

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

Cacao

(Theobroma cacao)

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USES AND PRODUCTS

Popular worldwide, chocolate and many other products are produced from the fruit of the cacao tree (*Theobroma cacao*). Two of the main commercial products obtained from the specially processed beans of cacao fruit are cocoa liquor and cocoa butter, which are mixed with other ingredients such as sugar and milk to produce chocolate. When cocoa liquor is pressed to remove most of the butter, the resulting press cake when dried is called cocoa powder (10–25% fat), which is used in beverages, cakes, and cookies. Cocoa butter also has applications in cosmetics and soaps. In certain countries traditional beverages are also consumed locally made from processing cocoa beans at home. The white, sweet and sour cocoa pulp surrounding the beans in their pod is extracted to prepare beverages.

The worldwide commercial production for 2007–2008 was estimated to be 3.7 million metric tons (MT, or 4.1 million tons [t]) with West Africa (Ivory Coast, Ghana, Nigeria and Cameroon) accounting for 2.6 million MT (2.9 million tons); the Americas (Brazil, Ecuador, Dominican Republic) 400,000 MT (440,000 t); and Asia/Oceania (Indonesia, Papua New Guinea [PNG], and Malaysia) 650,000 MT (715,000 t). Cocoa production in Pacific islands is relatively small, with Solomon Islands being the largest producer (5,000 MT or 5,500 t), followed by Vanuatu (800 MT or 880 t) and Samoa (500 MT or 550 t). Production in Hawai'i in 2009 was estimated to be 18 MT (20 t) on 20 ha (50 ac).

BOTANICAL DESCRIPTION

Preferred scientific name

Theobroma cacao L.

Definitions

cacao	The tree, often called cocoa
cocoa	The seeds (or “beans”) obtained from the cacao fruit
cocoa nib	Pieces of crushed cocoa beans with the shell removed
cocoa liquor	A highly viscous paste obtained by crushing cocoa nibs, contains cocoa solids and butter
cocoa butter	A pale yellow fat extracted from cocoa nibs and cocoa liquor under high pressure
cocoa powder	Solids left over after cocoa butter is pressed from the cocoa liquor
chocolate	A finished product containing varying amounts of cocoa butter, cocoa liquor, and sugar. Vanilla, milk powder, and other flavorings are added to create different types of chocolate.

Family

Sterculiaceae

Common names

English: cocoa, cacao. It is appropriate to use “cacao” to refer to the plant and its cultivation and “cocoa” to refer to the beans or the product used to make chocolate.

French: *cacaoyer*

Mayan: *cakaw*

Nahuatl: *cacahuatl*

Samoan, Tongan: *koko*

Spanish: *cacao*

Brief botanical description

The cacao fruit, often termed as the cacao or cocoa “pod” exhibits a wide variety of shapes, texture, color and sizes. Each pod on an average has 30–40 seeds (cocoa beans) embedded in a mucilaginous pulp called an aril. A developing



Left: An extremely wide range of products can be made from cacao, including chocolate, nibs, and baked goods. Middle: A line of high-quality chocolate products can distinguish a farm and open doors to crossover products with other farm crops and agritourism. Right: Raw cocoa beans, ready for value-added processing.



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Left to right: Flowers, young leaves and pod, seeds within whitish pulp inside pod, and seed with testa and pulp removed.

pod at its early stage of growth is called a cherelle. Each seed has an embryo and two cotyledons enclosed in a seed coat or testa. The color of the cotyledons within the seeds depends on the variety and usually ranges from white to deep purple in color. A large number of flowers are produced on 2–3-year-old branches and on the trunk, a flowering habit termed cauliflorous. The flowers are formed above old leaf scars (called flower cushions) are usually pink in color, have long pedicels, 5 sepals, and 5 petals. The male part of the flower or stamens, are present in two whorls of 5 each, with 5 inner whorls of fertile stamens with two anthers each and 5 outer whorls of long infertile staminodes. The ovary has a long style and 5 carpels with many ovules.

Variability of *Theobroma* species and known varieties in *T. cacao*

Of the 22 known species of the genus *Theobroma*, only *T. cacao* is widely cultivated outside of its native range of distribution. Several other species are cultivated or wild-harvested on a relatively small scale for human consumption, *T. bicolor* (mocambo, pataste), *T. grandiflorum* (cupuaçu), and to a lesser extent, *T. speciosum* and *T. subincanum*.

Since the mid 20th century, *T. cacao* varieties have been classified into three general groups: ‘Criollo’, ‘Forastero’, and ‘Trinitario’. Recent genetic studies indicate that this broad categorization is overly simplistic with regard to the term ‘Forastero’ and fails to acknowledge the significant amount of genetic variation contained within this group. In contrast, ‘Criollo’ refers to a group of genetically similar trees that produce lightly pigmented seeds and share several other morphological traits. ‘Trinitario’ refers to hybrids between ‘Criollo’ and ‘Forastero’ trees.

‘Criollo’

This group is genetically narrow and is believed to have been domesticated by the Mayan civilization. The seeds (beans) tend to be round in profile and contain white or pale purple cotyledons. Young seedlings can be identified by the presence of green cotyledons and by leaf stems (petioles) with a horizontally opposed orientation. Although rare ‘Forastero’ trees may have white seeds, several other unusual traits can be used to identify trees of ‘Criollo’ ancestry. Notable characters include a unique growth habit that frequently lacks the usual whorl of five branches (jorquette) and consists entirely of plagiotropic stems with occasional bi- and trifurcating branches. Fruits typically have a soft thin husk with a textured surface and usually have some degree of red pigmentation. Many ‘Criollo’ trees in Hawai‘i have pods that when mature have a deep red color with yellow grooves. ‘Criollo’ trees exhibit symptoms of inbreeding depression and have a



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Two distinct types grown in Samoa.



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Left: Young 'Criollo' seedlings can be identified by green cotyledons (not shown here) and by leaf stems (petioles) with a horizontally opposed orientation. Right: Many 'Criollo' trees in Hawai'i have pods that have a deep red color with yellow grooves when mature.

history of low vigor, poor productivity, as well as susceptibility to disease, insects, and stress. Until the mid-eighteenth century, 'Criollo' was the most commonly cultivated type of cacao but the vast majority of trees have been replaced by more vigorous and hardy trees of hybrid or 'Forastero' ancestry. Chocolate made from 'Criollo' is light in color and has a subtle or delicate taste that is low in basic chocolate flavor. 'Criollo' beans often sold at higher prices, which can somewhat offset their lower yield. "Criollo" may be translated as "native" or "first grown" in Spanish-speaking countries of the Americas. Therefore it should be noted that so called 'Criollo' cacao in many countries may not have the typical genetic profile of pure 'Criollo'.

'Forastero'

In contrast to 'Criollo', 'Forastero' means "foreigner" in Spanish. It refers to any trees that are not 'Criollo' or a hybrid thereof and that usually produce deep purple seeds. The term 'Forastero' encompasses a wide range of distinct populations with unique characteristics and is not a meaningful descriptive term. Because of the high genetic variability within this group, 'Forastero' types exhibit greater variability in tree and fruit morphology and are generally more vigorous and less susceptible to disease and pests than 'Criollo' trees. Several landraces are particularly well known. The 'Amelonado' type is widely grown throughout western Africa and produces the majority of 'bulk cacao' beans. Although 'Forastero' beans are said to produce chocolate that is rich in chocolate flavor but low in complex or fruity flavor notes, there are several well known exceptions. The 'Nacional' cultivar from Ecuador has long been renowned for its fine flavor. Also, cocoa produced from Waiialua Estate in

Hawai'i has predominantly 'Forastero' ancestry, yet has received several reviews praising its fruity and complex flavor profile.

'Trinitario' and other hybrids

In the strict sense, 'Trinitario' refers to clones, or the progenies, of hybrids originally produced in Trinidad between 'Criollo' and 'Forastero' trees that originated in the lower Amazon River basin. However, many modern cacao plantings around the world, including those in Hawai'i, are comprised of hybrids of mixed ancestry and do not fit into the traditional categories of 'Criollo', 'Forastero', and 'Trinitario'. Which is the best variety for any given agroecosystem in Hawai'i is unknown. Research is currently being undertaken by the University of Hawai'i in statewide field tests of replicated, grafted ten-selection plantings that represent a wide range of cacao germplasm.

DISTRIBUTION

Native range

The genus *Theobroma* is native to the tropical rainforests of South America and the primary center of diversity is in the upper Amazon region of Brazil, Peru, Ecuador, Venezuela, and Colombia. Its use and cultivation spread to Central America as far north as the Yucatan peninsula in pre-Columbian times.

Current distribution worldwide

Cacao is distributed 18°N and 15°S of the equator. After the arrival of the Europeans, the cultivation of cacao spread to the Caribbean islands, Asia, and Africa. It is currently grown

Elevation, rainfall, and temperature

Elevation range	lower: sea level upper: 500–600 m (1,640–1,970 ft). Exceptions include Colombia (1,400 m or 4,600 ft) and Uganda (1,200 m or 3,900 ft)
Mean annual rainfall	lower: 1,500 mm (60 in) upper: 2,800 mm (110 in)
Rainfall pattern	Cacao grows well in climates with summer, bimodal, and uniform rainfall
Dry season duration	3 months, exception Ecuador with 6 months
Mean annual temperature	lower: 18°C (64°F) upper: 32°C (90°F)
Minimum temperature tolerated	10–15°C (50–59°F) (Bahia, Brazil) and will not tolerate frost

in a number of Pacific islands, including Papua New Guinea, Fiji, Solomon Islands, Samoa, and Hawai'i.

ENVIRONMENTAL PREFERENCES AND TOLERANCES

The optimal conditions for cacao cultivation include uniformly distributed high rainfall (1,500–2,000 mm or 60–80 in) and temperatures of 18–21°C (64–70°F) minimum and 30–32°C (86–90°F) maximum. However, cacao can also be grown in areas with long periods (3 months) of dry weather such as occurs in West Africa and Rondonia state in Brazil. An exception to the rule is Ecuador, which has even longer dry periods (5–6 months), but quite unique environmental conditions such as lower temperature, high humidity, and cloud cover during the drier periods.

Soils

Cacao can be grown in a wide variety of soil. Soils with deep profile (1.5 m or 5 ft), permeable, clayey sand (sand 50%, clay 30–40%, silt 1–2%), good water holding capacity, fairly

high organic matter content (3.5+%), C:N ratio >9, and pH of 6.5–7.5 are considered favorable for cacao cultivation. Cacao can withstand flooding and long periods of drought, but cannot tolerate waterlogging, especially in acid soils. The soils that facilitate the unimpeded growth of the taproot to at least 1 m are ideal, especially in conditions where there are frequent high winds. Available P (40 ppm), and micronutrients such as Ca (8 ppm), K (0.24 ppm), and Mg (2 ppm) are considered essential for good nutrition of the tree.

GROWTH AND DEVELOPMENT

The first four leaves from germinating seeds are formed from short internodes and the subsequent leaves are formed from longer internodes arranged spirally. Seedlings grow vertically to a height of 1–2 m (3.3–6.6 ft) before 3–5 side branches appear (this branch point is called the jorquette). Leaf flushing in mature trees is often stimulated by environmental factors such as long dry periods followed by rainfall. The new leaves are pale green, pink, or red in color, and later become dark green as they mature and harden off. The plant has two types of branches or stems: vertical growing (orthotropic), also called chupons, and lateral growing (plagiotropic), also called fan branches. A seedling grows orthotropically until it forms the first jorquette. On young trees, new chupons may sprout at any point on the original orthotropic trunk but usually appear just below the jorquette. Mature trees will occasionally form chupons on large plagiotropic branches. Chupons can also grow from the base of a mature tree and often can replace the main trunk. The cacao tree can grow up to 20 m (66 ft) tall in tropical rainforests where the sunlight is poor, however, in small farms and plantations the tree height usually ranges from 4 to 10 m (13–33 ft). The taproot system is 120–200 cm (47–61 in) long with extensive



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Left: A chupon is a vertical growing stem such as these young shoots from the base of a tree. Middle: A jorquette is the point where lateral branches grow from a chupon. Right: Jorquette on an older tree.

lateral or feeder roots present in the top 20 cm (8 in) of the soil. Trees produced by grafting and rooted cuttings from fan branches naturally grow into highly branched shrubby trees unless pruned. If orthotropic shoots (chupons) are used for vegetative propagation, the tree architecture will be similar to the normal growth habit produced by seedlings.

Flowering and fruiting

Mature cacao trees are capable of producing pods throughout the year depending on the climatic conditions, often with one or two peak harvests. Pods are harvested usually 5–6 months after flowering, which may be synchronized by the first rainfall after a dry period. Flowering may also be related to warmer temperatures.

Out of the large number of flowers that are formed only 1–5% are pollinated. Pollination is often done by various small insects, including midges. During the first 40 days, the tiny pods grow slowly, after which pods undergo a rapid phase of growth. During the next phase (85–140 days) the growth of the pod slows down and the growth the cacao seeds commence with the accumulation of fat. This is followed by the ripening phase. It takes 5–6 months after pollination for the pod to reach its full maturity.

AGROFORESTRY AND ENVIRONMENTAL SERVICES

Agroforestry/interplanting practices

Cacao farms are established often in thinned (Brazil, West Africa) or cleared forests (South America, Asia) or intercropped with other tree crops such as coconut (*Cocos nucifera*), rubber (*Hevea brasiliensis*), or fruit trees. When being established in fallow land, cacao seedlings (ca 1,000 trees/ha or 400 trees/ac) are planted under temporary shade of banana or plantain or leguminous tree crops such as *Gliricidia sepium* (called “madre de cacao” in Spanish, meaning “mother of cacao”), *Inga* spp., and *Albizia* spp. Shade intensity is a critical factor for successful establishment and fruit production. Cacao trees are prone to wind damage and their cultivation often suffers in tropical trade winds as well as in cyclone-prone areas. Shallow-rooted shade trees that are not firmly anchored can also cause damage by falling on cacao trees.

Environmental services

Very few reports exist on environmental services provided by cacao trees. On the contrary, several indicators point to deforestation due to large-scale cacao farming. Rare examples do exist as in Brazil (*cabruca* system), Dominican Republic, Cameroon, and Nigeria where it has been shown that although cacao agroforests have an overall lower diversity of tree species than native forest, they are able to maintain better biodiversity and obtain better economic returns

to the farmers than non-shade cacao plantings. Recent studies (Rolim and Chiarello 2005) from Brazil have shown that *cabruca* forests are not only less diverse and less dense than secondary or primary forests of the region, but also, and more importantly, their natural succession and gap dynamics are being severely impaired. As a consequence, *cabruca* systems present a structure where tree species of late successional phases are becoming increasingly rare while pioneers and early secondary species are becoming dominant. It is pointed out that if current management practices of thinning and clearing of native trees are not improved, the long-term survival of these forests is questionable and their role in maintaining biodiversity in the long run is limited. Studies in Malaysia have shown that soil erosion and runoff, a problem in tropical ecosystems can be reduced by intercropping with the nitrogen-fixing shade tree *Gliricidia sepium*.

Advantages and disadvantages of polycultures

Cacao intercropping with other tree crops such as coconut, rubber, betel nut (*Areca catechu*), and fruit and timber trees is found around the world. There is evidence that polycultures can mitigate damage from certain pests, as in the Brazilian *cabruca* system, which has been shown to give much higher yields in witches’ broom infested areas than monoculture cacao farms. A critical economic analysis of capital and labor inputs is recommended for choosing the companion crop or crops. The factors that may negatively affect the cacao crop are competition for nutrients, water, and the possibility of associated crops as vectors of pests and diseases. The benefits of bananas and plantains at early stages of the crop have been well established. However, more work needs to be done on the selection of crops (fruit, timber, cash) in cacao polycultures.

PROPAGATION AND PLANTING

The least expensive and the most common way to propagate cacao is from seed. A major drawback however with seedlings is variability in yield, disease resistance, and a number of other agronomic factors. Some types of cacao (‘Amelonado’ and some ‘Criollo’) are self-pollinated and produce seedlings similar to the seed parent. Seeds collected from ripe pods must be planted immediately and not allowed to dry out. Drying destroys viability. Seeds can be sown directly in the orchard provided the soil is prepared (not sod) and a plastic film-covered cage or protective tree tube placed where the seedling will emerge.

Seedlings can be produced in pots using clean media such as compost and cinder, or commercial peat-based potting mix and perlite, or top soil. Plant seeds horizontally about 10–20 mm (0.4–0.8 in) deep. Use pots or plastic bags no less than 5 × 5 × 12 cm (2 × 2 × 8 in) with good water drainage. Shoots should emerge in 10 days in a warm (32°C or 90°F)



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Top left: Young planting of cacao with banana, papaya (*Carica papaya*), squash (*Cucurbita* sp.), Indian almond (*Terminalia catappa*), noni (*Morinda citrifolia*), and other crops in Samoa. Top right: Mature stand of cacao growing in a diverse system with fruit and timber trees in Samoa. Middle left: Cacao growing together with coffee (*Coffea arabica*), macadamia nut (*Macadamia integrifolia*), and coconut in Kona, Hawai'i. Middle right: Young cacao trees interplanted with banana (*Musa* sp.) in Hāmākua, Hawai'i. Bottom left: Polyculture of cacao, banana, and pineapple in Kona, Hawai'i. The latter two crops can provide early yields while the cacao trees come into bearing. Bottom right: Cacao and banana growing under the high-value timber tree *Cordia alliodora* in Panama.

screen house, longer if cooler. Germination can be hastened by removing the mucilage prior to sowing.

Seedling vigor depends on quality potting mix (including compost) and proper maintenance in the nursery. The nursery requires an adequate supply of water and protection from direct sunlight and wind. Seedlings can be maintained up to 12 months in the nursery, provided pots are deep enough, before transplanting in the orchard. Young seedlings are sensitive to over-fertilization. It is important that irrigation water does not have extremes in pH or contain a high level of total dissolved solids.

Recently, clonal materials have been propagated by grafting onto seedling rootstocks. High success rates (90%) can be achieved using a top cleft graft, paraffin wax grafting tape, and small plastic bags covering the scion and graft union.

Air-layering has also been successful for propagating cacao. Although labor intensive, air-layering is easy to accomplish with simple tools and does not require a rootstock.

In Ecuador (e.g., variety CCN51), Brazil (several varieties produced by BioFabrica), and several other countries, superior trees and varieties have been propagated by rooted



Top left: Four-month-old seedling transplanted (left) and seedling 5 weeks after direct-seeding (right). Top right: Newly grafted seedling. Bottom left: Container-grown seedlings for sale at 4-leaf stage. Bottom right: Hawai'i Statewide Cacao Trial planting using 90 cm (36 in) wide woven black ground cover cloth, with 90 cm x 10 cm (36 in x 4 in) tree tubes/shelters spaced 3 m x 3 m (10 ft x 10 ft) with rows staggered 1.5 m (5 ft), and irrigated with 3.8 liter/hr (1 gallon/hr) drippers.

cuttings. Tissue culture methods have also been developed, but large scale application of this method has not been practiced.

CULTIVATION

Basic crop management

Depending on the soil type, planting holes (40 × 40 × 24 cm or 16 × 16 × 10 in deep) are usually dug before transplanting the seedlings. If smaller pots (5 × 5 × 20 cm or 2 × 2 × 8 in) are used then the holes need only be 15 × 15 × 25 cm (6 × 6 × 10 in) deep. Adequate soil moisture is needed during establishment. Cacao seedlings require shade in the nursery or if direct-seeded in the field. Cages or tubes provide some shade, warmer temperatures, high humidity, and windless environment. Many farms in Hawai'i do not use shade beyond the first 4 months in the field. Windbreaks are essential in areas exposed to trade winds—these can be trees, tall bunch grasses such as bana-grass (*Pennisetum purpureum*), or an artificial barrier such as vertically mounted 50–80% shade cloth. Bananas and plantains are often used as shade crops and also provide income during the establishment period. Success of this system depends upon adequate rainfall and proper soil nutrition. Additional crops such as cocoyam (*Xanthosoma* spp.), pigeon pea (*Cajanus cajan*), papaya (*Carica papaya*), and cassava (*Manihot esculenta*) are planted as temporary shade in West Africa. Cover crops have been recommended to reduce weeds but are often difficult to implement and their management can be labor intensive.

Recommended planting density

Optimum spacing between cacao trees varies depending on the management system and ranges from 2.5 m × 2.5 m (8 ft × 8 ft) to 5 m × 5 m (16 ft × 16 ft), which results in densities of 750–1,500 trees/ha (300–600 trees/ac). Spacing depends on environmental conditions and whether cacao is grown together with other crops and/or shade trees. In Asia, cacao tree density averages 1,000 trees/ha (400 trees/ac) and pod yields are 25 pods/tree per year if good farming practices are adopted. For polycultures, the number of cacao trees may be 400–600 per ha (160–240 trees/ac).

Currently there are no standard spacing recommendations. Farmers practicing the high density methods of SE Asia plant trees 1–2 m (3–6 ft) apart in double rows separated by 2.4–3 m (8–10 ft) alleys. Another common spacing is 2 m × 4 m (6 ft × 12 ft). A spacing of 3 m × 3 m (10 ft × 10 ft) with the rows staggered by 1.5 m (5 ft) is being used in Hawai'i trials to permit a more natural tree shape to better evaluate the selections.

Special horticultural techniques

To obtain good yields, proper fertilization, weeding, and pruning to maintain the tree architecture are recommended



Top: Closely spaced cacao orchard in Kona, Hawai'i. The dense leaf litter and shade from the cacao trees covers the soil surface and helps to retain moisture and suppress weed growth. Bottom: Understory in Samoan cacao agroforestry.

during the life time of the crop. Commercial N-P-K fertilizer plus micronutrients (Fe, Zn, B) is applied at a rate of about 500 kg/ha/yr (310 lb/ac/yr), depending on the soil characteristics. A target for a producing orchard in Hawai'i is 150 kg/ha N, 75 kg/ha P, and 150 kg/ha K.

In addition, integrated pest management (IPM) practices are also recommended to reduce losses due to pest and diseases. IPM may or may not include use of chemical pesticides. While adequate rainfall is essential for good yields, waterlogging should be avoided by ensuring proper drainage.

PESTS AND DISEASES

Susceptibility to pests/pathogens

Depending on the region, cacao trees and pods are susceptible to a variety of pests and diseases and losses can range from 30 to 100%. Disease epidemics have often forced farmers to replace cacao with other crops or abandon cultivation altogether. There are numerous such examples in Brazil (witches' broom disease), Ecuador (frosty pod rot disease), Malaysia (cocoa pod borer), Indonesia (vascular streak dieback), and West Africa (cocoa swollen shoot virus). The major fungal diseases are witches' broom, frosty pod, vascular streak dieback, and black pod. While witches broom and frosty pod are confined to the Americas, black pod occurs worldwide. Fungal diseases can also cause tree death, but most such as vascular streak dieback, *Ceratocystis* wilt, and *Verticillium* wilt are not widespread. The viral disease Cocoa swollen shoot virus (CSSV), which is transmitted by mealybug, is widespread in West Africa. Examples of major pests are plant feeding or pod boring insects such as mirids and capsids (West Africa) and cocoa pod borers (Asia).

Pacific islands are currently relatively free of major pest and disease problems. However, a recent outbreak of cocoa pod borer (CPB) in Papua New Guinea is alarming. This pest could easily spread to neighboring Pacific islands. Extension personnel should be trained in monitoring (pheromone traps) and managing methods for CPB. Black pod is another disease that can cause severe losses if rainfall is heavy, including in Hawai'i (particularly the windward side of Hawai'i Island). However, low toxicity copper-based fungicides are available to manage black pod. Chinese rose beetles attack cacao leaves and coffee black twig borers affect branches in Hawai'i. Aphids, mealybugs, and thrips can cause substantial damage in nursery seedlings, but are not usually damaging in field plantings.

The most likely entry of cacao diseases and pests is the importation of live cacao, whether it be pods, seeds, plants, or bud wood. Importation is unnecessary into Hawai'i since there currently exists a wide range of genetic variation in cacao in Hawai'i, including high yield seedlings and varieties.

Importation of dried seed for roasting should be avoided unless the seed has been fumigated, but importing roasted nibs poses no danger.

Sustainable methods for pest and disease prevention

Preventing or managing pests and diseases requires good agricultural practices including maintaining tree height to less than 4 m (13 ft), phytosanitation, application of organic or chemical fertilizers, and Integrated Pest Management (IPM). In order to avoid large-scale pest outbreaks, many farmers must apply these practices throughout the growing region, especially if the pest or disease is a rapidly spreading one.

Pacific islands are currently relatively free of major pests and diseases. However, a recent outbreak of cocoa pod borer in PNG is alarming and this could easily spread to neighboring Pacific islands. Extension personnel should be trained in monitoring methods to help stop pest and disease outbreaks before they become widespread.

DISADVANTAGES

When production levels are low, as they generally are in the Pacific islands relative to other regions, marketing raw cacao beans for the commodity market may not be sustainable. Unless local consumption is high, unique regional flavor characteristics are developed, or there are possibilities for developing specialty markets, long-term economic viability of the crop as a dependable sole cash crop is debatable. To avoid the problems mentioned above, intercropping with other cash crops such as fruit trees can be recommended.

Pests and diseases may be another limitation. If invasive pests or diseases are introduced, losses may be too high for the crop to be sustainable. Unless the farmers are aware of good farming practices and prepared to meet challenges, long-term sustainability of cacao as a sole cash crop may be difficult.

Potential for invasiveness

Cacao is not known to be an invasive species and is rated as "low risk" by the Hawai'i Ecosystems at Risk (HEAR) project.

COMMERCIAL PRODUCTION

Fermentation

In addition to the varietal differences, fermentation of cacao beans is an important step for obtaining proper flavors. The method of fermentation varies depending on local tradition and amount of beans fermented. The fermentation infrastructure can be established at a household level (small boxes or baskets) or at a community level (large boxes). The latter needs better organization and leadership capabilities.

Quality processing is key for exporters or processors who are constantly looking for single-origin ingredients and unique flavors. The minimum quantity of wet beans for a normal commercial-scale fermentation is considered to

be 100 kg (220 lb). The duration of fermentation is usually 5–7 days (120–168 hours). The fermenting mass is usually mixed to encourage uniform fermentation at least once, but most often every other day.



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Common pests and diseases of cacao. Top left: Black pod caused by the fungus *Phytophthora* sp. Top center: Chinese rose beetle damage to leaves. Top right: Anthracnose fungal spots. Bottom left: Rats can cause considerable damage to pods. Bottom center: Small, black aborted fruit together with healthy red pods. Bottom right (upper): A symptom of black twig borer attack is whitish exudate on stem below or covering the entry hole. Bottom right (lower): pod damage caused by the cocoa pod borer.

Pods can be stored at ambient temperature for up to a week. With longer periods, some seeds may germinate, which is undesirable. During the fermentation process, molds and bacteria can enter the seed through the dying root of a germinated seed and cause off flavors, even after the seed is dried and roasted. Check a few pods periodically to make sure that the seeds are not germinating inside the pods. However, improper fermentation can result in invasion of undesirable microorganisms even without seed germination.

Fermentation in Hawai'i can be challenging for two reasons. First, starting the fermentation during cool periods (particularly November to May) at ambient temperature can be difficult. Second, farmers may not have sufficient mass of fresh seed at one harvest (100 kg or 220 lb) to easily sustain

fermentation. Many farmers attempt ferments as small as 11 kg (25 lb). Such small quantities of seed, cooler air temperature, constant breeze, and low humidity require controlling the starting temperature of the fermentation which should reach 35–37°C (95–100°F) within the first 24 hours. Use of solar energy to warm the pods prior to opening, warming the seed in plastic bag, fermenting in a insulated chest with drain holes, employing a nursery seedling warming mat, warming the air around the fermentation, and restricting airflow in the fermentation area are all strategies that can ensure a successful fermentation. A digital or composting thermometer with a long probe can be used to monitor fermentation temperatures. For hobbyists, even a cardboard box with a light bulb or small incubator that can reach 46°C (115°F) is effective.



Top left: Inexpensive materials for fermenting a small quantity of beans. Top right: Fermentation in a temperature-controlled environment. Bottom left: Freshly cut seed prior to fermentation, note white embryo. Bottom center: Freshly cut seed after 6 days of fermentation, note embryo has darkened and presence of brown to purple liquid. Bottom right: Freshly cut seed after drying to 6% moisture content.

Fermentation usually is carried out 5–7 days, depending upon variety, starting temperature, quantity of seed, and external temperature. ‘Criollo’ is often fermented for a shorter time than other types, with 2–3 days being common. Normally the fermentation begins with naturally occurring yeasts and bacteria. Small ferments (0.5–10 kg or 1–22 lb) benefit from the addition of baker’s yeast, which hastens the start of fermentation and prevents molds from growing. It is important that fresh yeast is used, as old yeast may be weakly active or dead. To ensure that the yeast is still alive before using, it can be proofed by adding ½ teaspoon to 12 ml (4 oz) of 37°C (99°F) water and ensure that there is active foaming after 5–10 minutes. To inoculate small fermentations, dissolve ¼ teaspoon of yeast in one liter (approximately a quart) of water and mix 2 teaspoons of yeast solution per kilo (1 tsp/lb) of wet cacao seed.

Cut tests on the beans should be conducted to evaluate the fermentation. Under-fermented beans are slaty (purple in color) inside. Fully fermented beans with good flavor are brownish-purple in color. Over-fermentation of the beans results in beans tasting too acidic or with tainted with flavors associated with undesirable fungal growth. Putrefactive and ammonia smells are clear indicators of over-fermentation. Overly acidic beans can also result from rapid artificial drying. Working with an expert in commercial operations is essential to standardize fermentation methods, which determine the flavor characteristics of the beans.

Drying of fermented beans is necessary to halt fermentation and avoid molding and off flavors. Sun drying to 6–7% moisture is often done on wood framed platforms with mesh or screened bottoms. The drying platforms are often kept within plastic-covered structures or are constructed with hinged waterproof lids to protect the beans from rain. Drying racks should be protected at all times from bird and rodent access, as these animals’ excrement is often a source of food born pathogen contamination (such as *Salmonella* and *E. coli*) in cacao seeds and chocolate. Sun-drying in acceptable weather conditions takes 7–14 days, depending on bean size and climatic conditions. In areas where drying is difficult due to heavy rains during the harvest season, platforms should be easily covered at the first signs of rain. Low temperature (45°C or 113°F) propane or electric heated air blowers can also be used during wet periods to avoid development of off flavors. Drying beans using wood-fired driers should be avoided, as this methods gives the beans a smoky flavor.

Value-added processing

Small-scale chocolate processing

Bittenbender and Kling (2009) present an annotated pictorial of harvesting, pod cracking, fermenting, drying, roasting, cracking, winnowing, and chocolate making for small-scale

producers. Briefly, the process is as follows. After drying to 6–8% moisture (seed coat and seed can be crumbed by hand) the seed is stored for at least one month at ambient temperature in a insect proof container such as a plastic bucket with fine mesh screen over the top to exclude insects. The seed is then roasted in a convection oven at 135–150°C (275–300°F) for 30–40 minutes for darker, more chocolatey flavors, and 15–25 minutes for fruitier flavors. Alternatively, it can be gently stir fried in stove-top pan. An aroma of baking brownies should be noticed. Stir seeds while roasting to ensure uniform roasting. After seeds have been roasted and cooled, they can be crushed with a rolling pin on a counter top, in specialized hopper crusher, or even in a coffee huller. The goal is to crack the roasted seeds into pieces of shell (testa) and nib (cotyledon). If the pieces are not too small, the shell and nib can be separated using a simple winnowing process. Winnowing can be done by gently pouring from a bucket to a drop cloth or pan using natural breeze or wind from a fan, hair dryer, or vacuum cleaner. Separating out the shell is essential as the shell pieces do not have a good chocolate flavor or texture.

Next, the nibs are ground into a thick paste, called cocoa liquor, which is mixed with cocoa butter, sugar, and other ingredients such as milk powder, depending on the type of chocolate desired. To achieve a smooth mouth-feel, this mixture is finely ground in a special machine called a melanger over a period of 6–72 hours. The heat of friction keeps the molten chocolate warm during the conching process. The final process is tempering, which is a controlled-temperature cooling while stirring to cause the chocolate to crystallize into in a form that has optimal texture and appearance (see photos next page).

Other value-added products

The Indonesian Cocoa Research Institute (ICCRI) and Cocoa research Institute of Ghana (CRIG) have developed various products such as jelly, soaps, cosmetics, cattle feed, and manure-based fertilizers from cocoa. Technology transfer from Indonesia of low cost methods to process cocoa should be explored.

Cocoa pulp is extracted using low cost machines in Indonesia, Brazil, and Ecuador and used to make drinks. Cocoa jelly is made from the first day’s sweating (drippings from fermentation heaps) during the fermentation process. Alcoholic drinks can also be made from cocoa sweating.

Cocoa husks are rich in potash, which should be returned to the cocoa fields after composting. Soaps are also made from ash of pod husks. Animal (cattle, pigs, poultry) feeds can be mixed with ground up cocoa husks.



Top left: Roasting nibs in home coffee roaster. Top right: Hand-cranked hop crusher does a good job of cracking the roasted seed. Middle left: Nibs after cracking. Middle center: The shell and nibs must be separated before the nibs are ground into cocoa liquor. A hair dryer on a cool setting can be used to winnow the shell from the nib. Middle right: For larger amounts, a vacuum cleaner system such as this can provide an airflow that carries the shell into one bucket (orange), while depositing the nibs into another bucket (white). Bottom left: A Champion™ juicer produces fine cocoa liquor in the left bowl and chunky liquor in the right. The right bowl contents are reground until all is in the left bowl. Bottom right: Cocoa liquor can be made directly in the melanger (wet grinder) before the other ingredients for chocolate are added.



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Top left: Cocoa liquor, sugar, cocoa butter, and other ingredients are combined in the melanger. Top right: After 24 hours in the melanger, the chocolate has become sufficiently smooth. Middle left: Cooling the chocolate to 45.5°C (114°F) prior to tempering. Middle right: Tempering on a granite slab to remove heat from the molten chocolate while working it and cause desirable crystals to form. Bottom left: Finishing the tempering in a bowl. Bottom center: Pouring chocolate into forms, in this case with a macadamia nut in each candy mold. Bottom right: After a slow cooling process, the chocolates easily release from the form.



Medium scale roasting and conching equipment can be used for chocolate processing at a community level, such in this facility in Kona, Hawai'i.

Product quality standards

The International standards (ICCO) can be described briefly as follows. The beans should be well fermented (with exceptions), well dried, free from smoky flavor, free of living insects, free of foreign matter (nails, stones, glass pieces), and broken beans. Variations are seen in percentage of fat content and melting point according to variety and harvest season. Physical characteristics also determine the market price of the beans. Recommended bean weight is 1.0–1.2 g, or 83–100 beans for 100 g dry beans.

Recently, a major issue in certain growing regions has been contamination with chemical residues, mainly pesticides, free fatty acids (FFA), aflatoxins, ochratoxins, and heavy metals. Only allowed pesticides should be used and labels followed strictly. Poor hygiene during manufacturing can lead to contamination with human pathogens (*Escherichia coli*, *Salmonella*, and *Shigella*) and strict food safety standards must be applied during manufacturing process.

Product storage requirements and shelf life

Dried beans should be stored in sheds preferably in plain jute bags (not treated with mineral oils) on wooden platforms to avoid water damage. Because of high humidity in the tropics, storage periods should not exceed 3 months. The sheds should also be away from sources of smoke contamination such as wood fire or engine exhaust, and chemical containers. Precautions should also be taken to avoid storage pests and bird droppings. The bags should be stored away from the walls and regular inspection should be carried out to check for storage insects and molds.

Storage of finished chocolate should be at 10–13°C (50–55°F) and humidity less than 50%, away from strong odors. Under these conditions chocolate is stable for years.

Recommended labeling

The labeling requirements for shipping raw beans or bulk cocoa are far less important than labeling of the chocolate. Labels should include contact information for the maker, type of chocolate, and ingredients. Location of origin labeling is a new trend in marketing finished products and single origin chocolates are being sold at higher prices. However, farmers do not benefit significantly from the extra proceeds unless sold under certain labels (including fair trade, eco-friendly, and organic).

New standards require nutritional labeling of the final product, mainly the caloric value, sugar, and fat content (saturated and unsaturated fats) per serving.

There are no special Hawai'i standards for chocolate. In order to use the "Made in Hawai'i" descriptor, at least 51% of value of the product must be added in Hawai'i.

SMALL SCALE PRODUCTION

Cocoa cultivation by small farmers in Indonesia (Sulawesi) is a good example of how the crop can be grown commercially in home gardens or in small farms of 0.5–1.0 ha (1.2–2.5 ac) size. Here, the cocoa tree density is high (1,000 trees/ha or 400 trees/ac) and average annual pod yields are 25 pods/tree. If maintained well (i.e., good pest and disease management, fertilization, etc.), yields up to 800–1,000 kg/ha (1,760–2,200 lb) have been reported. With the current

price on international commodity market of \$2,500/MT, this can be a good income for small farms.

However, in Hawai'i and many other Pacific islands, world commodity prices are not economically feasible for farmers. Much higher prices must be fetched through accessing high-value specialty markets.

The Hawai'i Department of Agriculture does not collect information on cacao production. Bittenbender estimates the average Hawai'i cacao farm size is 0.4–0.8 ha (1–2 ac); the largest mature orchard is 7 ha (18 ac).

Adding value

As mentioned earlier, commercial products other than selling of raw beans, are not a simple undertaking for small family farms, and require specialized skills and equipment.

An important criteria is the ability to maintain the necessary hygiene and food safety standards.

Hawai'i has a high-end chocolate confection industry, including chocolate covered macadamia nuts and roasted coffee beans, as well as truffles. Most Hawai'i-grown cacao is sold as dry beans to hobbyist and niche chocolate makers and as roasted nibs.

Nutrition

New findings about the benefits of consuming cocoa drinks are encouraging. Studies of the consumption habits of Kuna Indians in San Blas, Panama is a good example. A locally brewed cocoa drink rich in phytochemicals known as flavanols has been linked to a better blood chemistry of the islanders than their counterparts in the mainland. New clinical trials with human subjects consuming chocolate



The tradition of consuming homemade cocoa is prevalent throughout Samoa. The simple processing method used there involves roasting the dried beans over a fire and pounding them into a thick paste, which, mixed with sugar and hot water is served as “koko Samoa,” Samoan hot cocoa.

or cocoa powder rich in flavanols confirm these findings and continue to show that cocoa flavanols and cocoa butter can help protect against high blood pressure, aid in recovery from heart attacks, and lower cholesterol, among other health benefits. Cocoa powder is rich in proteins (18%), fat (22%), carbohydrates (11%) and minerals (K, Na, Ca, Fe, P, Mg).

Simple methods exist wherein the beans can be processed to make raw cocoa, which can be used for preparing beverages with milk and sugar. This type of product is nutritionally superior to many of the processed products available in the market, especially if high levels of flavanols are present. Higher flavanols in the end product can be achieved by reducing the number of days of fermentation or by using unfermented beans.

YIELDS

Expected range of yields per plant

An average yield per tree is 25 pods per year. If well maintained (e.g., appropriate IPM, fertilization), approximately 1,000 trees/ha (400 trees/ac) yields up to 800–1,000 kg dry beans/ha (700–900 lb/ac). A subsistence farmer who practices polyculture and has a lower density of cacao trees will have lower yields per unit area. High yielding varieties can help compensate for the lower densities of cacao trees in agroforestry systems.

MARKETS

Local markets

If the local demand for chocolate products is high, then good quality cacao products have market potential locally. Therefore, local consumption of cocoa products can be encouraged by introducing new specialty products. Mentioning documented health benefits, unique flavor or quality characteristics, or regionally identified products can strengthen market position.

Export markets

The cost of temperature-controlled transportation is a factor that may prevent reliable long distance chocolate products, especially through standard air services. A range of other cacao-based products that are not temperature sensitive may be more feasible to ship.

Specialty markets

Although demand for single origin, organic, eco-friendly, or fair trade products is still small, such markets are expanding. Attempts to market products to consumers in Japan and Oceania should also be explored. As pests and diseases are not an issue yet in the Pacific islands, organic cocoa from Pacific islands is feasible.



Top: Chocolate combined with the Pacific island medicinal herb kava (*Piper methysticum*). Middle: Crossover products such as roasted coffee sold together with a packet of roasted cacao beans can spark interest in customers who are looking for something new. Bottom left: Chocolate-macadamia nut spread. Bottom right: Raw processed cacao produced in Kona, Hawai'i.

The market for so-called superfoods and raw (unheated or processed) products, including cacao, is an expanding area in the health food market. By adopting short-term (<2 days) fermentation methods, production of beans with high levels of cocoa flavanols can also be marketed. However, quality control is extremely important if attempts are made to target the above high-end markets. Also, roasting to eliminate any pathogens may be necessary.

Hawai'i farmers are selling beans to small chocolate companies and to hobbyists, as well as processed products to farmers markets, gourmet shops, and roadside or farm stalls. "Suitcase" exports by tourists are as important for chocolate as they are for such crops as macadamia nuts and coffee in Hawai'i.

Branding possibilities

As mentioned above, single origin, organic, eco-friendly, and fair trade are some of the branding possibilities that countries in the Pacific regions should explore. Fermentation of cocoa beans to obtain unique flavors or introduce high-flavor varieties are strategies that could be adopted to differentiate a regional line of products. As tourism is an important source of revenue, products catering to tourists should be commercialized.

Potential for Internet sales

Internet sales can be explored, however, this would need a strong customer base. Also, shipping chocolate products from tropical locations could pose logistical challenges to maintaining product quality. When even short periods of high temperatures could spoil the product (e.g., chocolate), other non-spoiling types of products should be considered for export (e.g., nibs, powder, other products containing cocoa). There may also be a market for dry beans from hobbyists who process their own chocolate products.

EXAMPLE SUCCESSES

Waialua Estate Cacao Farm, Waialua, O'ahu

Waialua Estate Cacao Farm cultivates about 8 ha (20 ac) of cacao on former sugarcane land on O'ahu's North Shore. The low elevation field just above sea level was chosen because it is protected from buffeting trade winds and lies near a body of water (Ki'i Ki'i stream), which helps maintain humidity in what is typically a very dry area (average annual rainfall 230 mm or 9 in). The farm was planted in 1996 as part of a diversified agriculture program following closure of Waialua Sugar Company. Michael Conway brought previous experiences of growing cacao on Hawai'i Island in the 1980s to the operation. The project was leased out and eventually abandoned in 2001 but the field was rehabilitated and brought into production again in 2004.



Fermented cocoa beans drying on racks at Waialua Estate Cacao Farm.

Trees are planted on 3.6 m × 1.8 m (12 ft × 6 ft) spacing, which gives approximately 1,620 cacao trees/ha (630 trees/ac). Mixed hybrid seedlings of Forastero, Trinitario, and Criollo were planted from trees originating from varieties collected in the 1980s. The annual yield of dry beans per tree is 800–900 g (1.75–2.0 lb). Total dry bean annual yield has been 8,200–10,000 kg (18,000–22,000 lb).

Currently, Waialua Estate Cacao Farm harvests, ferments and dries beans for processing into chocolate (bulk and packaged) by E. Guittard Chocolate Co. in Burlingame, California. These products include 70% cacao extra dark, 55% cacao dark, and 35% cacao milk chocolates. A distributor on Hawai'i Island handles all Hawai'i sales except on O'ahu. Waialua Estate's own sales and marketing manager takes care of sales in the O'ahu market and outside of Hawai'i. In addition to retail sales, their products are sold through their web site.

Waialua Estate considers their products to be unique due in part to the taste of the chocolate, which is described as having deep, dark berry tones with a lingering taste. They have received international recognition at the prestigious London Academy of Chocolate (2009, for Waialua 70% Chocolate) and at the Chocolate Salon Awards in San Francisco (2010, for Waialua 35% Milk Chocolate). The mystique of Hawai'i helps to sell the product, as it is considered a new entry among the world's fine chocolates so long as the quality is high. Also, Waialua Estate has found that chocolatiers are sensitive to the source of cacao these days and are intrigued by a U.S.-grown product and are willing to pay the high price. Additionally, their product is pesticide-free.

The biggest challenge Waialua Estate faces is to get "buy-in" from investors to expand the size of their farm to 60 ha (150 ac), which they consider to be the critical mass necessary to justify construction of a chocolate manufacturing facil-

ity. They believe such a facility could bring down the cost of production compared with shipping their cacao to the U.S. mainland, then back to Hawai'i. Their expansion scenario includes a growers' program modeled after the Kona coffee industry, as this would be the main driver in producing a reasonably affordable product together with a manufacturing facility in Hawai'i. Waialua Estate also believes it is important to maintain the high quality of chocolate by all producers throughout the state so that everyone benefits from an exceptional regional reputation.

Original Hawaiian Chocolate Factory, Keauhou, Kona, Hawai'i

Bob and Pam Cooper grow cacao and process cocoa on their farm at 240 m (800 ft) elevation. They bought their farm in 1997 when it was already producing coffee and cacao, but it was the cacao that sparked their passion. Since then, the Coopers have made a conscious effort to support the growth of the Hawai'i cocoa industry by building a medium scale processing facility to make chocolate products from their own and other farmers' cacao.

Although they buy some wet beans from other local growers, the Coopers carry out all farm and processing operations



Top: Regular tours are given by the Coopers at their farm and factory in Kona, Hawai'i. Bottom: Wide range of products made at the Original Hawaiian Chocolate Factory.

including growing, harvesting, pod cracking, fermenting, drying, roasting, winnowing, conching, tempering, molding, packaging, and storing in humidity and temperature controlled room. Their processing facility yields a wide range of value-added products including milk chocolate and two types of dark chocolate (one made from 'Forestero' and one made from 'Criollo' beans), roasted nibs, and cocoa bean winnowings that are used in cosmetics. A local candy company produces a variety of candy products using their chocolate. As part of their outreach to new markets, the Coopers have regular tours of their farm and processing facility.

Over 65 retailers currently carry their products throughout Hawai'i and they have sales representatives on Maui, O'ahu, Kaua'i and Moloka'i (the Coopers handle sales on Hawai'i Island themselves). According to the Coopers, reaching new markets is one of their biggest challenges. They do a wide variety of marketing and advertising. They have print ads in local, regional, and national magazines and Hawai'i airline magazines. They frequently give talks at local farmers markets and fund raising events. They call retailers directly and make presentations at hotels and retail venues. Occasionally they attend national chocolate or specialty food shows on the U.S. mainland. Although they sell their products through a web site, shipping chocolate is problematic since it must be transported in controlled temperatures.

The Coopers believe they produce the first commercial chocolate made with 100% Hawaiian cacao beans. They are proud to be supporting small family artisan cacao growers in their area, while expanding the Hawai'i-grown chocolate industry.

Kuaiwi Farm, Captain Cook, Kona, Hawai'i

Una Greenaway and Leon Rosner were inspired to begin growing cacao after a tour of the Original Hawaiian Chocolate Factory (see above example) in 2001. As a certified organic farm, the concept of eating homegrown organic chocolate inspired them, and the idea of creating a local product for market captured their imagination.

Greenaway and Rosner acquired seeds and nursery-grown seedlings from local nurseries and planted 200 trees on their farm at 610 m (2,000 ft) elevation. Their trees were originally spaced at 1 m × 2 m (3 ft × 6 ft), but eventually half the trees died, leaving 100 trees at approximately 2 m × 2 m (6 ft × 6 ft) spacing. As weed control can be demanding in an organic operation, they used weed mat around the trees until they grew large enough to close canopy, suppressing weeds with shade and their own leaf litter.

Familiar with processing their coffee crop to a final roasted, packaged product, Greenaway and Rosner set about learning how to process their cacao from bean to finished chocolate. They learned about the chocolate making process from



Top: Greenaway and Rosner lead a tour of their certified organic cacao agroforest. Bottom: Chocolate-making workshop participants at Kuaiwi Farm squeeze molten chocolate into forms, some with macadamia nuts and coffee beans.

a wide range of experts including local, mainland U.S., and international chocolate makers through personal visits by the experts and also via their web sites. Finally, there was a great deal of trial and error to develop a small-scale process that works for them. Greenaway and Rosner carry out all steps in the process: fermenting, drying, roasting, cracking, winnowing, grinding, conching, tempering, and molding.

When they have a surplus (beyond their own consumption), they sell 110 gm (4 oz) bags of chocolate candy, some with their macadamia nuts and some with coffee beans. Customers are friends and people who learn about them by word-of-mouth and on a farm tour. Kuaiwi Farm also presents hands-on chocolate-making classes that introduce participants to all stages in the process, from fermentation to chocolate candy. All participants leave the workshop with a sample bag of chocolates that they made.

ECONOMIC ANALYSIS

Cacao can be sold in any of three unprocessed forms: pods, wet beans, or dry beans. From the farmer's point of view,

selling pods is the easiest way to sell cacao. Extracting wet beans requires extra postharvest cost and effort, and, being highly perishable, the wet beans require careful, timely handling. If the farmer were to continue one step further to fermenting and drying the wet beans, the dry beans could be stored for lengthy periods and shipped long distances. However, the marketing then becomes problematic. Alternatively, the farmer could consider vertical integration with the intent to manufacture and market a final, end-user product, such as chocolate. Other marketing possibilities include using the husks for soap making, drying and selling nibs, or exporting beans for chocolate manufacture on the U.S. mainland. Ultimately, many growers will likely see their most attractive marketing option to be selling wet beans to a local processor who is willing and able to pay a higher price for locally grown cocoa beans.

Regardless of the form in which the cacao is sold, the average farm gate price must be high enough to provide an "acceptable" profit but low enough to allow chocolate processing to remain economically feasible. Ultimately, each grower will need to decide to what degree his or her expected profitability is "adequate." Profit margins for both farming and processing are relatively small, and in some years the margins might become so narrow that the farming and/or the processing enterprise may not be economically profitable in the short run. Based on data provided by representative Kona growers, a well managed cacao enterprise that markets its production as wet beans generates a healthy gross margin. For full details of this analysis and a computational spreadsheet, see Fleming et al. (2009).

FURTHER RESEARCH

Potential for crop improvement

Adopting new high yielding and flavorful varieties included in the Hawai'i Statewide Cacao Trial or even propagating the most outstanding seedlings in existing orchards should be explored. Methods to rehabilitate old farms or replace low yielding trees should be initiated as soon as possible. Techniques exist to shorten the process by side-grafting on older trees or air-layering large branches from high yielding and quality trees.

Improving potential for family or community farming

Community farming depends on individual farm size and organizing farmers into associations. Community processing centers are a focal point for organizing farmers, as this would serve to increase quantity of commercial cocoa available and also improve the quality by processing the beans uniformly. This is key for cocoa importers or manufacturers who buy raw cacao for processing.

Genetic resources

Cacao clonal materials are available in Hawai'i from the USDA cacao germplasm collection in Hilo or quarantine stations at Reading University in the United Kingdom. Importing materials from Asian countries or Africa is not recommended due to the presence of invasive pests and diseases. Setting up a substation in one of the Pacific islands to receive the materials and graft them to rootstocks is the first step. Clonal gardens are also needed to facilitate the distribution of planting materials.

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OTHER RESOURCES

Internet

- Open Directory page for cacao: http://www.dmoz.org/Science/Biology/Flora_and_Fauna/Plantae/Magnoliophyta/Magnoliopsida/Sterculiaceae/Theobroma
- The Chocolate Life: <http://www.thechocolatelifelife.com>
- Chocolate Alchemy: <http://www.chocolatealchemy.com>
- World Cocoa Foundation scientific research and web site library: <http://www.worldcocoafoundation.org>

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

Farm and Forestry Production and Marketing profile for Cacao (*Theobroma cacao*)

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