

Specialty Crops for Pacific Island Agroforestry (<http://agroforestry.net/scps>)

**Farm and Forestry
Production and Marketing Profile for**

Banana and Plantain

(Musa spp.)

By Jeff Daniells, Lois Englberger, and Adelino Lorens

USES AND PRODUCTS

Global consumption of banana and plantain is about one trillion individual fruit each year. They are either consumed raw when ripe or cooked when hard, green, mature or at various stages of ripeness and represent one of the most significant sources of food energy in the Pacific. Banana leaves are commonly used as table mats and plates. They are also used for wrapping some foods before or after cooking. Banana blossom, also called bud or bell, is consumed as a cooked vegetable dish. The pseudostem (or “trunk”) is also used throughout the Pacific to line traditional above- and below-ground ovens together with banana leaves placed

over the food to keep it dirt-free. Fibres are extracted from the stems and leaves and used for various purposes. There are many medicinal uses that are important for banana. The fibre of the pseudostems and the juice of the stem are used in various treatments, such as for concussion, muscle ache, broken bones, cuts, burns, and fevers. Eating banana can also be used to clear fish bones that are caught in the throat.

Commercial production worldwide

Bananas and plantains represent the largest fruit crop in terms of both world production and trade. Total world production in 2006 was 113 million metric tons (MT). Almost



Top left: Many varieties of bananas are available at Pacific island farmers markets, such as this one in Apia, Samoa. Top right: A ripe bunch of ‘Ney Mannan’, also known as ‘Ice Cream’ bananas, Kealakekua, Hawai’i. Bottom left: Boiled bananas are a substantial component of many meals in parts of the Pacific, as in this Solomon Islands dish. Bottom right: Bananas are important in the diet of babies in the Pacific and can be given as a complementary food to breast milk after the age of 6 months. This photo shows a child enjoying ‘Karat’, a Fe’i banana of Pohnpei.

17 million MT were marketed in world trade in 2005, valued at about US\$5 billion. During this period about 980,000 MT were produced in Melanesia, Polynesia, and Micronesia but only 120 MT were exported. An insignificant amount was imported (FAO, n.d.).

In 2005, Hawai'i produced 10,000 MT of bananas for local consumption and imported 5,900 MT (NASS 2009).

BOTANICAL DESCRIPTION

Preferred scientific name

Musa species. All of the edible bananas belong to the *Eumusa* section of the genus *Musa*, except for the Fe'i bananas, which belong to the *Australimusa* section.

Family

Musaceae

Common names

The word banana refers to all members of the genus *Musa*, whilst plantain refers to a subset of bananas. The term plantain may be used in different ways, but usually is applied to fruits that are starchy when ripe and are almost exclusively cooked for consumption. Bananas apart from plantains can be eaten cooked and are also consumed uncooked when ripe.

In the discussion below, banana is used to refer to all plants of the Musaceae family. In some parts of the Pacific islands, there is a separate term for Fe'i bananas, those with upright bunches, and another term for non-Fe'i bananas.

The names listed below are only some of many used in the Pacific for banana.

Pacific islands

Chamorro, Guam, Northern Marianas: *chotda*, *aga'* (ripe banana)

Chuuk: *uchu*

Cook Islands: *meika*

Fiji: *leka*, *jaina*

French Polynesia: *meika*, *mei'a*

Hawai'i: *mai'a*

Kiribati: *te banana*

Kosrae: *usr*

Maori: *maika*, *panama*

Palau: *tuu*

Pohnpei: *uht*

Samoa: *fa'i*

Solomon Islands: *ba'u* (Kwara'ae), *husi* ('Are 'Are), *huti* (Rennell & Bellona), *sou*, *huki/fuki* (non-Fe'i varieties), *toraka* (Makira, Fe'i varieties)

Tonga: *siaine* (introduced varieties), *hopa* (native)

Yap: *dinaey*, *p'aw*

Other languages

French: *le bananier*

German: *die Banane*

Spain, Latin America: *banano* (plant), *platano*, *platanero* (plantain), *guineo* (dessert banana)

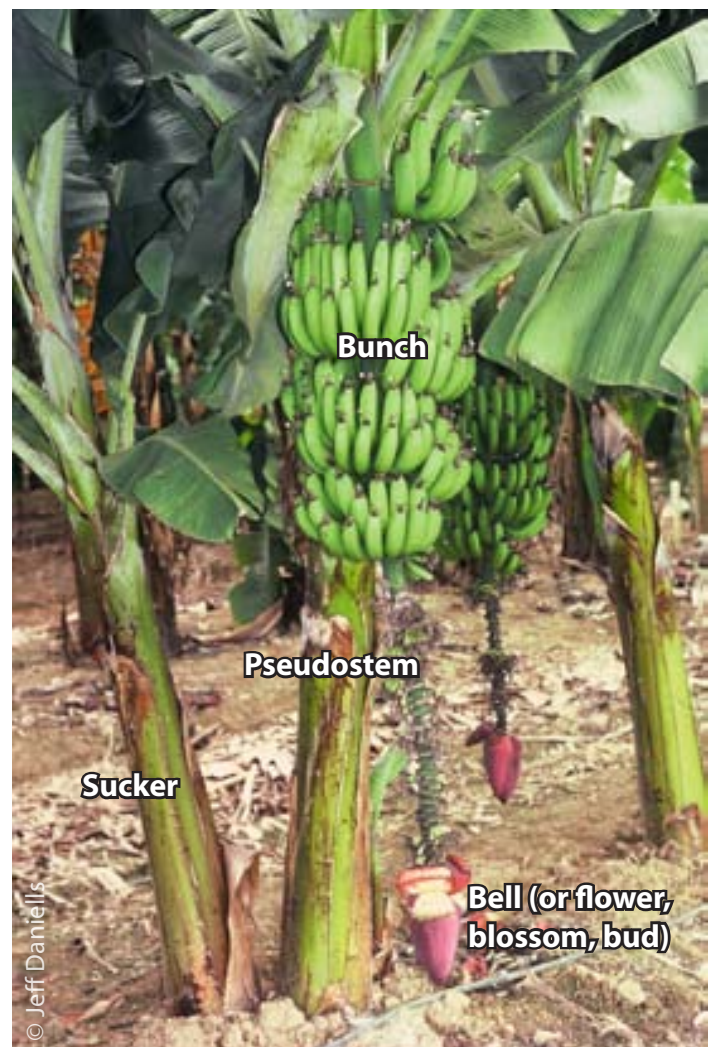
Indonesia: *pisang*

Philippines: *saging*

Mexico: *barbaro*, *zapotele*

Brief botanical description

The banana plant is a giant perennial monocotyledonous herb, which usually grows in height from 2–9 m. A mature banana plant consists of a basal rhizome with roots and suckers, a pseudostem with leaves, and a bunch with fruit. The pseudostem is made up of overlapping leaf sheaths with new leaves and finally the true stem bearing the terminal inflorescence growing up through the centre. The pseudostem usually supports a canopy of 10–15 large leaves. Flowering can occur at any time of the year, depending on plant maturity. The basal flower clusters (hands) are female and form the fruit bunch. Distal flower clusters are male, do not pro-



Cavendish banana with four plant parts labeled.



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Top left: Bananas are the largest herb in the world. *Musa ingens* is a wild seeded species which grows in the highlands of New Guinea and reaches about 18 m in height. Top middle: The Fe'i banana 'Toraka Gatagata' is prominent in Makira (Solomon Islands). Banana variety collection curator Dorothy Tamasia is pictured. Top right: Several Fe'i varieties from Solomon Islands. Aibwo and Suria were found to be alternate names for the same variety after this photo was taken. Bottom left: Some of the diversity of bananas. Bottom middle: Several seeds in fruit of the PNG variety 'Tainga' are shown. However, for most cultivated varieties seeds are relatively rare and depend on a fertile pollen source being nearby. Bottom right: Ripe hand of Cavendish bananas.

duce fruit, and are commonly deciduous. Banana bunches are mostly sub-horizontal to pendulous except for several members of the Australimusa section which have upright bunches. The fruit of cultivated varieties develop parthenocarpically, i.e., they develop without the stimulus of pollination. They are also relatively infertile and only rarely contain seeds.

Banana bunches can have up to 20 hands and take 2–6 months to reach maturity after flowering. Bunches at harvest weigh from 5–50 kg depending on variety and environmental conditions. Individual fruits can number up to 300 on a bunch and are usually from 15–30 cm in length and 50–300 g in weight. The peel of mature banana fruit is usually green and ripens to a yellow colour, but in some cases is orange, reddish or red-brown. Fruit flesh color ranges from whitish to cream, yellow, yellow-orange, and deep orange.

DISTRIBUTION

The primary centre of origin is thought to be Malesia (Malaysia, Indonesia, Philippines, and Papua New Guinea). Bananas are now cultivated throughout the tropics and in certain areas of the subtropics.

ENVIRONMENTAL PREFERENCES AND TOLERANCES

Bananas generally grow best in a wet tropical climate. They can be grown on a wide range of soils provided there is good drainage and adequate fertility and moisture. The best soils are usually deep, well drained, water retentive loams with high humus content. Volcanic or alluvial origin is preferred. Soil pH of 5.5–6.5 is desirable.

GROWTH AND DEVELOPMENT

Each plant produces a series of leaves, about 40 in total, followed by a terminal inflorescence. Plants produce lateral

Table 1. Elevation, rainfall, and temperature

Elevation range	lower: sea level upper: 2,000 m
Mean annual rainfall	lower: 500 mm upper: Produces when many other crops fail because it is too wet
Rainfall pattern	Uniform rainfall is preferred for production.
Dry season duration	Because bananas store a significant amount of water within the plant, they can survive extended periods of drought (3–6 months), but yield and fruit quality usually diminish if rainfall or supplementary irrigation is not supplied within 2 weeks of a soaking rain.
Temperature	Bananas grow best between 20°C and 30°C. The optimum for dry matter accumulation is about 20°C and for the appearance of new leaves is 30°C. Banana growth processes just about cease near 10°C. Temperatures above 38°C cause growth to stop and leaf burn is common. Chilling damage can occur in the plant and fruit once temperatures drop below 13°C. Frost causes death.

shoots (suckers) from the underground rhizome leading to the next crop, a process that can go on indefinitely. Initiation of the inflorescence occurs after the plant has produced about 30–40 leaves. Recent evidence suggests that bananas are facultative long-day plants, i.e., long photoperiods promote flowering but are not essential for it. Thus flowering and subsequent harvest can occur at any time of the year so long as plant establishment and development is scheduled accordingly. At lower temperatures and when soil moisture is limiting, the development process slows. To produce larger bunches of good quality fruit, the number of suckers selected for ratoon (resprout) crops is usually limited to 1–4 depending upon the original spacing at planting.

Flowering and fruiting

The sequence from planting to harvest usually takes from 9 months to 2 years, with slower growth in cooler climates. Some varieties require a longer period from planting to harvest, for example, some Fe'i varieties, generally take 2 years or longer. Subsequent ratoon crops usually take a further 7–15 months.



Top left: Bananas can be grown in a wide range of environments, as shown here around homes in the Sepik Wahgi Divide north of Banz in the PNG highlands at an elevation of 2,000 m. Bottom left: Underpeel discolouration due to chilling damage. Right: Banana clump showing stems of successive ratoons at various stages of development.

AGROFORESTRY AND ENVIRONMENTAL SERVICES

Agroforestry/interplanting practices

For subsistence purposes bananas are commonly intercropped with a range of other naturally occurring and cultivated plants such as papaya (*Carica papaya*), coconut (*Cocos nucifera*), kava (*Piper methysticum*), breadfruit (*Artocarpus altilis*), Marianas breadfruit (*Artocarpus mariannensis*), yam (*Dioscorea* spp.), sweetpotato (*Ipomoea batatas*), aibika (*Abelmoschus manihot*), and cassava (*Manihot esculenta*). Any variety can be used in agroforestry systems. 'Karat' and other Fe'i banana varieties of Pohnpei, appear to thrive under some shade of breadfruit trees and in some situations do better if replanted each year. If not properly managed, however, competition for water, nutrients, and light can lead

to low yields. The more pest resistant varieties can thrive for many years in such systems without the need for replanting.

Environmental services provided

Banana plants establish quickly and are used in various parts of the world as shade during the establishment of crops that are sensitive to excessive sun. Crops such as cacao (*Theobroma cacao*), coffee (*Coffea* spp.), mangosteen (*Garcinia mangostana*), and kava benefit from shade during the establishment period. Bananas can be used as windbreaks that produce a useful crop, but for stronger wind events such as cyclones bananas offer little protection and are readily blown over by strong wind. Bananas grow well on steep lands but require a shade tolerant cover crop such as perennial peanut (*Arachis pintoii*) if they are to be considered useful in the control of erosion. Banana plants are aesthetically pleasing with their broad leaves and sometimes very attractive



Top left: Banana-coconut intercropping in Samoa. Top right: Bananas intercropped with giant swamp taro (*Cyrtosperma chamissonis* [often considered syn. *C. merkusii*]) in Palau. Bottom left: Mixed agroforest of banana with cassava (*Manihot esculenta*), cocoyam (*Xanthosoma* sp.), fig (*Ficus carica*), and other fruits in Hawai'i. Bottom right: 'Karat', a Fe'i banana rich in provitamin A in Pohnpei.



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Top: Bananas intercropped with coffee in PNG highlands near Mt. Hagen, providing useful shelter (wind and shade) for the coffee. Note traditional bunch covers made of natural fibers. Middle: Banana providing shade for cacao trees in Kona, Hawai'i. Bottom: Variety 'Santa Catarina Prata' providing windbreak for papaya in Hāna, Hawai'i.

colours, and are a quintessential component of any tropical garden landscape.

Advantages and disadvantages of growing in polycultures

Bananas are well suited to polyculture/permaculture systems. This is evidenced by their ubiquitous presence in polyculture systems. How well they perform depends on crop management to ensure spacing associations and nutrient inputs are suitable. Bananas grow quickly and can produce either food or economic returns within 12 months of planting in a polyculture or other system. This quick growth can also provide valuable shade and wind protection to more sensitive species. Regular deleafing of the lower senescent leaves of the banana plants can also provide valuable mulch/weed control for other species. As for many crops including several different banana varieties, a polyculture system is likely to be more robust in the face of pest and disease threats.

PROPAGATION AND PLANTING

Bananas are usually propagated from suckers and bits (pieces of corms with attached growing points), but export-type commercial plantings more commonly use tissue-cultured plantlets. In the Pacific, very large suckers are the normal planting material and are usually established once the wet season has begun. Vigorous young suckers that still have narrow leaves ("sword suckers") are preferred and are dug from existing plantings using a sharp tool such as a narrow bladed shovel. This type of planting material is the most robust, and is not easily damaged by pigs and chickens. However, banana planting materials are vulnerable to free-roaming pigs, particularly Fe'i varieties as 'Karat'. Large suckers also compete better during establishment in a shaded agroforestry setting. One important drawback of this method is that roots and attached soil are not normally removed from the base of the sucker so pests such as burrowing nematodes, are readily transferred to new planting sites.

CULTIVATION

There is considerable diversity of bananas. Types such as Fe'i, Maoli/Popoulu, Iholena and various cooking bananas of Papua New Guinea and the Solomon Islands have their centre of diversity located in the Pacific and have risen to considerable prominence. Common varieties that arrived after Western contact include 'Cavendish' and 'Mysore'. Black Sigatoka resistant varieties such as 'Kluai Namwa Khom' ('Dwarf Pisang Awak') have become quite important in recent years in the Cook Islands and Samoa following introduction during the course of development projects.



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Top left: Typical planting using “island style” banana suckers. Top middle: Banana sucker for planting material plus narrow pointed shovel suitable for digging it out. Top right: Pest and disease-free tissue-cultured plants ready for field planting. Middle left: Wind damage is the single most important cause of yield loss in bananas. Middle right: Bamboo props for bunch support in Samoa. Bottom left: Plastic bunch covers in Hawai’i. Bottom right: Traditional bunch cover of dry leaves in PNG.

Basic crop management

Once bananas successfully pass the establishment phase, the management required to get a crop is relatively minimal. Their efficiency at producing food energy relative to energy inputs is better than most other herbaceous starchy staples. The more vigorous varieties can produce for year after year with very little input. However, yield and fruit quality benefit greatly by ensuring ample water, nutrients, and the control of pests, diseases, and weeds.

Some varieties have weaker pseudostems and/or are more prone to pests of the corms and roots. This leads to loss of yield when plants fall over in strong winds. Supporting the bunches by propping or tying them can be a good investment. For commercial production, banana bunches commonly have bunch covers (polyethylene, paper, or leaves) applied to prevent damage from insect and vertebrate feeders. However, the value of this practice depends on the pests present and the requirements in external appearance for a particular market/use.

PESTS AND DISEASES

Susceptibility to pests/pathogens

Pests and diseases are major constraints to production wherever bananas are grown in the Pacific. Black Sigatoka/black leaf streak (*Mycosphaerella fijiensis*), bunchy top (vi-

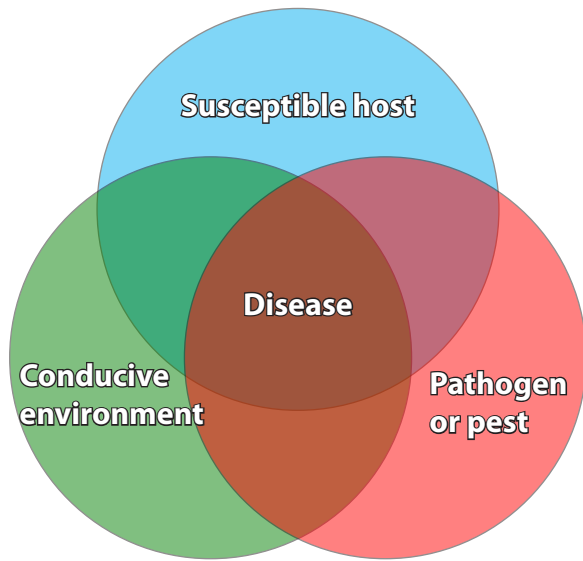
rus), burrowing nematode (*Radopholus similis*) and scab moth (*Nacoleia octasema*) all cause major yield losses in the region. There are also numerous other pests and diseases which can cause serious damage in some environments and for certain varieties. Also of major concern to sustainable production is the further spread of diseases such as bunchy top and Fusarium wilt and the entry of exotic pests and diseases such as blood disease, tropical race 4 Fusarium wilt, and banana skipper (*Erionota thrax*). In some locations fruit flies can cause serious damage to mature and/or ripening bunches but the application of bunch covers eliminates this problem. In-depth coverage of all these diseases and pests is given by Jones (2000) and Gold et al. (2002).

Sustainable methods for preventing and treating problem pests and diseases

Management of pests and diseases in an effective, efficient, and environmentally friendly manner is best understood using the conceptual framework of the disease triangle. The disease triangle illustrates the paradigm that the development of disease or pest damage caused by a biotic agent requires the interaction of a susceptible host, a virulent pathogen or pest, and an environment favourable for disease development/pest damage. Elimination or alteration of any of these three factors inhibits the ability of the pest/disease to do harm. Different pests and diseases differ in the manner in which they respond to the environment and



Left: Marasmiellus rot is a common problem in very wet climates and can be confused with other wilt diseases such as Fusarium wilt. Middle: Bunchy top is a major virus disease present in several countries of the Pacific. Right: Black Sigatoka is a major cause of reduced yields in the Pacific.



Disease triangle, illustrating the three factors required for a disease to be present.

characteristics of the host. Hot, wet weather favours leaf diseases like black Sigatoka, while hot, dry weather can favour mite damage. Some varieties including FHIA hybrids from the breeding program in Honduras are highly resistant to many pests and diseases, but not to all. Every variety has its own set of advantages and disadvantages and growers must assess what works best for their needs. Many pests and diseases are spread in infected planting material, so obtaining planting material from a clean source is an integral part of any control measure.

DISADVANTAGES

Bananas (plantains included) are the world's fourth most important food crop after rice, wheat and maize. They are

popular because their advantages far outweigh their disadvantages. That said, the most notable problem for bananas is their susceptibility to wind damage and this is the single largest cause of yield loss in banana worldwide. This is especially relevant to the many Pacific countries in the cyclone-belt. Despite their susceptibility to wind damage, some varieties of bananas are quickly able to produce another crop within about 9 months of a severe wind event without the need for replanting.

Potential for invasiveness

Most bananas are not considered to be invasive. However, wild seeded species have the potential to be spread via foraging vertebrates and can become invasive.

COMMERCIAL PRODUCTION

Postharvest handling and processing

Commercially grown bananas are normally harvested when they are mature but still hard green and transported to the market. For some international markets, the bananas may be artificially ripened. This has several benefits including (i) hard green fruit are less subject to mechanical damage/bruising during transport to the market (ii) fruit quality is generally improved as fruit fly damage and fruit peel splitting is eliminated (iii) fruit can then be uniformly ripened with ethylene gas (1,000 mg/l), which greatly facilitates marketing. The storage life of both unripe and ripe fruit is enhanced at cooler temperatures above 13°C to prevent underpeel discoloration and associated poor external fruit appearance due to chilling injury.

About half of the bananas produced are eaten raw when ripe as a dessert fruit, although some ripe bananas are cooked



Current location of bunchy top and Fusarium wilt in the Pacific region, two major banana diseases that can be managed and contained by the enforcement of agricultural quarantine restrictions. Pink = bunchy top, yellow = Fusarium wilt.

and prepared in various recipes. The other half are cooked, usually by frying, boiling, roasting, or baking. Processing of bananas is relatively uncommon because the fresh product is available year round. Processed products including chips (crisps) and dried green and ripe bananas have considerable potential but are still relatively uncommon.

Methods of processing that can be done to add value at a community or farm level

Advantages of processing bananas include:

1. Avoiding waste during production gluts. One large banana bunch alone at the household level is far more than the average family can consume fresh, so there is often excess available for drying, freezing, etc.
2. Turning the fruit into more valuable products, e.g., flour from dried green fruit, banana figs, banana juices, sweets, jam, and ice cream.
3. Increasing the quantity of fruit consumed by increasing the range of possible banana products and also replacing

other food items such as wheat-based flours, lollies, and dairy-based ice cream.

Ripe bananas, whole or sliced, can be dried with electric dehydrators or solar dryers on a small scale. They are also well suited to freezing and eating like an ice block/ice cream with various coatings. Homogenized frozen ripe banana is surprisingly creamy without the addition of dairy products. Deep fried chips can also be made on a small scale but because of the frying process their overall nutritional value is decreased. Other processing that can be considered at a community level are jams and vinegar.

Banana “figs” are simply ripe bananas that are dried. Dried bananas are healthy snack foods, providing energy, vitamins and minerals with no unhealthy added ingredients, such as fat, salt, or sugar. Varieties producing sweet fruit and slender fingers, such as ‘Pisang Kelat’, known as ‘Daiwang’ in Pohnpei, have been shown to be excellent for producing banana figs. They can be dried in a solar dryer and if there is good



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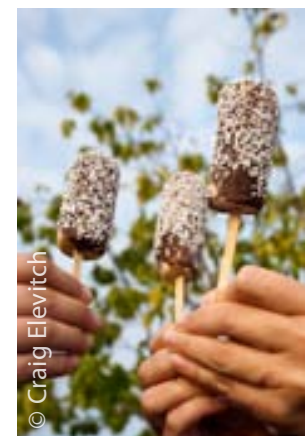
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Top left: Bananas can be dried with solar energy (in drier climates) or with forced air heating units. Top middle: “Banana figs,” bananas sliced lengthwise and dried. Top right: ‘Karat’ banana with coconut jam made in Pohnpei. Bottom left: Chips made from two types of bananas are packaged up for sale as attractive snacks. Bottom middle: Banana chips made from three different Fe’i (Toraka) bananas on Makira, Solomon Islands. Bottom right: Chocolate-covered frozen banana makes a tasty dessert treat.

sunny weather, the fruits may be sufficiently dried after about 4–5 days. The directions are as follows:

- Select a variety with a thin fruit. With good hygiene, peel bananas and place in a dryer or dehydrator. Large fingers can be sliced lengthwise to speed the drying process.
- Dry the fruits for about a week, or until they are about one-third of the original size. If a solar dryer is used for the first day and there are rainy periods, a dehydrator or oven at low temperature can be used to complete the drying process.
- Serve the “banana figs” as snacks. These are good for school lunches, workshops, or gifts.
- Store in airtight plastic bags or other containers with lids. If dried properly, the bananas can be stored without refrigeration for several weeks.

For the preparation of banana flour, select green fruit, cut into 2 mm thick slices, place in a dehydrator for about 5–6 hours at 60–65°C until crispy, or dry with a solar dryer. The dried slices can then be ground in an electric grinder and resulting flour used in common recipes such as pancakes mixed 1:1 with wheat flour.

Product quality standards

Bananas that are sold for export must be of a high standard and relatively free of blemishes. They must meet product specifications of size and appearance for the retail outlets where they will be sold. Minimum quality requirements for bananas in international trade are set by Codex Alimentarius for which there are three classes for overall appearance and degree of defects/blemish. It is essential in all three classes that any defects do not adversely affect the quality of the edible flesh. A common problem in the past in the Pacific has been ensuring management systems are in place so that banana fruit reaches the marketplace while still hard green.

Storage requirements and shelf life

If bananas are exported, it can take up to 3 weeks from harvest before they reach the market. Therefore, they must have sufficient greenlife (the period after harvest for which the fruit stays in a hard green condition) to survive this journey. No postharvest treatment can improve upon the inherent greenlife, but treatments can reduce the rate of decline. In general, the earlier the harvest, the greater is the fruit greenlife, but any gain in greenlife must be balanced against the loss in bunch weight (5–10% per week). A key to profitable banana growing is to maximize yield without premature ripening occurring. Under some circumstances fruit may be harvested early to capitalize on temporary high market prices. Maximum greenlife for a particular finger diameter (grade) at harvest is achieved by trimming excess hands

from the bottom of the bunch soon after flowering and ensuring that inputs such as water, nutrients, and pest control are optimal.

Bananas are usually consumed within a few weeks from the day of harvest, with no long-term commercial storage possible, unlike citrus and pome fruits. It is possible to delay the onset of ripening by a few weeks using modified atmosphere storage with high carbon dioxide (5%) and low oxygen (2%) and with ethylene absorbents, such as potassium permanganate, but because banana fruit is available year round there is usually no advantage in such storage methods. However, in places where refrigeration is too expensive or not available, these storage techniques may be valuable for export.

Once the fruit ripens, the period over which it may be eaten, its shelf life, is relatively short. It is usually of the order of 2–10 days depending upon variety and ambient temperature. The perishable nature of banana is associated with its high rate of metabolism. The rate of respiration during the climacteric (ripening phase) can be as much as 30 times higher than that of apples. Lower temperatures will reduce the metabolic rate. A reduction of 10°C usually halves the rate. Chilling injury occurs when the fruit is kept for a long period below 13°C.

Recommended labeling and packaging

Fruit packaging and labeling requirements vary greatly depending on the country of production and the markets in question.

For export, recommended packaging is in new fibreboard cartons (18 kg capacity or less) with ventilation holes for temperature control. Polyethylene film liners in the carton help to reduce fruit moisture loss in transit. Sheets of polyethylene between the hands of fruit can minimize rubbing damage. Transport life can be enhanced by packing all the fruit in a sealed bag under partial vacuum and by incorporation of an ethylene absorbent (e.g., potassium permanganate).

Required labeling includes exporter identification, fruit name and variety, country of origin, and official inspection, including phytosanitary certification, where appropriate. Requirements for domestic markets are far less demanding and vary greatly. Often bananas are just sold as whole bunches without any particular labeling.

SMALL SCALE PRODUCTION

Bananas are ideally suited for homegardens and are probably grown and cultivated in more gardens throughout the Pacific than any other single plant species. Bananas easily fit into the landscaping of gardens and produce a crop that can be consumed as well. They are well suited to polycultural systems and can contribute significantly to the income from

a small property within 12 months of planting (longer for some varieties), and continue to do so with relatively modest inputs. The nutritious and tasty fruit of banana is eaten by people of all ages and health conditions. The relative importance of banana as a staple in the diet depends largely on the ethnic background.

Adding value

Dried bananas and banana chip production make good cottage industries. If refrigeration is available, frozen banana and banana-based ice cream can make viable products. These processed products have a long shelf life and can be stored and sold over time to add diversity to farm sales.

Nutrition

Bananas can be eaten raw and ripe as a snack, dessert, or cooked at various stages of ripeness, including while still green and starchy as well as half-ripe and fully ripe. It is a major starchy staple in countries such as Papua New Guinea and Samoa. As a snack they are convenient, hygienic, and readily available. The soft texture of ripe bananas makes them an excellent food for the very young and old alike. Green bananas are rich in resistant starch. Research has recently shown that resistant starch acts as fiber, providing protection against diabetes. Ripe bananas, in particular those that are deep yellow or orange are rich in provitamin A and other carotenoids. Foods rich in provitamin A carotenoids help protect against vitamin A deficiency disorders



Top left: Preparing green bananas for cooking in Samoa. Top right: Banana chips are made by deep frying thin slices of green fruit, which is easily done on a small scale. Bottom left: A typical Maoli/Popoulu banana, a unique and culturally significant type of banana in the Pacific. Bottom middle: The Fe'i banana 'Asupina' has attractive orange flesh and is a rich source of beta-carotene. Bottom right: Bananas have considerable cultural significance throughout the Pacific, such as here where they figure prominently in display component of the "Houra" feast on Makira (Solomon Islands).

(vulnerability to infection and night blindness) and anemia, whereas carotenoid-rich foods help protect against certain cancers, heart disease, and diabetes. Bananas also contain substantial amounts minerals and vitamins; for instance, potassium, which is important for muscle relaxation, and vitamin C. Bananas also are rich in tryptophan, which is converted in the body to serotonin, a mood-enhancer, leading to recent information that bananas may be helpful as a “happy” food.

Import replacement

Raw and processed bananas as a snack/dessert are a cheap and nutritious alternative to sweets, ice creams, and other highly processed imported foods. As a starchy vegetable, bananas can help replace imported rice, wheat, and maize, which are rapidly escalating in price with the current world food crisis.

YIELDS

Expected range of yields per plant

Yields depend upon variety and the environment, which includes the crop management system. In commercial planta-

tions, Cavendish (AAA) bananas can yield up to 70 MT/ha (40 kg/bunch × 1,750 plants/ha), while Pome (AAB ‘Lady Finger’/‘Brazilian’) bananas can yield about 25 MT/ha (29 kg/bunch × 875 plants/ha). In polycultures, bunch weights will usually be less, but this is largely dependent on the level of inputs.

Recommended planting density

In monocultures, Cavendish bananas can be grown at about 1,750 plants/ha, while a density of about 875 plants/ha is more appropriate for those in the Pome subgroup, which are taller. Only a fraction of this density of banana plants is used in a polyculture system.

MARKETS

Local markets

The best market prospects for bananas are domestic. The more people who are employed outside of the agricultural sector, the higher demand will be at roadside stands, farmers markets, and retailers. There is potential for sales to restaurants and hotels, particularly for the tastier varieties, and those with cultural significance. The latter include varieties

Table 2. Nutrition comparison (100 g edible portions)

Food Items	Kcal	Fibre (g)	Calcium (mg)	Potassium (mg)	β-carotene equivalents (µg)	Riboflavin (mg)	Niacin (mg)	Vitamin C (mg)	Vitamin E (mg)
Ripe banana common varieties (white-fleshed, raw)	100	0.8	11	241	46	0.08	0.7	17.3	0.4
Ripe banana, cream-fleshed, raw/cooked	na	na	na	na	85–205	na	na	na	na
Ripe banana, yellow-fleshed, raw/cooked	na	na	6.5	269	232–892	na	na	na	na
Ripe banana, yellow/orange-fleshed, raw/cooked	na	na	68.6	253	565–2473*	0.47–14.30***	22.6	na	1.55
Ripe banana, orange-fleshed, raw/cooked	na	na	na	na	1450–8508**	1.76	na	na	na
Ripe cooking banana, fried, flesh colour not specified	265	2.3	6	610	149	0.02	0.6	12.0	2.2
Sweet biscuit	451	2.0	31	103	6	0.02	1.6	0	0.3
White rice, boiled	123	0.8	4	10	0	0.01	0.6	0	trace

References: The data for white-fleshed banana most likely refer to a Cavendish variety. These data and those for biscuit and rice are from Dignan et al. 2004. The data on varieties with cream, yellow, yellow-orange, and orange flesh are from bananas grown in Pohnpei and Kosrae, FSM.

Note: Age, gender, biological state, and activity levels are among the factors determining Recommended Dietary Intakes (RDI). For a non-pregnant, non-lactating female 19-65 years of age, the RDI per day are: calcium 1000–1300 mg; potassium 50–140 mg; vitamin A 500 ug Retinol Activity Equivalents (RAE); riboflavin 1.1 mg; niacin 14 mg; vitamin C 45 mg. Conversion of vitamin E 7.5 mg (Dignan et al. 2004). Note that beta-carotene equivalents divide by 12 RAE.

* These data are from ‘Karat’, a Fe’i banana from Pohnpei, FSM, which has a yellow-orange flesh when ripe. The levels are thought to vary due to several factors, including different methods of sending them to the laboratory, ways of sampling and storage, analysis, as well as the ripeness, stage of maturity and time of harvest.

** These data are from ‘Utin Iap’, another Fe’i banana from Pohnpei that has orange flesh when ripe.

*** Rich content of riboflavin (vitamin B₂) has been found in certain Fe’i bananas, in particular ‘Karat’, and to a lesser degree, ‘Utin Iap’, from Pohnpei. Newer findings on Solomon Islands bananas also indicate that Fe’i varieties are rich in riboflavin (Englberger et al. 2010).

in the Maoli/Popoulu subgroup, which are excellent if fried when ripe and served as a dessert. The Fe'i bananas, which include the famous 'Karat' variety, also make delicious desserts, especially when prepared in earth ovens and served with coconut cream, according to traditional recipes. There are numerous dessert bananas depending on the location, which can be eaten uncooked when ripe, for example, 'Sucrier', 'Cavendish', 'Gros Michel', 'Red', 'Mysore', 'Silk', 'Pisang Raja', and 'Pisang Awak'.

Maoli/Popoulu and Fe'i bananas are unique to the Pacific and with a bit of imagination would appeal to a higher end market in restaurants and hotels.

Export market

The potential for export of bananas from Pacific island countries is extremely limited. Countries such as the Philippines and Ecuador have much cheaper costs of production. The market for certain processed banana products is also likely to be very limited, because products like banana chips and dried bananas are produced much more cheaply in several

Asian countries. There may be potential for export of some varieties of Pacific island bananas, such as the Fe'i types (e.g., 'Karat', 'Utin Iap') that offer novelty and health benefits due to their rich content of carotenoids and riboflavin.

There has been a sizeable, but erratic, export of banana from Pohnpei to Guam, reaching 33.7 MT in 2004. Of the 3,977,914 MT of fresh bananas imported into the U.S. in 2008, none was imported from any Pacific island (NASS 2009). FAO data suggests only 120 MT were exported from Niue in 2005, with no other Pacific island country mentioned.

Speciality markets

Countries such as the Philippines also export some niche varieties, so the opportunity is only there while markets are very small and not of interest to larger players. An opportunity exists for some of the particularly nutritious varieties, especially if importation controls on supply are possible to ensure a sustainable and profitable market.



Top left: Small market in Pohnpei with bananas figuring prominently can be a good source of income for small family farms. Bottom left: The true stem of the banana grows up through the middle of the pseudostem, then flowers to produce the bunch. If the pseudostem is cut low enough when harvesting the bunch, the large section of true stem makes a useful handle to balance the bunch whilst carrying (Fe'i bunches pictured). Right: Variegated plantain bunch in Madang market, PNG.

BANANAS FROM MAKIRA, SOLOMON ISLANDS

Carotenoid-Rich Varieties

Yelo an orens banana an toraka blo Makira
Olketa helti tumas

Grow and eat orange- and yellow-fleshed banana varieties to help protect against:

- Malaria
- Diabetes
- Heart disease
- Certain cancers
- Vitamin A deficiency (infection and night blindness)
- Anaemia (weak blood)

Grow an *kaikalm olketa* yelo an orens banana fo *folem olketa siki olsem*:

- Malaria
- Suga
- *Siki blo hat*
- *Samfala kaen kansa*
- *Siki blo no enaf Vitamin A (olsem infekson an ae blaen fo naet)*
- *Wiki blad*



Note:

- μg (microgram) is a weight measure (one millionth of a gram). The amounts given here are per 100g.
- After you eat food containing Beta-carotene, it can be changed in the body to Vitamin A, to protect health.
- Orange and yellow colour in fruit and vegetables shows that there is Beta-carotene; darker colour flesh has higher amounts.
- Beta-carotene values are only listed for bananas that have been analysed in a laboratory at USF.
- Bananas are richer in Beta-carotene when they are ripe. Some photos are of green bananas as the ripe ones were not available when the photos were collected.

Rice 0 μg
Beta-carotene



Toraka Ailwa/Soria
3945-2172 μg Beta-carotene
Section: Australimusa
Group: Fc1
Flesh colour: Orange



Toraka Fagofaga
3428 μg Beta-carotene
Section: Australimusa
Group: Fc1
Flesh colour: Orange



Huki Ropa
1324 μg Beta-carotene
Section: Eumusa
Group: AAF
Flesh colour: Yellow



Toraka Gotageta
605 μg Beta-carotene
Section: Australimusa
Group: Fc1
Flesh colour: Yellow/Orange



Toraka Panwa
526 μg Beta-carotene
Section: Australimusa
Group: Fc1
Flesh colour: Orange



Toraka Baubaunio
333 μg Beta-carotene
Section: Australimusa
Group: Fc1
Flesh colour: Yellow



Huki Matawa
296 μg Beta-carotene
Section: Eumusa
Group: AAB (Maoti/Papouli)
Flesh colour: Yellow



Huki Twitlie
Beta-carotene not analysed
Section: Eumusa
Group: AAF
Flesh colour: Yellow



Huki Agoa
Beta-carotene not analysed
Section: Eumusa
Group: AAB (Hollina)
Flesh colour: Yellow



Huki Raesi
315 μg Beta-carotene
Section: Eumusa
Group: AA (Sierini)
Flesh colour: Yellow



Toraka Wareware
166 μg Beta-carotene
Section: Australimusa
Group: Fc1
Flesh colour: Cream



Ai samoa
58 μg Beta-carotene
Section: Eumusa
Group: AAA (Carenaholi)
Flesh colour: White

Note: The Beta-carotene values are from the same study (2004) as in the text.

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Left: The variety ‘Mangaro Akamou’, a Maoli/Popoulu-type. Bananas like this are popular and unique to the Pacific, such as here in Cook Islands. Right: Bananas are diverse in their characteristics and add much to any tropical fruit display.

Domestic supply for tourist markets including restaurants and hotels could be further developed, supplying locally grown, certified organic traditional varieties. Many Pacific islands would be better able to tap this market by adapting their cuisine to better match the expectations of their customers.

Branding possibilities

Branding helps identify the goods of a seller and differentiate them from those of others. It is about creating the perception that a product best meets potential buyers’ needs.

Pacific branding should capitalize on the region’s reputation as a place of romance, peace and tranquility, to which the customer will be “transported” if he or she buys and eats such products. Since the products are associated with pristine surroundings, the emphasis should be on producing them organically. Thus there are real opportunities to promote the perception of their health benefits.

Since the Pacific is home to some unique banana varieties, including those in Fe’i and Maoli/Popoulu subgroups, there is the opportunity to promote them as unique traditional varieties that also happen to be exceptional functional foods, rich in beta-carotene and riboflavin.

Potential for Internet sales

Due to the perishable nature of fresh bananas, there are limitations on the distance that products can travel without significant reduction in quality. Thus, Internet sales depend on freight services that can deliver quickly and inexpensively. Processed bananas do not have the same limitations as the fresh product. Most banana varieties dry well and all

are a little different from one another. Carefully marketed, 5–10 different varieties could be sold separately to develop a variety of interesting products. For example, ‘Goldfinger’ (FHIA-01) sliced in half and dried for 30+ hours produces a crisp product that is cream in colour (not brown because oxidation does not occur as for many other bananas).

EXAMPLE SUCCESSES

The Family Farm, Hāmākua, Hawai’i Island

Chris Yuen and Noelie Rodriguez started producing certified organic bananas on 0.6 ha in 1995. They learned about producing high quality bananas from friends. Almost all of their production is sold in local health food stores, with small quantities shipped to Canada together with other tropical fruits that they produce.

In order to maintain cosmetic quality and avoid sun scalding, the bunches are bagged in the field. They also have a system for keeping track of the age of bunches so that harvesting is done at an optimal time. Postharvest processing includes cutting into clusters, washing and drying, labelling, and boxing. Bananas that are shipped to Canada are boxed hard green and shipped right away, whereas bananas for the local market are ripened on a drying rack, as they sell better with a little yellow color. Great care is taken to deliver fully mature fruit free from blemishes.

The Family Farm primarily targets the certified organic market. The bananas are clearly labeled with the farm name and their organic certification. Although they do not have a way to quantify how much their organic label adds value to sales,



Banana plants at The Family Farm, showing bagged bunch and colored flagging tape for keeping track of the age of bunches.

they feel the label is important to distinguish their bananas in the marketplace. It also gives them access to health food stores.

The Family Farm has established long-term relationships with its customers. Additionally, Yuen and Rodriguez have found that it is important to deliver their product consistently over time. By having reliable production, they are set apart from hobby farmers in the eyes of the buyers, and can count on receiving a fair price.

The farm's biggest challenge is weed control, which involves much more labor than on farms that use herbicides. A secondary challenge is competition from cheap banana imports. Many consumers who buy imported bananas are unwilling to pay higher prices of the local organic bananas. Unfortunately, they are mostly unaware that organic bananas are more flavourful, free from pesticides, and have a much smaller carbon footprint than those produced overseas.

Hana Farms, Hāna, Maui, Hawai'i

In the small, remote community of Hāna, Hana Farms has developed a business model based on value-added products. About 3 years ago, the owner/operators of Hana Farms recognized that a great deal of fruit was going to waste in their area. Their business model is oriented toward bringing value to their community by purchasing fruit from local growers. Therefore, in addition to production on their 3 ha farm, Hana Farms makes use of large quantities of bananas and other tropical fruits from neighbouring small farms and home gardens. In practice, this means they purchase hundreds of dollars of fruit from local producers on a daily basis.

The company currently has 12 workers and a large number of local suppliers. Their primary product is banana bread and they also produce a popular banana-coconut curry hot sauce, as well as a range of other products. They consistently sell out of their breads and other fresh products at their



Hana Farms roadside stand along the well known Hāna Highway is the main outlet for their value-added products.

retail roadside store and via Internet sales. Recently, they have been developing plans to expand sales to other parts of Maui by establishing other retail locations.

Hana Farms believes that their locally-based product line and high quality ingredients make them unique in the marketplace. They also think that their community-based business model is appreciated by their customers because it strengthens the local economy in their remote area.

The biggest challenge is to grow their business in the current economic climate, where capital investment is difficult to obtain. However, they also appreciate the lessons learned in slow expansion based on reinvestment of profits only, rather than relying on borrowing.

Banana Joe's Fruit Stand, Kilauea, Kaua'i, Hawai'i

The Halasey family purchased their 2.5 ha farm in late 1970s with the goal of starting a family farm enterprise. They started planting banana in 1980 and selling fresh bananas at retail the year after. In order to add value to their product, they built a dehydration facility in 1981. By 1984, they were producing Banana Joe's Dried Banana Strips and wholesaling retail-size packets to Kaua'i stores. They continue to dehydrate fruit to this day. In 1986, they opened Banana Joe's Fruit Stand on the their farm, which gave them the ability to sell their fresh and value-added banana products directly to consumers.

Today, Banana Joe's sells fresh and processed products from their own farm and from other local producers. Currently, they produce banana chutney and jam, chocolate dipped frozen bananas, and smoothies and frosties (frozen fruit put through a juicer) made with 'Apple' banana (AAB, Pome). Other value-added products include dried fruit, jams and jellies, salad dressings and mustards, herbed vinegars, a range of baked goods, goat cheese, and macadamia nuts.

Most of their sales are through their fruit stand, with some limited mail order and wholesale sales. Their locally-grown product line differentiates them in the marketplace. Additionally, they specialize in particular varieties of fruit unique to their area.

FURTHER RESEARCH

Potential for crop improvement

Despite considerable efforts of banana improvement programs, banana production still depends almost entirely upon a limited number of landraces selected from the natural germplasm. It is only in recent years that modest numbers of hybrids from the breeding program in Honduras (e.g., 'Goldfinger') have been distributed and begun to be popularized. Such hybrids have been specifically bred for disease resistance including black Sigatoka. However, growers should not be under the illusion that hybrids will solve



Joe Halasey in front of Banana Joe's Fruit Stand in Kilauea, Kaua'i, Hawai'i.



The resistance of 'Goldfinger' to black Sigatoka has broken down in Samoa.



Left: Community groups are an important vehicle for reciprocal transfer of information and the general advancement of community gardening knowledge and welfare. Right: Only virus-indexed, tissue-cultured banana plants can be guaranteed free of pests and diseases.

all their problems. Experience has shown that resistant varieties cannot be relied upon in the fight against pests and diseases. It should become normal to use integrated management practices when growing a resistant variety to prevent a breakdown in resistance.

Improving potential for family or community farming

Control of pests and diseases in bananas at a commercial level is made much more difficult by poor control in nearby backyard plantings. In order to reduce pests and diseases in commercial and backyard plantings, community gardening associations need to be established to facilitate a partnership between community, government and business. This would increase the capacity of growers to better manage



“Let’s go local” campaign billboard in Pohnpei aims at increasing consumption of locally grown, healthy foods.

their banana plantings. The associations might also lead to improved marketing, greater awareness of health issues, and a general overall sense of community belonging. As an example, Pohnpei was included in a global health project, led by the Centre for Indigenous Peoples’ Nutrition and Environment (CINE), Canada, to increase local food production and consumption by targeting an entire community. It did it under the banner of “Let’s go local” as its campaign slogan. This intervention used an inter-agency, participatory, multiple method approach and showed significant improvements after a 2-year period, including an increased number of banana varieties and frequency of banana consumption. This approach could be adapted in communities in other Pacific island countries and to improve awareness of health issues and the relationship between health and local food production and consumption.

Genetic resources where collections exist

New varieties can bring new opportunities but it is extremely important to ensure that planting material obtained for their establishment does not introduce pests and diseases or lead to further spread of existing problems. Virus-indexed tissue cultured plantlets are necessary to guarantee freedom from pests and diseases. SPC’s Centre for Pacific Crops and Trees (CePaCT) in Suva, Fiji has a tissue culture collection of about 30 elite banana varieties available for distribution. A number of field collections also exist in various Pacific island countries but these sources may not be free of major pests and diseases.

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INTERNET

Bananas and plantains: <http://bananas.bioiversityinternational.org>

Specialty Crops for Pacific Island Agroforestry (<http://agroforestry.net/scps>)

Farm and Forestry Production and Marketing Profile for Banana and Plantain (*Musa* spp.)

Authors: Jeff Daniells, Principal Horticulturist, Agri-Science Queensland, Department of Employment, Economic Development and Innovation, PO Box 20, South Johnstone 4859, Australia; Tel : +61 7 40641129; Fax: +61 7 40642249; Email: jeff.daniells@deedi.qld.gov.au; Web: <http://www.dpi.qld.gov.au>

Dr. Lois Englberger, Island Food Community of Pohnpei, PO Box 1995, Kolonia, Pohnpei 96941 FM, Federated States of Micronesia; Email: nutrition@mail.fm; Web: <http://www.islandfood.org>

Adelino Lorens, Pohnpei Agriculture, Office of Economic Affairs, Pohnpei State Government, PO Box 2251, Kolonia, Pohnpei 96941 FM, Federated States of Micronesia; Email: pniagriculture@mail.fm

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