese grasshopper)**

OTHERS

***Leptoglossus australis* (leaf-footed plant bug)**
***Proutista moesta* (erect-winged blue plant hopper)**
***Lamenia caliginea* (derbid planthopper)**
***Lamenia caliginea* (a fulgorid planthopper)**
***Siphanta acuta* (torpedo bug)**

DISEASES IN THE PACIFIC

Diseases are major production constraints wherever bananas are grown. The most significant disease of bananas in the Pacific is black leaf streak, caused by the fungus *Mycosphaerella fijiensis*. Bunchy top, a viral disease caused by the banana bunchy top virus (BBTV), has also emerged as a major problem for banana plantations in Hawai'i and the Pacific. Here we briefly identify and summarize current information on the most common and important biotic (infectious) and abiotic (noninfectious) diseases of banana in the Pacific. More in-depth coverage of these diseases is found in Ploetz (2003) and Jones (2000).

BIOTIC DISEASES

Biotic diseases are infectious and caused by plant pathogens.

DISEASES CAUSED BY FUNGI

Fungi are the most important and prevalent pathogens of banana. All banana plant organs are attacked by fungi. Fungal diseases cause the greatest pre- and postharvest production losses and account for a large share of plantation management expenses.

Leaf diseases

***Phyllacora musicola* (black cross)**

Black-cross is a distinctive but relatively minor leaf disease of banana. The disease is found in Australia, Indonesia, the Philippines, and the southwestern Pacific. Symptoms are most evident on the undersides of older leaves, scattered about the leaf or occurring in large groups. The lesions are black and star-shaped, with four cardinal points and elongated along the leaf vein axes. **Management:** Specific control measures for this black cross are usually not warranted; 'Cavendish' varieties are resistant.

***Pseudocercospora fijiensis* (**syn. ***Mycosphaerella fijiensis*) **black sigatoka, black leaf streak**

A debilitating and contagious leaf disease caused by the fungus, *Mycosphaerella fijiensis*. It is globally distributed and epidemic in many locations and is the most important disease of *Musa* worldwide. Symptoms develop as follows: reddish-brown streaks (1–5 mm [0.04–0.2 in] long and 0.25 mm [0.1 in] wide) appear initially on the undersides of the third or fourth youngest leaf; streaks develop into elongated spots with gray or tan centers and dark brown to black margins; lesions may be surrounded by yellow halos; lesions may coalesce to form large, blighted areas of leaves in parallel with leaf veins, or bands of dark streaks, causing leaves to turn brown and wither. Significant defoliation may occur; a banana plant may have only a few or no green (disease-free) leaves upon flowering. The cost of disease management is high. Bunch yield loss can be significant. **Management:** A combination of cultural and chemical practices is recommended: field sanitation, host nutrition and sound cultural practices; fungicides; de-trashing (deleafing); pruning; ensuring good drainage and canopy aeration; plant nutrition; resistant cultivars. The indigenous Fe'i banana of Pohnpei, 'Karat', shows good resistance to black leaf streak in that region. The best way for the homegardener to control the disease is to destroy the severely diseased leaves or remove them and place them topside-down on the ground to reduce the chance of spore dispersal into the banana canopy.

***Pseudocercospora musaea* (syn. *Mycosphaerella musicola*) sigatoka, yellow sigatoka**

Yellow sigatoka was formerly of greater importance in the Pacific than the similar black sigatoka. Symptoms are yellowish streaks on leaves, enlarging into narrowly elliptical gray spots with dark brown borders, up to 15 mm (0.6 in) long and 5 mm (0.2 in) wide. Leaves may turn gray or brown and hang from the plant, defoliating it. Bunches are small due to the presence of relatively few, healthy leaves at flowering. **Management:** see black sigatoka.

***Cladosporium musae* (cladosporium speckle)**

Cladosporium speckle is a leaf spot disease of minor importance to most banana varieties and locations. Symptoms are variable among regions, affecting older leaves. Control is usually not warranted. Other fungi may also cause leaf speckle, such as *Acrodontium simplex*.

***Drechslera gigantean* (eye spot)**

Leafspots

***Cordana musae* (cordana leafspot)**
***Curvularia* sp.**
***Phyllosticta* spp.**
Hendersonia toruloides
***Helminthosporium* sp.**

Cordana leaf spot is a common but minor leaf spot disease on most banana varieties but can be severe on plantain varieties. Symptoms are pale brown, oval patches on leaves, surrounded by bright yellow halos. The disease may be controlled with the same fungicides used to control the sigatoka diseases.

***Fusarium oxysporum* f. sp. *cubense* (Panama disease, fusarium wilt)**

A lethal disease caused by races of a soil-borne fungus, *Fusarium oxysporum*. It is a devastating disease of banana worldwide. Infection occurs through roots and progresses to the pseudostem. Symptoms are internal stem necrosis (reddish or reddish-brown xylem), root and rhizome rot, yellow leaves, plant wilting, and plant death. Plants may die during flowering or during periods of moisture stress. The fungus may survive decades in soils. **Management:** Largely preventive, by planting resistant varieties or pathogen-free materials (preferably tissue-cultured plants) in non-infested soil.

Pythium root rots

Pythium arrhenomanes
Pythium aphanidermatum
***Pythium* sp.**

***Marasmiellus inoderma* (stem rot)**

A sometimes-severe pseudostem disease occurring in marginal soils (soils with poor nutrition or physical structure, low in organic matter, high in clay) or poorly drained or wet areas where *M. inoderma* occurs. The causal fungus is able to penetrate leaves, pseudostems, or roots to cause the following symptoms: decay and withering of outer leaf sheaths/blades; leaf stunting; cracked pseudostems; slow plant growth; plant stunting and death; and narrow pseudostems. White mushrooms often appear along the cracks in the affected pseudostems. Alternative hosts of *M. inoderma* include coconut, rice, taro, and maize. **Management:** Selection and use of disease-free planting material; moderate irrigation; fertilizers; soil improvement (compost, mulch); removal and destruction of diseased plants; promote conditions for vigorous plant growth.

Fruit diseases

***Colletotrichum musae* (anthracnose)**

A spot, rot, or blemish of ripening banana fingers. Initial lesions are roughly lens-shaped to circular and sunken and brown. The spots turn black, enlarge, and merge eventually; the spots become deep depressions covered in pink fungal spore masses. The splash-borne fungus, *Colletotrichum musae*, the spores of which infect the green banana fruits well before ripening, causes anthracnose. **Manage-**

Left: Black sigatoka symptoms. Right: Cordana leaf spot. PHOTOS: S. NELSON

Left: Banana fruits affected by anthracnose. PHOTO: WAYNE NISHIJIMA **Right: Crown rot.** PHOTO: R. PLOETZ

ment: Regular cutting and removal of overly necrotic banana leaves (>50% necrotic) near bunches and throughout the field; careful fruit handling to minimize abrasions and wounds; keep fruit as cool as possible to slow down the disease; prompt ripening; on-time harvest; good packing house hygiene (e.g., clean water and equipment); prompt cooling of fruits to appropriate storage temperature after processing.

***Colletotrichum musae*, *Nigrospora sphaerica*, or *Fusarium* spp. (black end)**

Black decay of the finger stalk and the adjacent part of the finger; usually confined to the banana peel. **Management:** Good plantation and packinghouse hygiene and ventilation; mulch dead leaves in field; keep packing house free of plant debris, rejected fruit, and other trash; de-hand bunches in clean water; use sharp de-handing knife for good, clean cut surfaces; keep fruit as cool as possible after harvest (both before and after ripening).

***Ceratocystis paradoxa* (syn. *Chalara paradoxa*) (ceratocystis fruit rot)**

A crown rot, stem end rot, and tip rot of green or ripe fruit. Crowns are soft, black, and water-soaked; dark fungal growth may develop in a mass; stem ends and skin may turn black. Fungal growth may cover the fruit skin with a white to greenish-black color; the pulp may rot and fingers may drop or ripen. **Management:** Good packing house hygiene (clean and disinfest the packing house regularly; do not allow rotting fruit to accumulate). See also management for black end.

***Verticillium theobromae* and *Trachysphaera fructigena* (cigar end rot)**

A finger tip rot, dark brown to black; the fruit pulp is characteristically dry and fibrous or stringy; spore masses occur on the lesions, gray and powdery. **Management:** Frequent removal of dead flowers from banana fingers, followed by bagging of bunches with perforated polyethylene sleeves; removal of bracts and dead flower parts that may accumulate in the sleeves after bagging; field sanitation; field cultural practices (de-leafing, pruning) to modify the environment (promote canopy aeration and exposure to light);

packinghouse sanitation; culling of infected fruits before placing them in a wash tank; fungicide sprays.

***Fusarium* spp., *Verticillium* spp., *Colletotrichum musae*, and *Acremonium* sp. (crown rot)**

A blackening and rotting of the cut ends of banana fruit hands. As the fruit ripens, the rot advances down into the fruit stalks, contributing to fruit rot and premature ripening. A whitish-gray fungal growth may be present on the surface of affected crowns. Numerous fungi are associated with this disease. **Management:** Good packing house hygiene (e.g., clean water in the wash tank); approved fungicides; rapid cooling of fruit after de-handing; refrigeration of fruit at not less than 13°C (55°F) during storage and sale.

***Phyllosticta musarum* syn. *Guignardia musae* (freckle)**

A relatively minor fruit disease in the Pacific. However, the pathogen also infects *Musa* leaves, which can serve as a source of disease for fruits. The symptoms are raised black pinpoint spots, occurring in groups, on leaf or fruit surfaces. The disease may render fruit unmarketable. **Management:** Choice of banana variety ('Cavendish' is resistant); periodic and regular de-trashing (removal of diseased leaves, especially near developing or unprotected bunches); bagging of bunches; fungicides.

Sooty mold

A patchy, black, sooty surface mold on green or mature banana fruits. Sooty mold is the surface growth and spores of fungi, which use as their food source the sugary excretions of sap-feeding insects such as aphids, mealybugs, scales, and whiteflies. **Management:** Bagging of the developing bunches to block access of insects to fruit and to block fruits from deposition of sooty mold from insect-infested leaves surrounding the bunch; bunch sprays of copper fungicides; insect control methods; soak bananas in 1% bleach solution for a few minutes in a postharvest wash tank.

***Deightoniella torulosa* (swamp spot, speckle, black tip)**

A widely distributed disease but rarely a severe problem in maintained orchards; symptoms are reddish brown to black speckles on fruit skin or black fruit tips; overall, considered to be a common but minor disease that is dependent on poor air circulation within *Musa* plantations or habitats.

NEMATODE DISEASES OF BANANA

Banana nematodes are microscopic roundworms that live as soil-borne parasites of roots. The root-knot nematodes (*Meloidogyne* spp.) and the burrowing nematode (*Radopholus similis*) can significantly weaken root systems, reduce yields, topple plants before harvest, make plants more prone to wind knockdowns, reduce fertilizer uptake and utility, and reduce the banana-growing lifespan of a given piece of land. Nematodes are managed with avoidance, clean (nematode-free) planting material, heat treatment of planting material, pre-plant soil fumigation, crop rotation, mulching and composting, fallow, chemical nematicides, plant propping, fertilizer use, and varietal resistance.

Toppling caused by burrowing nematode damage. PHOTO: R. PLOETZ

Following are the principal plant-parasitic nematodes associated with banana, in order of their relative threat to *Musa* production and/or as plant quarantine pests:

***Radopholus similis* (burrowing nematode)**

This is a major banana root pathogen, causing lesions to roots and rhizomes, banana decline, yield losses, and toppling; the nematode has relatively wide non-*Musa* host range. **Management:** Nematode-free rhizomes are required to prevent large losses and dissemination of the nematode; nematicides; in severe infestations, bunch-bearing plants must be supported to prevent toppling before harvest; composting and mulching; soil treatment before planting; crop rotation; fallow.

***Meloidogyne* sp.*, Meloidogyne incognita* (root-knot nematodes)**

Infection leads to swelling and galling of banana roots. Galled roots may crack and rot. Plants rise from the soil ("float") and can topple during bunch development coupled with wet weather or water draining through the field. Root-knot nematodes can make a field unusable for commercial banana production after 5 years. **Management:** Avoidance; nematicides; cultural practices; nematode-free planting material; composting and mulching; soil treatment before planting; crop rotation; fallow.

Other nematodes

***Helicotylenchus* spp. (spiral nematode)**
***Rotylenchulus reniformis*, *Rotylenchulus* sp. (reniform nematode)**
***Pratylenchus coffeae* (lesion nematode)**
***Tylenchorhynchus* sp. (stunt nematode)**
***Criconemoides sphaerocephalum* (ring nematode)**
Criconemella sphaerocephala
***Hoplolaimus* sp.**

VIRUS DISEASES OF BANANA IN THE PACIFIC

Banana bunchy top virus (BBTV) (bunchy top)

Banana bunchy top is a very severe disease of banana. Initial symptoms are dark green dots and streaks ("Morse code" streaking, up to 25 mm (1 in) in length) on the veins of banana leaves. As the disease progresses, leaves become progressively smaller, erect, and brittle, with pale, ragged, necrotic margins. The most conspicuous symptom is the "stacking up" or bunching up/rosetting of leaves; the disease name derives from this reduced internode distance between leaves of affected plants. Symptoms can appear on plants of all ages, although young plants, when infected, may not bear fruit. Banana varieties vary somewhat in their reaction to the disease. Disease is spread by planting infected material or by insect transmission of the virus between plants. The banana aphid, *Pentalonia nigronervosa*, is

Left: Symptoms of bunchy top disease. PHOTO: S. NELSON **Right: Symptoms of bunchy top in suckers.** PHOTO: HAWAIʻI DEPARTMENT OF AGRICULTURE

Green dots and streaking, a subtle symptom of banana bunchy top disease. PHOTO: S. NELSON

Banana field destroyed due to banana bunchy top infestation. PHOTO: W. NISHIJIMA

the sole insect vector of BBTV and can transmit the virus by feeding on banana leaves, petioles, or pseudostems. *P. nigronervosa* is specific to *Musa* spp. **Management:** Aphid scouting and management or spot-treatment (kerosene, mineral oil, soapy water, or conventional insecticides); field surveys for symptomatic plants; complete eradication of diseased plants and mats; use of virus-free planting material; tissue culture; and effective regional and international plant quarantine are important to control bunchy top. Once a region has been contaminated with BBTV, eradication is very difficult. Prevention of the disease is a key component to its management. There are no known resistant commercial banana cultivars, and there appears to be more than one strain of the virus. However, in Hawai'i the 'Dwarf Brazilian' cultivar is more tolerant of bunchy top than Cavendish cultivars.

***Banana streak virus* (BSV) (banana streak)**

The symptoms consist of a combination of chlorotic streaks (broken or continuous) and narrow lesions on leaves. As the leaves age, the yellow streaks may turn brown and necrotic, resulting in a pattern of fine black streaks running parallel to leaf veins. Diseased plants may be stunted and have smaller bunches. Banana streak is transmitted by mealybugs. **Management:** Control the disease through the use of virus-free planting material and eradication of diseased plants. Banana plants infected with BSV may periodically show no symptoms and therefore should be kept in quarantine for a period of 9 months or more.

***Cucumber mosaic virus* (CMV) (banana mosaic)**

Banana mosaic is a disease of relatively minor importance to banana. Symptoms included yellow streaks or flecks on leaves in a mosaic pattern, leaf yellowing, and leaf mosaic. CMV is distributed worldwide and has perhaps the widest host range of any plant pathogenic virus. **Management:** Use of pathogen-free planting material and control of alternate hosts (weeds, legumes, cucurbits, members of the Solanaceae, such as tomato).

BACTERIAL DISEASES IN THE PACIFIC

***Ralstonia solanacearum* race 2 (biovar 1) (moko disease)**

Moko disease is a wilt of banana and plantain and cooking banana (especially Bluggoe [ABB Group]) common in Central and South America (moved there in seed pieces). There is no known resistance to *Ralstonia solanacearum* among edible bananas ('Pelipita' ABB and FHIA-03 have some resistance where the insect-transmitted form exists; the absence of a male bud and/or "dirty stem" below the bunch provides useful control). Insect transmission of the bacterium enables the disease to spread rapidly in some locations. **Management:** Control of the disease is difficult and expensive. Methods include quarantine; routine plant inspection and destruction of diseased plants; variety selection; tool disinfestations; destruction of neighboring

plants (adjacent to diseased areas); prompt removal of the male flower bud after the last female hand has emerged.

***Erwinia* spp. (rhizome rot)**

This disease is caused by a bacterial genus known for its ability to cause soft rots on a wide range of host plants and tissues. These bacteria infect banana plants through leaves and pseudostems, causing the following symptoms: wilting or death of leaves before fruit has ripened, vascular discoloration, and internal rot of the pseudostem (usually accompanied by a characteristically foul odor). **Management:** Cultural control tactics such as planting of disease-free material, and prompt identification and eradication of diseased plants (preferably by burning).

ABIOTIC DISEASES OF BANANA IN THE PACIFIC

Abiotic diseases are noninfectious and include nutrient deficiencies and environmental disorders.

Common nutrient deficiencies and abiotic conditions of Musa in the Pacific

Nutrient deficiency symptoms are common for banana grown in Pacific island soils. In some cases, deficiency symptoms may appear as a group because several elements may be lacking (e.g., N, K, Ca, and B). The symptoms are usually both preventable and correctable with choice of location, improved soil characteristics and fertility, and the use of amendments and fertilizers.

Boron (B)

Chlorotic streaking of leaves, oriented perpendicular to and crossing the primary veins; leaf malformation; interveinal chlorosis. Foliar malformation may result. This deficiency can develop slowly over time.

Calcium (Ca)

General dwarfing; reduced leaf length; reduced rate of leaf emission; leaves are undulated; tissue near midrib thickens, may turn reddish-brown. Fields should be limed periodically; correctable with calcium nitrate.

Iron (Fe)

General chlorosis of the entire lamina of young leaves; retarded plant growth; small bunches. Apply iron compounds to soil; foliar sprays of Fe using naturally occurring or manufactured iron-containing compounds.

Magnesium (Mg)

Marginal chlorosis of older leaves; violet-colored marbling of petioles; fruit may have defective flavor and not ship well; symptoms are reduced by use of magnesium sulfate.

Nitrogen (N)

A generalized yellowing of leaves; rose-colored tints on petioles and leaf sheaths; stunting; rosetting; slender pseudostem; small petioles and leaves; reduced life span of leaves; notable reduction in yield. Banana is more sensitive to a lack of nitrogen than any other element; problem is compounded by dense stands of weeds or grass.

Potassium (K)

Rapid yellowing of oldest leaves, which then turn orange and dry up; leaves may become tattered and fold downward; leaves are crumpled in appearance; bunches are poorly filled; correctable with potassium fertilizers such as potash.

Sulphur (S)

Leaves are chlorotic and reduced in size, with a thickening of secondary veins; undulating leaf edges; necrosis along edge of lower leaves. Correctable with sulfate fertilizers

Calcium and boron deficiencies are a big problem throughout the Pacific. PHOTO: S. NELSON

such as ammonium sulfate, potassium sulfate, and magnesium sulfate.

Zinc (Zn)

Rosetting and stunting; chlorotic, strap-shaped leaves; leaf chlorosis in stripes or patches; abnormal bunch and hand characteristics; symptoms may be more severe in sandy soils.

Abiotic fruit disorders

Abiotic fruit disorders reduce fruit quality and may reduce fruit grade or render fruit unmarketable.

Chilling injury

A necrotic flecking just below the surface of the green skin and pulp of the banana fruit, caused by exposure of banana fruits to temperatures below 13°C (55°F). **Management:** Avoid refrigeration at below 13°C (55°F).

Fused fingers

The fusion of banana fingers is the result of a genetic mutation or defect, seen particularly in Cavendish varieties. Hands with fused fingers may not be marketable but are completely safe to eat. **Management:** Destroy the affected plant and its suckers if found on a commercial farm; use the fused hands as animal food.

Maturity bronzing

A reddish-brown to brown discoloration of mature green bananas; fruit skin may develop cracks and scabs. The cause of this problem is unclear; however, it appears to be a physiological disorder resulting from periodic water stress. Calcium deficiency may also be implicated. **Management:** Irrigate to avoid moisture stress when bunches are young. Do not allow bunches to "over-fill" before harvest.

Precocious ripening or mixed ripe

Individual fingers ripen prematurely, which could be caused by harvesting over-mature bananas; excessive postharvest storage or transit temperatures; anthracnose wound infections on fruit skin. **Management:** Harvest fruit that is at a proper stage of maturity; adequate temperature control after harvest; fungicide dips of fruit; well ventilated fruit storage. This problem may occur as a result of severe leaf disease, such as black leaf streak (black sigatoka).

Sap damage

Stains on banana fruit skin, caused by contact of the sensitive green fruit surface with its own banana sap during de-handing and packing activities. **Management:** Avoid sloppy de-handing work; soak banana hands in clean water in a washing/de-sapping tank for enough time to allow the fresh wounds (from the cutting and de-handing process) to stop emitting the staining sap. The water in the tank dilutes the flowing sap so that it cannot damage the green banana tissue.

Herbicide (paraquat) injury to banana leaves. PHOTO: S. NELSON

Rat feeding injury to banana fruits. As shown here, their feeding is not restricted to ripe fruits. PHOTO: S. NELSON

Senescent spots

Senescent spots, a natural part of the ripening process for Cavendish bananas, are numerous, superficial brown flecks on peels. Spots are shallow (less than 1 mm [0.04 in] deep) and do not enlarge or change color. The brown spots are caused by the death of small groups of cells in the outer peel, usually after treatment in a ripening room. The condition is associated with the forced ripening of overly mature banana fruits. **Management:** Avoid the harvest and ripening of overly mature fruit.

Splitting of fingers

Longitudinal splits in fingers; ripe fingers separate from the hand. The splitting can be caused either by high relative humidity (>95%) during final fruit ripening or harvest and ripening of over-mature fruit or over-caliper fruit (bunches left on plant too long, leading to overly swollen fingers). **Management:** Lower the relative humidity to 70–75% during fourth and fifth day of ripening; ensure good aeration in ripening room; restack cartons so that ventilation slots are aligned with each other; harvest fruits on time according to caliper grade. Avoid harvesting and ripening bunches with swollen fingers due to late or missed harvest.

Other pests

Wild birds, bats, and rodents not only feed on banana fruits but often construct nests within the bunch, poised to feed their young when the bananas ripen. Rats can be a serious problem for islanders dependent on bananas; therefore bananas should be harvested just before or at the first sign of rat damage, then hung upside-down in a rat-free environment until ripe.

Compost piles made primarily of banana leaves and stalks. PHOTO: C. ELEVITCH

AGROFORESTRY/ENVIRONMENTAL PRACTICES

Mulch/organic matter

Musa species produce profuse amounts of vegetative mass that, upon composting, produces a significant amount of natural mulch and organic matter. The cut leaves and stems are also laid down on the ground around the plants to suppress weed growth. However, it is important to remember that cut-up trunks used as mulch will stifle the growth of suckers if placed too close to the mother plant (this is a common error, even among backyard gardeners who are anxious to expand their banana mat). Also, if banana corm weevils are present, avoid using cut-up banana pseudostems as mulch, as these will serve as a breeding ground for the weevils.

Left: Pineapple cultivated under banana, American Samoa. Right: Kava grown in the shade of banana, Kona, Hawai'i. PHOTOS: C. ELEVITCH

Soil stabilization

Musa species grow very well on steep, soil-covered banks of stream gulches, provided there is vegetative cover. If the soil is bare and rainfall high, banana plants tend to topple.

Crop shade/overstory

Banana is a source of shade when grown in and around gardens, and in multi-cropping systems. A vigorous monocrop of banana can suppress many weeds with a combination of natural mulch and shade.

Alley cropping

Banana is suitable for alley cropping with a wide range of plants.

Homegardens

Banana is ideally suited for homegardens, growing readily and fruiting reliably and profusely. Dwarf varieties are easy to harvest. Also, dwarf varieties are relatively wind-tolerant and tend to be more disease resistant.

Living fences

Musa coccinea, a brightly colored, crimson-flowered ornamental, has been recommended as a component in a living fence. *Musa balbisiana,* one of the parents of edible hybrid bananas, was introduced into Hawai'i for this purpose (as a windbreak). However, because it is seeded and fruit-eating birds eat the seeds, it has come to be regarded by some as a pest in some areas of Maui. In windy and dry areas, a living fence of banana tends to look ragged and unkempt.

Animal fodder

Banana fruits, stems, and cut-up pseudostems (trunks), are suitable for animal fodder for horses, cattle, and pigs (provided the material is not contaminated by pesticides already recommended in the text)

Wildlife habitat

Birds feed on banana fruits and on the insects that are attracted to the plant. Flying foxes (bats) are banana eaters in the Western Pacific, where they are indigenous.

Ornamentals

Musa species and banana varieties are used ornamentally in many locations and under a wide range of landscapes, from backyards to coastal resorts. Some examples of ornamental *Musa* species include self-peeling 'Hot Pink' or 'Fuzzy pink' (*M. velutina*); 'Ornata' (several varieties of *M. ornata*); 'Blood/Rojo/Zebrina' or 'Variegated Red' (*M. acuminate* subsp. *zebrina*); and 'Okinawa torch' (*M. coccinea*).

USES AND PRODUCTS

Staple food

Bananas, consumed cooked or raw, either as the green, half-ripe, or ripe fruit, are one of the most significant sources of calories for the human diet worldwide. Bananas are a particularly good source of potassium. The yellow and orange-fleshed bananas are also rich in provitamin A and other carotenoids. Provitamin A carotenoids (including beta-carotene, the most important one) are important for protecting against vitamin A deficiency and anemia (as vitamin A is involved in iron metabolism). Carotenoid-rich foods may also protect against diabetes, heart disease, and certain cancers, which are serious emerging problems of epidemic proportion in the Pacific. Recently, attention has been focused on the carotenoid-rich bananas in Pohnpei, in particular the 'Karat', a Fe'i banana with an erect bunch. It has been shown that levels of beta-carotene may reach as high as 8508 µg/100 g edible portion in some Fe'i bananas. Other bananas in Pohnpei were also found to be carotenoid-rich, including 'Kudud' (internationally known as 'Sucrier'), which contained 315 µg beta-carotene/100 g. This is over 10 times higher than the beta-carotene content in the common Cavendish banana (21 µg/100 g).

Famine food

All banana plants have starchy corms and pseudostem bases that were and still are used in times of famine on Pacific islands (mostly SW islands and New Guinea). This was evidently the original use of banana for human food (de Langhe 1995).

Beverages

Alcohol, beer, vinegar, and wine can be produced from fruit. More of this was done in the past, but even in modern French Polynesia, vinegar is produced in small quantities by small-holding farmers (in this case, using 'Yangambi km5' (AAA, Ibota subgroup) bananas, introduced initially for livestock but found to be perfectly edible and excellent for fermenting into vinegar.

Flowers

The small male flowers (inside the "bud") of certain varieties, notably 'Saba' and 'Dippig', are cooked and eaten in the Philippines and within the Filipino community of Hawai'i. The entire bud can also be cooked as a vegetable; however, it is necessary to use the correct variety and boil it in several changes of water, otherwise it will be very bitter. Thick nectar from the male flowers of the Iholena, Maoli, and Pōpōʻulu subgroups was traditionally fed to babies in pre-contact Hawai'i. In contrast to the flowers, this semi-jelled

Left: Bananas are a staple of the Pacific islands: here plantains accompany sweetpotato, yam, and breadfruit in Tongatapu Market, Tonga. PHOTO: C. ELEVITCH **Right: Home-made banana dryer, heated by an open fire, in remote Hanahi Valley, Hiva 'Oa, using 'Giant Cavendish' bananas (called "Hamoa" here). O'Connor farm, MQ, French Polynesia.** PHOTO: A. K. KEPLER

"honey" is a delightful gift of the banana plant to those with a sweet tooth.

Leaf vegetable

Leaf buds can be eaten as vegetable. Evidently, leaves of the beautiful, red-variegated ornamental *M. acuminata* subsp. *zebrina* are particularly tasty.

Medicinal

Flowers, fruits, and roots are still used medicinally in some Pacific cultures, but most of these practices have died out. Stalks were mashed and used as poultice for sprains or broken bones (Hawai'i). Root sap from certain varieties was used as a medicine for thrush, a child's mouth irritation (Hawai'i), and to treat skin warts (French Polynesia). Pounded banana peels—used in many Pacific cultures as a wound "bandage"—have been found recently to contain antibiotic properties.

Flavoring

Ashes produced from burning banana leaves and pseudostems are used in curries and as a salt substitute (India).

Cut flowers

Some *Musa* species and hybrids with colorful floral bracts and flowers are utilized in ornamental landscapes and tropical flower arrangements.

Fuel wood/cooking

Throughout the Pacific, banana trunks are still used to line underground ovens (to provide steam), together with banana leaves placed over the food to keep it dirt-free.

Fodder and silage

Fruits and stems are made into silage and used as cattle feed. Underground parts are also used for pig and cattle feed (e.g., Marquesas).


Banana grows together with many other useful plants, as here on Tongatapu Island, Tonga (left), and ʻUpolu Island, Samoa (right). PHOTOS: C. ELEVITCH

Canoe/boat/raft making

Stalks were used as canoe rollers in ancient times in Hawai'i, and still today in some of the remote Micronesian and Polynesian communities (e.g., Yap and Tuvalu).

Fiber/weaving/clothing

Leaf and plant fibers are used to make thread and cloth. The shiny black outer trunk sheath surface of *M. fehi* and "black" traditional Polynesian-introduced varieties (e.g., 'Maoli 'Ele'ele' in Hawai'i, 'Mā'ohi 'Ere'ere' in Tahiti) was formerly used in weaving pandanus mats and other crafts to achieve dramatic patterns. This was practiced throughout Oceania, including New Guinea. *Musa basjoo* (the Japanese fiber banana) and *M. textilis* are still used to make high-quality clothing and fabrics. Thin parings carefully cut from the outer pseudostem of these fiber bananas are shiny, strong strips of natural fiber suitable for hand or machine weaving. In old Hawai'i, early Polynesian settlers braided their clothing (especially skirts) from dried banana sheaths and also plaited banana leaves for inner house linings.

Rope/cordage/string

Leaf fibers are used to make string, thread, cordage, and rope, e.g., *Musa textilis* for "Manila hemp" and "Taiwan hemp."

Wrapping/parcelization

Leaves are used as packing material and as parcels to hold things, leis and garlands for example. Banana leaves are also used to separate layers of paper mulberry bark at a soft, partly fermented stage of making tapa (Hawai'i and elsewhere in Polynesia). In Micronesia, banana leaves are used as liners in the traditional method of preserving breadfruit via pit preservation, as is now an historical traditional art in the Marquesas Islands. Banana leaves are also used for wrapping foods such as pulasami and valuvalu.

Thatch/roofing/mats

Leaves are used for house roofs and wall linings. Leaf sheath fibers are used in thatching.

Resin/gum/glue/latex

Banana sap has been used in many cultures as dye. Any banana sap will stain clothes indelibly black. The bright magenta sap of Fe'i bananas still finds uses in SW Pacific cultures.

Body ornamentation/garlands

Leaf sheath fibers are used to string leis and garlands and for tying and plaiting clothing. Some lei makers in Hawai'i still prefer to use twisted strips of banana trunk (about 2.5 cm [1 in] wide) on which to thread their leis, particularly haku-style leis. One of Hawai'i's ancient varieties, 'Maoli Manai-'ula', was named for its tough outer leaf sheaths, which were used—along with a needle fabricated from a coconut leaflet midrib—for stringing leis.

In many remote Pacific islands, especially in the southwest close to New Guinea, islanders still use banana fibers for tying together food packets or as string. However, beach hibiscus (*Hibiscus tiliaceus*) bark fiber is preferred if available, because it is stronger and more durable.

Fishing

Fruits of certain varieties were used to feed sharks and ensure good fishing (Hawai'i).

Tannin/dye

The sap is used as dye and ashes used for dye, tanning (India), and, on some Pacific islands, for tattooing.

Eating utensils

Leaves are used as plates and tablecloths (e.g., Polynesia and India).

Agricultural

Leaves are used to wrap root balls of seedlings or plants before transplanting.

Protection

Leaves are used as umbrellas and temporary raincoats.

Smoking

Leaves are used as tobacco paper, especially in the southwest Pacific and Micronesia.

Ceremonial/religious importance

- Fruit was used as offerings throughout the Pacific, including Hawai'i. In the latter case, tradition tells us that all mai'a ("native" bananas) were planted by the gods Kane and Kanaloa, so fruit was routinely offered to them as "gifts of the land" at heiau (places of worship) and other sacred places.
- Consumption of the fruit of some varieties (Maoli Group, except 'Maoli Ka'ualau') was taboo for females or was considered as food for male ali'i (royalty) and priests (Hawai'i). Varieties that have red (and later gold) pseudostems, petioles, or fruit at some stage of their development were considered royal or sacred.
- Leaves were used to cover altars in Hawai'i and throughout Oceania.
- Stalks were used to symbolize a man and under certain circumstances, Maoli bananas were utilized in ceremonies where banana offerings were substituted for human sacrifices (Hawai'i).
- Bananas were regarded as the embodiment of Kanaloa/Tangaroa/Ta'aroa, one of the four primary Pacific deities (Hawai'i, Society Islands, Samoa, and possibly Fiji).
- Wild bananas were regarded as primordial sustenance for the gods (Polynesia).
- Fruit was used in the ceremonial feeding of ancestral spirits (Hawai'i). The variety particularly planted around heiau for this purpose was 'Iholena Lele', a delicious cooking banana with salmon-fleshed fruit.
- The fruit was used as "love magic" (Hawai'i). Throughout the Pacific, Maoli bananas in particular are closely linked with sexuality. This is very evident even today in the Society and Marquesas Islands, where most of the

Typical home and garden, Nuku Hiva, with 'Rio' ('Pome'), a native Maoli banana ('Maoli Maoli'), 'Hamoa' ('Giant Cavendish'), and 'Kina' ('Dwarf Chinese'). Upland of Taiohae, Nuku Hiva, MQ, French Polynesia. PHOTO: A. K. KEPLER

common Maoli and Pōpōʻulu-type bananas are graced with old (and new) "specially appropriate" names. This was likely one of the reasons that Maoli bananas were forbidden for women to touch or eat in old Hawaiʻi.

- Banana plants were used in rituals associated with the birth of children, especially royal children (e.g., Marquesas Islands and Tahiti).

URBAN AND COMMUNITY FORESTRY

Bananas and plantains are ideally suited for homegardens. They are probably grown and cultivated in more gardens throughout the Pacific than any other single plant species. The nutritious and tasty fruits are eaten by people of all ages and health conditions. The plants are easy to grow, regenerate themselves without re-planting, and produce good yields. Bananas in highly maintained landscapes require regular fertilizing, irrigation, pruning, and debris removal. In natural landscapes, some of these intensive inputs may not be necessary. Bananas also provide high starch yields relative to most root crops.

Size in an urban environment

The height and canopy spread of the plants in urban environments depends on a number of factors including the variety, impact of pests and diseases, plant nutrition, soil moisture, amount of sunlight, soil conditions, and other environmental factors. Under optimum conditions, most banana varieties grow to about 5 m (16 ft) tall and produce bunches which are higher than the average person can reach. Some varieties can be even taller, growing to about 6 m (20 ft) or more in height. The dwarf Cavendish type (the so-called 'Chinese' variety in Hawaiʻi) grows to a height of 3 m (10 ft) or less and is preferred by people who are not prepared to harvest bunches from tall plants. Canopy spread for mature plants is 3–4 m (10–13 ft) for most varieties. Plants grown in shade may become taller than the same plants grown in full sun.

Rate of growth in a landscape

With minimal disease and weed competition and fertile and consistently moist soil, most bananas in the Pacific reach maturity (bunch production) in about 12–18 months. A plant that reaches 4 m (13 ft) in height at flowering grows at a rate of about 30–50 cm/month (12–20 in/month), on average. Each mother plant can produce several suckers during its lifetime. Plants in locations that are close to the equator may grow and develop more quickly than plants at other latitudes.

Root system

Banana root systems are not considered invasive; plants coexist very well with a wide range of landscape plants, including grasses and other aggressive plants.

Products commonly used in a Pacific island household

Musa species are most widely used in Pacific island households for fresh fruit and for cooking. Traditionally, the fruit is cooked in underground ovens and the foliage (leaves and pseudostems) is used to separate food from coals or hot rocks. Leaves have a wide variety of useful everyday applications, including as disposable umbrellas, food wrappers, and plates. Banana peels make a very nutritious food for pigs.

Light requirements

Musa species can grow well in the shade as a forest understory plant or in full sun. However, larger bunches and plants growing in full sun produce more vigorous growth.

Water/soil requirements

Bananas grow best where rainfall is distributed evenly throughout the year. The plants are susceptible to stunting and damage due to prolonged drought.

Life span

The life span of individual plants is about 1–1.5 years. Where plants receive care, the life span of a banana mat is virtually unlimited because it continually regenerates new plants.

Varieties favored for use in homegardens or public areas

Both dessert and cooking types are commonly grown in homegardens. Older people or those who want an easy harvest prefer dwarf varieties. Locally popular varieties vary throughout the Pacific; some are apparently well suited for certain geographic areas and preferred by certain populations.

Seasonality of leaf flush, flowering, fruiting

Plants produce leaves, flowers, and foliage throughout the year. Individual plants only flower and fruit once.

Exceptional ornamental values

A few species have exceptional ornamental value. There are varieties with green-and-white variegated foliage and fruit and some with unusual or beautiful inflorescences, such as the ornamental *Musa velutina* that produces inedible fruit.

Use as living fence, hedge or visual/ noise barrier

Musa species may be used as a living fence. The plants absorb noise well, grow quickly, and can block the view.

Maintenance requirements

Musa species are beautiful landscape plants and add to the tropical feel of a garden. Bananas do require management because the mats tend to expand radially and use up more and more space over time. New suckers along the perimeter of the mat should be cut off to prevent encroachment upon the landscape or nearby buildings.

Musa species are heavy feeders and, in the presence of other landscape plants with equally demanding nutritional requirements such as grasses, may develop nutritional deficiencies rather quickly. However, where esthetically acceptable, banana mats provide a very good place to compost yard waste and mulch; this feeds the plants and helps retain soil moisture during dry periods.

Although beautiful ornamental plants, they are not as well suited for high-maintenance, high visibility landscapes and parks because they tend to create a lot of unsightly leaf and stem debris. For this reason, it is usually better to plant bananas at the edges of landscaped areas, out of full view. In low-maintenance or more natural landscapes, banana debris is not a problem.

Top: A dense commercial planting of bananas, taro, and breadfruit in American Samoa. Bottom: Bananas are widely spaced in this taro field along with coconut and sago palm, Tutuila, American Samoa. PHOTOS: C. ELEVITCH

Special considerations regarding leaf, branch, and fruit drop

Bananas may topple during average storms, especially if they are bearing bunches or are undermined by the erosive effects of running water. Toppled plants may sometimes be saved by propping them back up. Bananas usually topple during hurricanes but can re-grow readily from underground parts.

Nuisance issues

Banana sap can be a great nuisance; it can permanently stain clothing and is very sticky to the touch. Banana plants can attract undesirable wildlife such as rodents, pigs, chickens, and other nuisance birds. Because banana debris can hold small puddles of rainwater, banana serves as good habitat for mosquitoes. Banana produces a considerable amount of plant debris that must be dealt with in some landscapes and gardens.

Hazards

If ladders are required for harvesting fruit, there is a potential for falling.

Common pest problems

Some banana pest and disease problems are locally severe. The most important and damaging disease is probably banana bunchy top virus. It is critical to plant only virus-free plants and to consult with the local extension agent or

agricultural office as soon as symptoms of the disease appear. If the disease is not controlled, it may make growing bananas impossible in some locations. The most common, widespread problems in gardens and landscapes in the Pacific are probably fungal leaf diseases (i.e., black leaf streak), nutritional deficiencies, moths, weevils, and insect attacks, nematodes, banana bunchy top virus, and soil-borne root-infecting fungi such as *Fusarium* and *Marasmiellus*. Please refer to the "Pest and disease" section above for more information. Plants should be kept well irrigated and fertilized to help them withstand the effects of pest and disease attacks.

Other comments about this species in urban environments

Bananas are probably best suited for natural landscapes, due to the debris they create. Although they regenerate themselves and may grow to maturity without many inputs, the size of the harvest depends greatly upon the plant care provided. So if bunches are not important, they can be grown without much input or attention at all.

COMMERCIAL PRODUCTS

Primary commercial products

Spacing

Homegardens

Bananas should be planted at least 2–3 m (6.6–9 ft) from the side of a building.

Plantations

Two-line system with access roads: 1.8 m (6 ft) within rows (Cavendish subgroup); 2.1 m (7 ft) within rows ('Dwarf Brazilian'); roads are 3–3.7 m (10–12 ft) wide on 6 m (20 ft) centers. Two adjacent plant lines (1.8–2.1 m [6–7 ft] apart with plants on 1.8–2.1 m [6–7 ft] centers) separate each road. This gives a planting density of about 1850 plants/ha (750 plants/ac).

Agroforestry

Bananas are planted at random spacing, usually a minimum 2 m (6.6 ft) from nearest banana plant.

Along roadsides

To make use of marginal lands along roadsides, bananas are planted a minimum of 2 m (6.6 ft) apart.

Design considerations

- Avoid flood-prone areas or areas where surface water runs off or drains through. Running water undermines the root systems of banana plants, making them prone to topple when bearing a heavy fruit load or during windy weather.
- Avoid windy areas or areas prone to very high winds. Dwarf banana varieties (less than 4.6 m [15 ft] tall) withstand winds better than tall varieties (up to 9 m [30 ft] tall).
- Avoid areas where the topsoil has been scraped off, leaving only a hardpan or soil with very high clay content and poor aeration. Although banana requires large amounts of water, they also need drainage. If banana must be planted in heavy soils, allow side channels or French drains (channels with gravel and/or wire netting) to siphon off excess water. Planting on a gentle slope (not too steep) is recommended to facilitate drainage, with the plants in bowl-shaped terraces, so that water has a change to infiltrate rather than immediately running off downslope.
- Choose southern or western exposures (northern exposure in Southern Hemisphere) for a new plantation, and orient the rows according to wind and/or sun considerations. Planting bananas in alignment with the east-west movement of the sun encourages banana mats to "walk" in a straight line over the life of the farm, preserving row spacing and road width.
- Consider single-row planting or intercropping for high-rainfall areas with black sigatoka. Single rows allow good aeration of the banana canopy, allowing wet leaves to dry more rapidly, reducing fungal disease severity.

Yields

Yields depend largely upon the cultivation system, species or variety.

Commercial plantations

- For the Cavendish subgroup, e.g., 'Grande Naine', given a planting density of approximately 1750 bearing plants/ha (700 plants/ac), yields can be as high as 40,000 kg/ha/yr (35,000 lb/ac). Higher yields are possible in productive commercial ratoon crops.
- For the Pome subgroup, e.g., 'Brazilian' (often also called by some people "Apple" in Hawai'i), 'Improved Australian Lady Finger' (Central and West Pacific), 'Rio' or 'Pime' (French Polynesia), yields of 22,800 kg/ha (20,300 lb/ac) are expected.

Subsistence or wild cultivation systems

The bunch weight can be 1–18 kg (2–40 lb) or more, depending on variety, conditions, soil richness, amount of care, and fertilization application (bananas need large amounts

Intercropping of banana with cassava (left), taro (center), and sweetpotato (right) in Pohnpei. PHOTO: S. NELSON

of potash, as well as nitrogen and phosphorus), whether dead leaves are pruned or not, and the degree of disease infestation. Subsistence-style or low-input banana farming typically yields bunches in the 9–13.5 kg (20–30 lb) range.

Processing required

Commercial farming

Activities include harvesting, transport to packing shed, hanging, de-handing, cutting, sorting, labeling, washing, drying, packing, handling, boxing, stacking, storing, refrigeration, ripening, shipping, and marketing. Other types of commercial processing are employed for *Musa* fruit, such as drying, juicing, baking, chip making, fiber extraction, etc. The "native" Samoan variety, 'Fa'i Pau Manifi' (a Maoli type), is now exported to New Zealand for use as ice cream and drink flavoring.

Subsistence agriculture (food)

Cutting and hanging of bunches is the primary processing carried out.

Markets

In the Pacific, the primary markets are urban and metropolitan centers, farmer's markets, and roadside stands.

INTERPLANTING/FARM APPLICATIONS

Although *Musa* species require space and light, they co-exist well with a wide range of plants and trees in the Pacific, with the exception of allelopathic plants.

Some benefits of interplanting include

- disease and pest control
- complete diets for subsistence agriculture
- maintenance of soil fertility
- wind protection
- soil stabilization.

Some potential drawbacks of interplanting are

- Disease transmission from alternative hosts can be a problem.
- Root competition is a very important consideration, especially in areas where exceptionally invasive species not only shade but drastically drain the banana plants of water and nutrients. Be aware of this intense root competition with trees such as Java plum (*Syzygium cumini*), ironwood (*Casuarina equisetifolia*), eucalyptus trees (*Eucalyptus* spp.), and Christmas berry/Brazilian pepper (*Schinus terebinthifolius*).
- Most banana plants will not yield well if planted under more than 50% shade. The more sun, the better the yields and smaller the likelihood of fungal diseases. A few ornamentals, e.g., 'Blood' banana (*Musa acuminata* subsp. *zebrina*) flourish in, and actually prefer, 60–80% shade.

EXAMPLE INTERPLANTING SYSTEMS

Example system 1

Location

Micronesia (Pohnpei).

Description

These are traditional, subsistence cultivation methods where banana is intercropped with a range of other naturally occurring and cultivated plants such as papaya (*Carica papaya*), coconut (*Cocos nucifera*), kava (*Piper methysticum*), breadfruit, yam, sweetpotato, cassava, palms, ornamentals,

etc. This system is low maintenance and usually easy to plant and harvest.

Yields

Approximately 11–13.5 kg (25–30 lb) per bunch.

Spacing

The spacing is more or less random.

Example system 2

Location

Micronesia (Pohnpei).

Description

This method is to plant bananas along roadsides. This system is more recently developed as a part of governmental assistance to address losses due to banana pests and diseases, which may be so serious that people must leave their land fallow for 1–2 years before replanting. The only other available soil is along common roadsides.

Yields

Approximately 11–13.5 kg (25–30 lb) per bunch.

Spacing

Spacing is systematic in relatively close and dense patches along roadsides.

PUBLIC ASSISTANCE AND AGROFORESTRY EXTENSION

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

INTERNET

California Rare Fruit Growers: <http://www.crfg.org/pubs/ff/banana.html>.

"Canoe Plants" of Ancient Hawai'i: <http://hawaii-nation.org/nation/canoe/canoe.html>.

Crop Knowledge Master, University of Hawai'i at Mānoa, College of Tropical Agriculture and Human Resources: <http://www.extento.hawaii.edu/kbase/crop/crops/banana.htm>.

Julia Morton's chapter on banana: <http://www.hort.purdue.edu/newcrop/morton/banana.html>.

Promusa—Bananas in the World: <http://www.inibap.fr/promusa/bitw.html>.

Promusa's home page for more information and banana links: <http://www.inibap.fr/promusa/>.

Tico Ethnobotanical Dictionary: <http://www.ars-grin.gov/duke/dictionary/tico/m.html>.

USDA's "The Ethnobotany Database:" <http://probe.nal.usda.gov:8300/cgi-bin/browse/ethnobotdb>.

International Network for the Improvement of Banana and Plantain (INIBAP): <http://www.inibap.org/>.

Insect pests of Micronesia: <http://www.crees.org/plantprotection/AubWeb/bugweb/bugroot.htm>.

Science and Technology Reference Department, Pacific Botany Internet Resources: <http://www.hawaii.edu/sciref/pacbotany.html>.

Advancing Banana (INIBAP): <http://www.inibap.org/publications/proceedings/advancingbanana.pdf>.

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

Musa species (bananas and plantains)

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