

**Farm and Forestry  
Production and Marketing profile for**

# Coffee

*(Coffea arabica)*

By Virginia Easton Smith, Shawn Steiman, and Craig Elevitch

## USES AND PRODUCTS

The coffee seed, referred to as “bean,” is processed, roasted and brewed for beverages. The roasted beans and brewed coffee are also used in candies, desserts and savory dishes. Many uses for the fruit, seed, and by-products can be found. The fruit pulp can be dried and used to make tea, which contains caffeine and antioxidants. The fruit pulp is high in nitrogen and potassium and is used, fresh or composted, for fertilizer and to add organic matter to the soil. The parchment skins also add organic matter and are used as mulch in coffee orchards and around other plants.

Worldwide production in 2009/2010 is forecast at 127.4 million bags (132.3 lb/bag [60 kg/bag]) and in 2008/09 it was 134.8 million bags (USDA FAS, 2009). Hawai‘i State produced 6.9 million lb (3.1 million kg) of green coffee on 6,300 ac (2,600 ha) in the 2008–09 season (USDA NASS, 2009).

## BOTANICAL DESCRIPTION

### Preferred scientific name and author

*Coffea arabica* L.

### Family

Rubiaceae

### Common names (PIER, 2009)

Chamorro: *cafe, kafé*

English: coffee, Arabian coffee

Fiji: *kofe, kove*

French: *café, cafeier, caféier d'Arabie*

Hawaiian: *kope*

Maori (Cook Islands): *kaope, kaope Maori*

Marquesas: *kafe*

Niue: *kofe*

Palau: *kohi*

Samoa: *kofe*

Spanish: *café, cafeto, cafeto arábico, cafeto de Arabia*

Tahiti: *taofe*

Tonga: *kofi*

### Botanical description

Shrub or small tree, usually 6.5–25 ft (2–7.5 m) tall, leaves are opposite, shiny, oval, pointed, 3–6 in (7–20 cm) long, 1.5–3 in (3–7 cm) wide. Flowers are white, fragrant, massed in thick clusters at leaf axils along the branches, corolla has 5 narrow lobes, longer than the tube, which is about 0.75 in (1 cm) long. Fruit is dark red, yellow, or pink when ripe, drying to brown, ovoid, fleshy berry about 0.5 in (1.2–1.6 cm) long, 0.4–0.5 in (1–1.2 cm) in diameter, usually containing two seeds.

## DISTRIBUTION

### Native range

Coffee is native to tropical Africa, probably to the highlands of Ethiopia, where the climate is considered subtropical, rainfall is high, and soil pH is slightly acid. It occurs as a mid-story species in semi-open forest, rather than in dense tropical rainforest.

### Current distribution

Coffee is currently grown as a major crop in tropical and subtropical regions of Africa and Asia (such as India, Thailand, Indonesia, and Vietnam); South and Central America, Papua New Guinea, the Caribbean (e.g., Jamaica, Cuba, and



A bumper crop of coffee. Kona, Hawai‘i.



Flowers and fruit.

Puerto Rico), and the Hawaiian Islands. In Hawai'i, coffee farms are found on all the major islands and range in size from ½ to 3,500 ac (0.2–1,400 ha), with 3–5 ac (1.2–2 ha) being the most common farm size. It is grown as a minor crop in many other island states of the Pacific including Guam, Tonga, Vanuatu, Papua New Guinea, and Samoa.

## ENVIRONMENTAL PREFERENCES AND TOLERANCES

### Climate

A favorable climate would have approximately 60 in (1,500 mm) of rain a year distributed over 7 months, with a few rains during the other 5 months. A dry period long enough to induce water stress in the tree is necessary for normal flower development. Sufficient rain is needed to keep the root zone moist during the 7–8 months the crop is developing (see “Flowering and fruiting” for more specific information). Dry, sunny weather is ideal during the harvest season when the crop ripens and is harvested and dried.

### Soils

Coffee tolerates a wide range of soil types and textures. Preferred soils are deep and porous, with excellent drainage. The ideal pH is in the range of 5.8–6.2. Coffee does not do well in heavy soil with poor drainage or in soils where the topsoil is eroded away. In soils with pH below 5.5 or above 6.7, micronutrients and some macronutrients become much less available and deficiencies, particularly iron, become visible. In soils with low pH and high aluminum levels, aluminum toxicity can occur.

## GROWTH AND DEVELOPMENT

Coffee plants have vertical and lateral branches. The first shoot growing from the seed becomes a vertical branch; as it grows, two lateral branches grow from buds produced at each node. Depending on the variety, coffee plants can reach a height of up to 25 ft (7.5 m) at maturity when left unpruned. Fruit is borne on 1-year-old lateral wood. Once a node has produced fruit, it usually will not produce again. While the crop is developing on the bearing wood, the branch is putting on growing wood, which will bear the next year's crop. The amount of growing wood produced in the current season will, to a large extent, determine yield of the following season. The plant has a distinct tendency for an alternating cycle of heavy production one year, followed by light production the next year, and so on.

### Flowering and fruiting

First fruiting occurs at about 2 years old if grown in full sun or possibly longer if grown in shade (when plants are transplanted into the ground at 1 year old). After initiation, flow-

## Elevation, rainfall, and temperature

|  |   |
|--|---|
| Elevation range  | <p><b>lower:</b> 500 ft (150 m) for Hawai'i latitudes of 16°55' to 23° N, although it can do well down to sea level with sufficient water and nutrients.</p> <p><b>upper:</b> 2,700 ft (825 m) for Hawai'i latitudes, higher at latitudes closer to the equator. It will grow and produce to 3,400 ft (1,040 m) in Hawai'i. However, above about 2,700 ft yields will be less than at lower elevations, although the quality can be high.</p> |
| Mean annual rainfall   | <p><b>lower:</b> 47 in (1,200 mm)</p> <p><b>upper:</b> 120 in (3,000 mm)</p>  |
| Rainfall pattern   | <p>The ideal climate for coffee production has a distinct dry period with a majority of the rainfall during the months when the beans are developing, and uniform rainfall during the remainder of the year. However, coffee will grow in climates with a diverse range of rainfall patterns.</p>   |
| Dry season duration (consecutive months with <40 mm [1.6 in] rainfall) | 1–3 months  |
| Mean annual temperature  | <p><b>lower:</b> 55°F (13°C)</p> <p><b>upper:</b> 80°F (27°C)</p>   |
| Mean maximum temperature of hottest month                              | 85°F (30°C)   |
| Mean minimum temperature of coldest month                              | 52°F (11°C)   |
| Minimum temperature tolerated  | 41°F (5°C)  |

er buds grow to an average of 0.16–0.24 in (4–6 mm) long, then stop and go into dormancy. Bud dormancy is gradually decreased by water stress (insufficient water) during the next 1–4 months during which time there is no visible growth. The more profound the water stress is, the easier it is to stimulate regrowth of the buds.

After the water stress, the buds are no longer fully dormant, but they need a stimulus, namely water and/or a sudden drop in temperature (7°F [4°C] per hour), to continue development. Both are usually provided by the first heavy rainfall of the season, sometimes called a “blossom shower.” Following the rain (or soaking irrigation), the buds swell and, over the next 6–12 days, they grow rapidly in length, and open into blossoms. The number of days it takes depends on temperature (faster with higher temperatures) and whether or not there are leaves at the flower nodes (faster development). There are usually 4–8 flowerings per season over approximately 4 months. For about 6 weeks after fruit set, although actively developing, the fruits grow very little in size and are called “pinheads.” During the following 10



Blossoming is stimulated by a heavy rain shower after a dry period, leading to simultaneous flowering throughout a region. There are usually 4–8 flowerings during a season.

weeks (6–16 weeks after flowering), the fruits grow quickly and the maximum size of the bean is determined. The main factor is water received by the plant as rainfall or irrigation. In the 8–18 weeks after flowering, the beans “fill,” increasing in dry weight with little increase in fruit size. Approximately 30–35 weeks after flowering, the fruits ripen and are ready for harvest. The time from fruiting to harvest varies with location and variety. Generally, trees at lower elevations (warmer temperatures) will develop fruit in a shorter time than those at higher, cooler elevations.

### Pacific island cultural importance

In Kona, Hawai‘i, coffee has achieved significance in the local agricultural economy for more than 150 years. Since 1970, there has been an annual festival celebrating Kona-grown coffee including a parade, vendor exhibition, cupping competition, and many coffee-related field tours and workshops. In Ka‘ū, Hawai‘i and on Maui, similar events have been started in recent years.



### PROPAGATION AND PLANTING

Coffee is commonly propagated by seed. Cherry (a common term for the ripe fruit) is selected from vigorous trees with excellent production. After pulping, seed should be dried in the shade for about 10 days, if not planted immediately. Seeds are planted 0.5 in (1.3 cm) deep in flats or pots in clean, well aerated soil or soilless media, then kept moist (not saturated) and placed in full sun. Six pounds (2.7 kg) of coffee cherry produce about 1 lb (0.45 kg) of seed, which can yield about 1,000 seedlings. The germination percentage is high for fresh seed and is reduced when seeds are dried. Germination takes 6–10 weeks.

Grafting can be done in the seedling stage, in order to have desirable varieties on pest or disease resistant rootstocks. Propagation by cutting is occasionally used, but is difficult.

### Outplanting techniques

Outplanting is done when plants are 12–14 months old, at the beginning of the rainy season or with irrigation. It is important that the trees are planted at the right level, i.e., the



Coffee has been a part of the local agricultural economy in Kona, Hawai‘i for over 150 years. Top left: The annual Coffee & Art Stroll in Hōluāloa, one of many coffee-related activities that takes place during a one-week coffee festival each year in Kona. Top right: Judges determine the winner of a Kona coffee cupping competition by an exacting method. Bottom: Other coffee growing regions in Hawai‘i outside of Kona have begun establishing production, processing, marketing, and reputations for high quality coffee.

soil level should be at the same place on the trunk as it was in the pot. Soil should also be kept moist, but not too wet.

## AGROFORESTRY AND ENVIRONMENTAL SERVICES

### Agroforestry/interplanting practices

In many parts of the world, coffee is interplanted with other crops. These crops vary in size and description and are chosen depending on the needs of the producer. Since coffee is tolerant of moderate shade, it is commonly grown beneath taller plants. These plants can be part of a relatively simple agroforestry system composed of a small number of tree species or a complex, multi-strata forest.

Around the world, there exists a wide range of shaded coffee systems. In a simple shade system, coffee is grown together with one other crop, thereby providing two sources of income from the same land area. On family-run subsistence farms, there may also be a scattering of fruit trees for on-farm consumption and additional shade coverage. The range of fruit trees on shaded coffee farms is extensive and is determined by the subsistence and commercial goals of the farmer. Some examples of species interplanted with coffee in Hawai'i are citrus (*Citrus* spp.), Macadamia nut (*Macadamia integrifolia*), mango (*Mangifera indica*), breadfruit (*Artocarpus altilis*), avocado (*Persea americana*), papaya (*Carica papaya*), and jaboticaba (*Myrciaria cauliflora*).

Many coffee farms in Hawai'i include native Hawaiian and non-native trees for shade cover. Aside from shade and other traditional shade tree benefits (see "Advantages and disadvantages of polycultures" below), these trees offer natural

beauty, conservation of native species and, potentially, a future crop of timber. These species include koa (*Acacia koa*), 'ōhi'a (*Metrosideros polymorpha*), monkeypod (*Samanea saman*), and gliricidia or madré de cacao (*Gliricidia sepium*).

Around the world, many different species of trees are used in coffee agroforestry systems. Nitrogen-fixing trees like inga (*Inga* spp.), coral tree (*Erythrina* spp.), and leucaena (*Leucaena leucocephala*) are common. Timber trees include Spanish cedar (*Cedrela odorata*), laurel (*Cordia alliodora*), and eucalyptus (*Eucalyptus* spp.).

Globally, many farmers plant the coffee within existing forests. These agroforestry systems are complex since they usually have many different plant and animal species living within them. They also tend to have a smaller environmental impact since they usually involve a small alteration of the existing forest, rather than complete removal.

### Environmental services

Coffee provides some environmental services, primarily erosion control, as it has extensive, fibrous feeder roots. Occasionally it is used as a windbreak, a trellis for vanilla orchid, and sometimes shade for low-growing species that cannot tolerate sun. Additionally, coffee is an attractive plant and can beautify any location.

## CULTIVATION

### Variability of species and known varieties

The coffee grown in Hawai'i is *Coffea arabica*, which is considered to be superior in cup quality to *C. canephora* (commonly called robusta). *C. arabica* is at least 90 percent self-pollinated, contributing to very little variability in the



Left: Outplanting and mulching seedlings. Right: Potted seedlings, those in the back are ready for planting.



Top left: Polyculture with avocado, mango, banana, and macadamia in Hōlualoa, Hawai'i. Top right: Multistorey coffee agroforestry with poro (*Erythrina poeppigiana*) and laurel (*Cordia alliodora*), Turrialba, Costa Rica. Middle left: Growing under native 'ōhi'a lehua forest in Opihihale, Hawai'i. Middle right: Grown as a dense boundary hedge in Mountain View, Hawai'i. Bottom left: Shaded by the nitrogen-fixing tree monkeypod. Kona, Hawai'i. Bottom right: Shaded by koa, inga, and *Erythrina* spp. Kula, Maui.

species. There are many commercial varieties of *C. arabica*, including 'Guatemalan' (also called 'Kona typica' in Hawai'i), 'Red' and 'Yellow Caturra', 'Red' and 'Yellow Catuai', 'Mokka', and 'Kent'. 'Guatemalan' has been grown in Kona, Hawai'i since the late 1800s.

### Basic crop management

Annual pruning is recommended to stimulate new growth and to moderate the tendency for biennial bearing. There are two common methods; a selective, multiple-aged vertical system (referred to in Hawai'i as Kona style) and a stumping system (referred to in Hawai'i as Beaumont-Fukunaga). In the first, the oldest one or two vertical branches of every tree are cut off at their base, every year. One or two new shoots are allowed to grow into new verticals to take their place.

In the stumping method, each tree to be pruned is cut off at about knee height, leaving only the stumped trunk. There are several stumping systems, but it is common to stump every third row each year, although the rotation cycle will vary depending upon the variety and farm environment. That is, a third of the rows are pruned each year. In this system, three to four new shoots are allowed to develop into verticals. Stumping by blocks in the field, rather than rows, is also a common system. If the orchard is irrigated, fertigated, or mechanically pruned or harvested, then stumping should be in blocks rather than rows to exploit the efficiency of irrigation and mechanization.

Kona style pruning is more labor intensive but causes less stress to the trees than the stumping method. The stumping method should not be used when trees are under stress due to insufficient or excessive soil moisture, high incidence of insect or disease damage, insufficient sunlight, or other factors, as trees may regrow very slowly or even die.

Both systems require the selection of new verticals (by removing excess, less desirable new shoots) a couple of months after pruning. New shoots appearing after that are removed monthly for 2–3 months. The removal of new shoots (suckering) must be done on every tree every year with the Kona style pruning, but is concentrated on the cut rows or blocks in the stumping system and is needed primarily only in the first year after stumping is done.

Fertilizer applications can be done via irrigation systems (fertigation) or by manual spreading using a variety of naturally (organic) or synthetically derived materials. Fertilizer needs and schedules will vary based on several factors including soil type, variety, and crop yield.

Manual fertilizer applications are made 3–4 times per year, at regular intervals when there is rainfall, whereas applications through the irrigation system are usually made at a lower rate more frequently, perhaps as often as at every irrigation. Coffee is considered a heavy feeder and has a high

need for both nitrogen and potassium. The majority of the potassium application should be made every 2–3 months during the period beginning 3 months before flowering and continuing for 3 months. Applications of nitrogen are made every 3–4 months. Minor and other nutrients may be applied once a year or throughout the year as needed and vary from farm to farm.

The cherry skin, or pulp, is high in both nitrogen and potassium and is often returned to the field. Lime should be applied at regular intervals (perhaps every year or two) to maintain a favorable pH in the range of 5.8–6.2 and to provide calcium, as needed. Fertilizer and liming schedules are ideally based on soil and leaf analysis from an individual farm.

Harvest takes place about 7–8 months after flowering and is extended over several months. The harvest season is earlier and shorter at lower elevations (warmer temperatures and more sunshine) than at higher elevations. Following harvest, the cycle begins again with pruning.



Top: Kona style pruning leaves 3–4 verticals and gives dependable annual production. Bottom: The stumping method of pruning is easier and faster to implement, but may cause additional stress on trees by removing all foliage. On an area basis, both methods take about 25–33% of the verticals out of production each year.



## Advantages and disadvantages of polycultures

As coffee has a high nutrient demand when grown in full sun, it benefits from tree cover by a reduction in nutrient demand and the nutrient input and organic matter addition from litter fall decomposition. Tree cover also can decrease water demand, help prevent erosion, provide wind protection, and can sometimes help moderate pests and diseases. Coffee grown in the shade tends to bear fruit more regularly, unlike sun-grown coffee, which tends to have a biennial high/low production cycle, unless it is pruned annually.

In addition, the diversification of crops in a polycultural system also helps protect the producer from volatility in the world market by spreading the risk of demand fluctuations across several crops. Examples include coffee/banana, coffee/fruits and nuts, and coffee/timber. In the case of timber, coffee provides a short to medium-term yield while waiting for timber to be harvestable, which may also apply to slow-producing commercial crops such as macadamia.

In areas where soil fertility is low and fertilizers are in short supply, moderate shade results in reduced flowering and production, which helps to prevent dieback due to bearing too much fruit. In hot, sunny environments, shade-grown coffee is less stressed and has larger, darker green leaves than coffee grown in full sun. Polycultural systems offer several intangible benefits. Most simply, working in the shade is much more pleasant than working in full sun. Since shaded coffee usually matures over a longer period of time than sun-grown coffee, fewer laborers are needed for harvest at any one time and harvesting can more easily be done by family members than if the harvest season was shorter and more concentrated. However, if labor is in short supply and is paid by the pound picked, shaded coffee could prove to be a disadvantage. Other intangibles include habitat stability, usually resulting in increased biodiversity of all organism classes (birds, mammals, insects, plants, etc.), conservation of native plant and animal species, and the maintenance and integration of species having cultural value.

The major disadvantages of coffee polyculture are the potential reduction of yields caused by shading from trees or fewer trees per unit area with intercropping. The actual yield reduction from shade varies greatly, ranging from 0–90%, although 30–70% is more characteristic. Microclimate and management practices largely determine yield loss resulting from shade cover. A recent survey in Kona, Hawai'i showed that yields are not reduced with up to 40% shade (Elevitch et al. 2009).

The non-coffee species in these polycultures also command time and labor attention. Neglecting to prune the shade trees can lead to too much shade and reduced yields, as well as occasional damage to the coffee trees from falling limbs.



**Top:** Properly managed shade can benefit the coffee trees and is a more pleasant work environment. **Middle:** Litterfall from shade trees adds organic matter and helps hold soil moisture. **Bottom:** Too much shade, as from these macadamia nut trees, reduces coffee yields greatly.

Lastly, other plants may compete with the coffee for necessary resources.

Carbon sequestration could be a potential value-added product of coffee plantations that include shade trees. If any of the current carbon trading proposals become a reality, farmers may be able to sell carbon credits based on the shade trees they plant.

## PESTS AND DISEASES

In Hawai'i, young trees are often infested by green scale (*Coccidis viridis*) carried to the leaves by ants which harvest a sweet substance exuded by the scale. A fungus, called black sooty mold grows on the sweet exudate covering the leaves. Other insect pests which can cause significant yield reduction are black twig borer (*Xylosandrus compactus*), and banana moth (*Opongona sacharis*). Leaf and berry spot caused by the fungi *Cercospora coffeicola* and *Colletrotrichum*, and rootknot nematode (*Meloidogyne konaensis*) are diseases



Top left: The twig borer insect bores a hole in lateral branches, killing the branch from the hole to the tip. Top right: Green scale insects that have been killed by the white halo fungus have a white ring around them. Bottom left: This ladybug larva, on the underside of a coffee leaf, is a voracious eater of green scale. Bottom middle: Symptoms of *Cercospora* leaf spot. Bottom right: Ants feed on the sweet exudate from green scale, protect them from predators, and move them around the plants.

that can cause problems in coffee production. Recently, the coffee berry borer's (*Hypothenemus hampei*) presence was confirmed in Hawai'i. The beetle bores through the fruit and into the seed, greatly reducing yields if not controlled. (See Nelson 2007, 2008 for more information on coffee pests and diseases.)

### Preventing and treating pests and diseases

First, keep the plants as healthy as possible by starting with vigorous young trees planted in a suitable location. Provide fertilizer and supplemental water as needed and do not overfertilize the trees for heavy early production or water them too frequently. A soap and oil mixture can be used to control soft-bodied sucking insects, such as green scale, and for sooty mold. The larvae of lady beetles are voracious feeders on scale and can control them. Another successful biological control is the white halo fungus (*Verticillium*), which infects and kills the scale. Infected scales appear to have a white halo (circle) surrounding them.

For other insects such as black twig borer, removing infested branches regularly can help reduce populations. The coffee berry borer is best controlled by sanitation methods that remove all fruit from the field at the end of the harvest season. Traps can help reduce the population and, if present, the fungus *Beauveria bassiana* will attack the beetle. Good ventilation around and between trees will reduce leaf and berry spot; sprays of copper hydroxide can be used if cultural practices do not control it. For nematodes, start with clean plants; if soil is infected, consider not planting coffee. When first planting coffee, work in organic matter such as cherry skins and chicken manure to soil before planting. Using trees grafted onto a resistant rootstock can help prevent pest and disease problems that may be present.

### DISADVANTAGES OF THE CROP

Proper coffee maintenance and harvesting are time and labor intensive. Having sufficient, affordable labor is a challenge in many coffee-growing regions.

In the early years of growth, coffee has minimal nutrient demand. However, when full production begins, the demand can be deceptively high, sometimes catching producers off-guard. The consequence is often overbearing dieback. Overbearing dieback is common in full-sun production systems but rare in shaded systems. The high light environment causes the coffee to produce more fruit than it can sustain with low nutrient inputs (overbear-

ing). This nutrient demand causes severe plant stress resulting in plant injury (dieback), reduced production in the current and following seasons and occasionally, death. If it survives, the plant requires two seasons to recover and produce a crop.

If synthetic chemical fertilizers and herbicides are used for production, the high demand and price can be a burden for producers. In addition, fluctuations in world prices could create a situation where growing coffee produces little, if any, profit. Finally, production of high quality coffee requires careful attention to growth and processing. If production, harvest, and processing are not well tended, the resulting low quality coffee will not command high prices.



**Top:** This tree cannot support the fruit that it set and is suffering from overbearing dieback. **Bottom left:** Coffee quality depends on many environmental and horticultural factors. Picking unripe and overripe beans can lead to poor cup quality. **Bottom right:** Highly selective picking for beans at perfect maturity is an important factor in producing a high quality cup.



Commodity prices fluctuate greatly. Shown here, coffee (mild arabicas) commodity prices 1989–2009, International Coffee Organization. Prices are ex-dock New York in U.S. cents per pound. Source: International Monetary Fund.

Coffee exists in several global markets. Its placement is dependent upon its quality and access to those markets. The commodity market accepts lower quality coffee at lower prices. The specialty market, on the other hand, offers higher prices but only for higher quality coffee. Attaining high quality coffee requires diligence, time, and effort.

### Potential for invasiveness

Coffee is described by Hawai'i Ecosystems at Risk project (HEAR) as naturalized in Hawai'i and other locations (HEAR 2009) and it is rated by the Pacific Island Ecosystems at Risk database as high risk for becoming invasive. Invasive species are defined as plants or animals that adversely affect the habitats they invade economically, environmentally, or ecologically. While coffee does not fit into this definition in Hawai'i, it can be easily spread by seed, especially when trees are not harvested. Coffee is not designated as a noxious weed in Hawai'i. However, careful consideration should be given to this matter before coffee is planted in a new area.

## COMMERCIAL PRODUCTION

### Postharvest handling and processing

After harvesting, the fruit skin and other layers around the seed must be removed and the seed dried before roasting and consuming. The seed is usually removed from the fruit and the mucilage is removed by fermentation (wet process) or machine (demucilaging). However, fruit and mucilage removal is not mandatory (dry process). The coffee seeds (beans) must be dried to 8–12.5% moisture for storage and international trade (International Coffee Organization standards, but not all locales follow these standards). If the fruit

skin is removed, the dried seed can be stored in the parchment until shipping or roasting. If the seed is dried in the fruit, it can be stored as-is or hulled to be stored as green bean.

Once the fruit or parchment is removed, defective and oddly shaped seeds and non-seed materials should be separated out and the seeds should be sorted by size and density to achieve highest quality and facilitate uniform roasting.

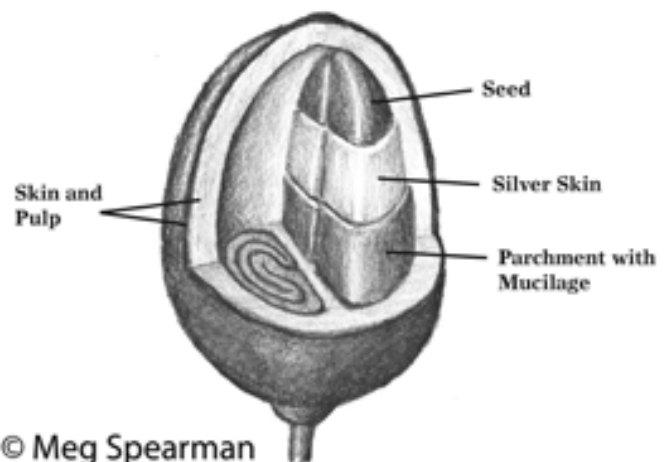
### Pulp removal

Pulping is the removal of the coffee skin. Removing coffee seeds from the fruit manually is arduous and impractical with any significant amount of fruit. Fortunately, simple machines are available to accomplish this.

The simplest machines are hand driven pulpers. A common design consists of a perforated drum and a breastplate between which the coffee fruit is squeezed and then separated into “beans” and pulp. These pulpers can accommodate relatively small amounts of coffee and, depending on their size, vary in their maximum output. The smaller versions have maximum throughput of several hundred lb/hr or more. These models can be fitted with a treadle, bicycle, or small motor to replace manual operation. Larger quantities of coffee can be pulped using larger motorized pulpers, which are available with a range of throughput capacities.

### Mucilage removal

Removing the mucilage, which has a high sugar content, is not absolutely mandatory, but is advisable. Coffee is difficult to dry properly with the mucilage as it tends to absorb moisture from the air in high humidity, which may contribute to the development of undesirable quality traits resulting from microbial or fungal growth.



Anatomy of a coffee cherry.

The simplest and cheapest method of mucilage removal is to ferment the freshly pulped seed. Commonly, the pulped coffee is placed in a vat, large tub, or similar container to which enough water is added to just cover the coffee. After 12–24 hours (depending on ambient air temperature), the mucilage will decompose and the surface of the coffee will

have a rough feel to it. In cooler areas where fermentation is slower, water should not be added to the coffee. As soon as the fermentation is complete, the coffee is rinsed with clean water to remove the mucilage. Coffee left in the fermentation vat too long will develop undesirable characteristics.



Top left and right: Small mechanized pulpers. Bottom left: A hand cranked pulper can process large amounts of coffee. Bottom middle and right: Pulped coffee beans in a fermentation vat.



Top left: Covered drying platform with fan to assist in air circulation. Top right: Raking parchment coffee. Middle left: Hand-cranked parchment milling. Middle right: Larger commercial parchment mill. Bottom left: Grading machines such as this table that sorts beans by density are used to remove defective and lower quality beans. Right: Graded and sorted Hawai'i Extra Fancy grade beans.

Mechanized demucilaging machines are available that pulp and remove the mucilage simultaneously, using a fraction of the water required with the fermentation method. This avoids wasting water resources and is especially important where water is expensive and in areas where properly treating the waste-fermentation water is difficult or expensive.

### **Drying**

After mucilage removal, the coffee is called parchment coffee, or simply parchment, and consists of the seed covered by the extremely thin silver skin enclosed in a thick papery skin. The parchment must be dried to 11–13% moisture content, so that the green coffee will have a moisture content of 10–12.5%. Sun-drying coffee on a platform or elevated rack is a low cost drying method and has the added advantage of avoiding use of expensive electrical or gas power. The coffee layer should not be thick (4 in [10 cm]) and it should be raked several times a day. Care must be taken to protect the drying area from rain. Coffee can also be dried in forced-air dryers alone, or in combination with sun drying. The drying temperature should not exceed 122°F (50°C), but more

important is the bean temperature, which should not exceed 104°F (40°C).

### **Parchment or fruit/parchment removal**

Hulling (or dry milling) is done once the coffee is dried. Removal of the parchment layer and silver skin (or fruit husk, parchment, and silver skin, if the coffee was dried in the fruit) is necessary prior to roasting. Manual removal of the parchment skin is impractical.

Two basic machine methods exist to remove the parchment skin. One method rubs the skin off the seed by squeezing the coffee between two surfaces. The other method involves gently beating the coffee until the parchment falls off. After the parchment and silver skins are removed, the coffee is referred to as green coffee or green bean.

### **Grading**

Removal of defective seeds, due to either biological or processing problems, results in a coffee of higher quality. Manual removal, while arduous and difficult, is possible when labor is cheap. Machines that sort the green coffee by density



Various low and high-tech roasters. Top left: Cast iron skillet on propane stove. Right: Small sample roaster. Bottom left: Small programmable electric home roaster.



Left: Coffee roasting in an air roaster. Right: Coffee pulp is an excellent fertilizer.

can remove many of these defects. Optical color sorters can further assist with this process.

Grading the coffee by bean size is desired by buyers as roasting is enhanced by bean size uniformity. Green coffee is passed through a series of sieves, each with holes of a different size, to separate the beans. These machines can be manually powered (small screens) or electric (for various volumes).

During size sorting, peaberries can also be separated out, thereby producing an additional category of coffee that often commands a slightly higher price.

### **Coffee roasting**

Coffee is typically not consumed until it is roasted. Roasting consists of heating the coffee for 8–20 minutes depending on temperature and roasting method. Constant agitation is necessary to create an even roast. Commonly, the coffee is roasted using a heated, rotating drum or by forcing heated air through the coffee mass. Roasting begins at temperatures of 350–420°F (177–216°C). Temperature changes dramatically throughout the roast. The time-temperature profile of a roast makes or breaks the quality of the resulting coffee. Developing an optimal profile for a particular coffee comes with the experience and attention to detail by the roaster.

For home use, several methods are commonly used. Coffee can be roasted in a skillet, an electric popcorn popper, or other open container where constant stirring is possible. Small drums can also be constructed to roast the coffee using fire as a heat source. Commercially, well designed and

constructed machinery is strongly advised for coffee roasting. Temperature control, agitation, and consistency are necessary for high quality coffees demanded by consumers.

### **Adding value at farm or community level**

The most lucrative processing that can be done with coffee is to serve it brewed by the cup, followed by selling it roasted locally at retail. Selling high quality, roasted coffee internationally is financially challenging due to the rapidity of staling after roasting. Ideally, the coffee should reach the consumer less than a week after roasting. Thus, the costs of shipping may prevent this from being a profitable selling strategy.

Coffee can be graded and sorted according to different properties: bean size, density, and shape, and the number of defective beans in a given lot. Processing to achieve the highest grade generally results in the ability to sell the coffee at a higher price.

Peaberries are often sorted out, roasted, and sold separately as they often command a higher price than the regular flat-faced beans. Peaberries are coffee beans that are round and lack a flat face because only one seed, rather than the usual two, developed in the fruit.

Roasted coffee can be used in a variety of forms other than a beverage. For example, it can be used as a component of soap or brewed and used as a clothing dye.

Roasted coffee can also be combined with other foods. Often, roasted coffee beans are coated in or mixed with choco-





Diversifying coffee products can access new markets. Top left: Green coffee sold for home roasting. Top right: Specialty variety ‘Mokka’, which has very small beans. Middle left: Dried coffee pulp, which can be used to make a tea. Middle right: Hydrosol extract of green coffee for health food market. Bottom left: Nutraceutical coffee, whole roasted coffee beans including seed, parchment, and pulp, is brewed like regular coffee. Bottom right: Coffee is used in various skin care products such as soaps and skin defoliants.

late. Coffee is also commonly added into a mixture of spices for use in cooking or as a component of other sweet and savory food dishes.

### Product quality standards

No mandatory, international quality standards exist. However, members of the International Coffee Organization are requested to conform to the following for green coffee: Fewer than 86 (*C. arabica*) or 150 (*C. canephora*) defect equivalents per 300 g (10.6 oz) sample and a moisture content between 8–12.5%. Since not all coffee defects affect quality the same way, each defect type is given a weighted number value. In all coffee standards, the defect equivalent is the number of total defect points within a given amount of coffee (ICO Resolution 420).

Most countries exporting green coffee establish criteria based on some or all of the following: number of defects, moisture content, bean size, and bean shape. In Hawai'i, coffee is graded on all of these criteria. Higher grades have larger beans and fewer defects. The moisture content in coffee that is sold labeled with a Hawai'i-grown origin must be 9–12.2% according to the Hawai'i Revised Statutes.

### Product storage requirements and shelf life

The preferred way to store unroasted coffee is as parchment, but green coffee can be stored in climate-controlled conditions for approximately a year. Uncontrolled conditions drastically reduce shelf life. There is a range of air temperature and relative humidity conditions that maintain the appropriate green bean moisture content and quality. The target to shoot for is generally agreed to be approximately 70°F (21.1°C) and relative humidity of 50–70%. It is important that the coffee be kept at a stable moisture content to maintain the quality.

While roasted coffee can be consumed indefinitely after roasting, noticeable quality differences can occur even a week after roasting. Ultimately, acceptable shelf life of roasted coffee is decided by the consumer. The best way to preserve roasted coffee quality is to bag it in a container fitted with a one-way exhaust valve that permits the exit, but not the entrance, of air. Bags with one-way valves are commonplace in the specialty market. If containers with valves cannot be used, then any container can be used (can, paper bag, etc.) however, the coffee must be de-gassed for 1–2 days before completely sealing in a container that does not allow the release of gas.

### Recommended labeling for products

Detailed labels engender trust and loyalty from consumers seeking high quality coffees. Consequently, labels should have as much product information as possible: country of origin, region within the country, farm name, species, and variety. Taste descriptors and roast date can be included if

sold as roasted product. Depending on where it is sold, laws or regulations may determine the minimum information on the label as well as the various font sizes.

## SMALL SCALE PRODUCTION

Coffee can be an excellent homegarden crop. It is easy to manage a small number of trees, especially when grown under shade. The coffee can be interspersed with other plants or grown in uniform rows or blocks.

Since parchment/green coffee is relatively non-perishable, it can be stored and accumulated before bringing to market. Thus, it can be grown commercially in home gardens if farmers are able to properly process and store it on their farm. Access to knowledge and the proper equipment is important. Some coffee-growing regions have central processing mills where smallholder farmers can take their harvested coffee cherry. Often, the farmers sell their cherry to the mill on delivery.

### Small-scale value-adding

Value is added to the coffee crop by processing it in several stages leading up to a ready-to-consume product, such as a brewed beverage. Thus, processing coffee to green bean, while requiring more time and effort, is more valuable than selling cherry. Selling brewed coffee will attain the greatest value.


The chart below shows a rough comparison of the relative prices earned by the producer for selling coffee at different stages of production. All prices are standardized against coffee cherry. In other words, the numbers give the relative price for processed products relative to cherry (assigned the value of 1), allowing for weight loss that is normal in processing. The chart is not a measure of profit, as each stage requires additional time, labor, and equipment input. These values are based on current market prices in Kona, Hawai'i.

| Product   | Relative price per unit weight |
|-----------|--------------------------------|
| Cherry    | 1                              |
| Parchment | 1.5                            |
| Green     | 1.6                            |
| Roasted   | 3.7                            |
| Brewed    | 7                              |

### Nutrition

Coffee is not usually consumed for nutritional benefits. However, many recent studies suggest coffee may have beneficial health effects, independent of the energy boost offered by caffeine. For example, coffee and caffeine consumption have been linked to a lower risk of Parkinson's disease and lower rates of Type 2 diabetes, gallstone development, and liver cirrhosis. Also, coffee is high in antioxidants.

## Relative value along the processing chain

| Product   | Steps to achieve product  | Value   |
|-----------|---|---|
| Cherry    | Harvest beans, bring directly to processor within 12 hours.   | Lowest  |
| Parchment | Process by pulping, demucilaging, and drying, sell to processor or wholesaler. Storing the coffee as parchment may permit waiting for market prices to improve if currently low, however, it must be stored at the proper temperature and humidity. |  |
| Green     | Process by dry milling and grading, sell to wholesaler or roaster. Storing the coffee as green may permit waiting for market prices to improve if currently low, however, it must be stored at the proper temperature and humidity.                 |   |
| Roasted   | Process by roasting green coffee, sell to retailers or consumers. Rapid loss of quality does not permit long-term storage.  |   |
| Brewed    | Process by brewing freshly roasted beans, sell to consumer.   | Highest   |

## Import replacement

Producing households tend to drink coffee as well as sell it. They tend to drink the lowest quality coffee they produce, however, so that the highest quality coffee can be sold, fetching the highest price. According to the FAO, per capita consumption of coffee in 2003 reached as high as 24 lb (11 kg) in Samoa and 9 lb (4 kg) in New Caledonia, while consumption in the U.S. was 9 lb (4 kg) per capita. Fewer than 10 well tended coffee trees could easily supply this much coffee for a person.

## YIELDS

Expected yields are 10–15 lb (4.5–6.8 kg) of coffee cherry per tree. A reasonable yield attained in sun grown fields in Hawai'i for 2.5 ac (1 ha) is 25,000 lb (11,400 kg) of cherry. The table below shows the recovery rate of parchment, green,

and roasted coffee expected from this amount of cherry. Recovery varies somewhat based on location and variety.

## Recovery rate of parchment, green, and roasted coffee

| Product   | Weight                |
|-----------|-----------------------|
| cherry    | 25,000 lb (11,400 kg) |
| parchment | 6,250 lb (2,850 kg)   |
| green     | 5,000 lb (2,300 kg)   |
| roasted   | 4,000 lb (1,800 kg)   |

## Recommended planting density

When planted in a pure stand, a density of 680 trees/ac (8 ft × 8 ft [2.4 m × 2.4 m] spacing) up to 968 trees/ac (5 ft × 9 ft [1.5 m × 2.7 m] spacing) is common. On older family farms of 'Kona typica' in the Kona districts, approximately 15–20% of the land is dedicated to fruit trees.

## MARKETS

### Local markets

Tourists love to buy locally grown, roasted coffee. Coffee should be available anywhere tourists may visit: farms, roadside stands, markets, airports, and hotels. In addition, coffee can be featured wherever food is served, any time of day.

### Export market

Specialty coffee consumers are always eager to discover new and interesting coffees. As very little specialty coffee is currently exported out of the Pacific islands except from



Left: Packaging which includes the brand name, farm location, type of bean and roast, weight, contact information, and other specific information uniquely identifies the product. Right: On-farm sales can attract tourists who enjoy getting a glimpse into coffee production and processing.

Hawai'i, there is an excellent opportunity to sell high quality, unroasted coffee to North America, Europe, Asia, Australia, and the Middle East.

While the novelty of coffees from the Pacific islands will aid their export, the novelty will not last forever. Consumers will always seek out interesting and unique tasting coffees. To sustain an export market, the coffee must be of very high quality. Medium-high quality green coffee currently can be purchased in the U.S. for \$2–3 per pound (\$4.40–6.60/kg) from specialty coffee importers. Much higher prices can be found for coffees of exceptional quality and from certain origins with strong reputations such as Kona and Jamaica Blue Mountain.

### Specialty markets

Specialty markets/certifications with coffee are very popular in consuming countries and the prices paid for these coffees are typically higher than uncertified coffees. Coffee can be certified under one or several labels simultaneously. These certification schemes are: organic, fair trade, Utz Certified–

Good Inside, shade-grown, and bird-friendly. Consumers appreciate these certifications because it assures them that the coffee is produced according to certain guidelines.

Fair Trade coffee is, by definition, bought at a higher-than-market price by green coffee buyers. While organic and shade-grown/bird-friendly coffees are not bought at a higher-than-market price, they are typically sold at higher prices at retail. Utz Certified–Good Inside prices are higher than market value because they are negotiated by the buyers and sellers.

Based on an informal survey by the authors of six Kona retailers who sold both conventional and organic Kona coffee in 2009, organic roasted coffee sells for a premium of about \$6/lb (\$13.20/kg) over non-organic coffee. It is up to the farmer to determine whether this expected price increase can offset the cost of certification.

Some certifications require that the farmers pay an initial fee to use the services and label of the organization and most certifications require regular audits that are usually



Top left: The Kona Coffee Queen, selected annually at the Kona Coffee Cultural Festival, is part of a large organized effort to promote Kona coffee. Right: Certified organic coffees can stand out in the marketplace. Bottom left: The choice of organic certification should be based on the farmer's personal preferences and estimates of profitability.

paid for by the farmer. Consequently, the extra prices earned with the certification may not offset the cost of the fees. Because most of these certifications include a range of requirements consisting of social, economic, and environmental values, quantifying the cost/benefit of these certifications is difficult as some benefits may be non-monetary. Producers interested in these certifications need to take several factors into account when considering organic growing methods and certification. Some of these factors include: potential crop yield, profits, social benefits, and the amount of work necessary to fulfill the requirements of the certification.

Some roasters in importing countries have established personal relationships with coffee farmers who produce exceptional coffee. The roasters work with the farmers to maintain and enhance the coffee quality over time and they pay higher-than-market prices for the coffee. No certification scheme exists for these coffees that have become known as direct trade coffees.

### Branding possibilities

Pacific island coffees can be branded as new, interesting, and of unique origin. If the varieties grown are rare or atypical, advertising them will help with branding, as well. Consumers, entranced with the romance of the islands, will quickly seek out these coffees. If they are high quality, customers will continue to purchase them.

To ensure origin identification and quality standards, and to protect the reputation of Hawai'i coffee, Hawai'i State law requires that all green coffee beans in amounts greater than 10 lb (4.5 kg) leaving the district where they were grown be inspected and certified by the Hawai'i Department of Agriculture (Chapter 147, Hawai'i Revised Statutes).

In addition, the State of Hawai'i Department of Agriculture and the Hawai'i Coffee Association have received federal certification trademarks for green coffee beans. The trademarks identify the location in which the coffee was grown. The "100% Hawai'i Coffee" certification identifies coffee that is certified grown anywhere in Hawai'i.

Federal trademarks grant exclusivity throughout the U.S., whereas state laws apply only in Hawai'i. Also, federal trademark registration is enforceable, with stiff penalties and the ability of the U.S. Customs Service to seize falsely labeled imported goods at ports of entry.

### Potential for Internet sales

Roasted coffee is successfully sold via the Internet. However, delivery of the coffee must occur very quickly after roasting. If coffee roasted in the Pacific islands is quickly and economically transported to consumer markets, then Internet



An example of an informative direct trade coffee label.

sales have an excellent chance of succeeding. However, given the remoteness of Pacific islands and high airfreight shipping costs to many locations, bulk green coffee may be the only feasible way to deliver a high-quality product overseas. It may be prudent for growers to cater to both local and export markets to buffer the effect of overseas market demand.

## EXAMPLE SUCCESSES

### Rusty's Hawaiian 100% Ka'ū Coffee

Located in Ka'ū, on Hawai'i Island, Rusty's Hawaiian has 12 ac (4.8 ha) in coffee. Farm owners Lorie and Rusty Obra started producing coffee from farm to cup in 1999. Since Rusty passed away in 2006, Lorie has carried on running the business on her own, except for certain labor intensive farm operations such as fertilizing, pruning, and picking. Since Lorie is very particular about how processing is done, she does it all herself, including pulping, drying the parchment, dry milling, roasting, packaging, and marketing.

Because of Lorie's background in science as a medical technologist, she runs the operation like a laboratory. In 2008, before the main harvest, Lorie began experimenting by varying the wet process fermentation timing between 8 and 24 hours. She also compared dry fermentation versus wet fermentation. As a result, she developed timing and processing methods that work well for her coffee. Lorie also experimented with a wide range of creative fermentation techniques, including adding cola flavored soft drinks, chili pepper, or sea water to her fermentation process, as well as trying a Kenya-style fermentation (dry fermentation, then cold water soak and second rinse). These were cupped by different expert mainland cuppers and received very positive results.



### Pele Plantations 100% Kona Coffee

Pele Plantations, owned and operated by Cynthia and Gus Brocksen, has been growing and processing coffee in Hōnaunau, Hawai‘i since 1990. From the outset, they selected reliable methods of growing and processing quality coffee and to this day continue to refine their processing methods. Cynthia had an 18-year career in marketing with a large corporation in California prior to moving to Hawai‘i and was able to apply her marketing skills to the coffee business, making their coffee more visible in the marketplace.

The Brocksens quickly found they could sell more coffee than they could produce and began buying coffee from carefully selected farms. The number of supplying farms grew as demand increased and now numbers six farms. The Brocksens found that customers enjoyed the subtle differences between estate-grown coffees, so each of their supplying farms' coffees is processed and sold separately with its estate name on the Pele Plantations label. In the recession that began in 2008, they saw only about a 10% drop in purchases, as they



Lorie Obra mowing her farm and loading parchment into a hulling machine.

The innovative work Lorie has done is now garnering the attention of top roasters in the country. In July 2009, her careful processing and creative experimentation resulted in a Bourbon varietal that *Coffee Review* awarded the highest rating (95) in a comparison with coffees from El Salvador, Costa Rica, Honduras, and Kenya. A medium-roast coffee blended from Guatemalan and other varieties in Lorie's field received a 92 rating.

Lorie says that her biggest challenges are to keep the production high without compromising on quality and to market high quality coffee at prices that customers are willing to pay. She was able to name her price on her recent award-winning Bourbon and her goal is to be able to attract similar prices for her other coffee varietals. Lorie sells all her coffee as roasted product, mostly customer direct, at farmer's market, and via the Internet.



Cynthia Brocksen rakes sun-drying parchment at Pele Plantations.

have been able to attract clientele willing to pay premium prices even during tough economic times.

The Brocksens believe that a quality cup begins with quality cherry. They only accept perfectly ripe cherry from their pickers and supplying farms; bags that are not up to standards are returned to the farmer. Every bag is inspected to ensure it does not contain underripe or overripe cherries. Because of their uncompromising picking standards, the Brocksens pay their farmers about 10% above the average regional price for cherry. There is an additional premium of \$0.65/lb for certified organic coffees.

After delivery to their wet mill, the cherry is processed within 2 hours to ensure quality is preserved. Fermentation is done for exactly 18 hours, after which the wet parchment is moved to a full-sun drying deck. Drying to the target moisture content of 11.5–12% usually takes 5–10 days, after which the dry parchment is kept in climate controlled storage at 65°F (18.3°C) and 65% relative humidity. The Brocksens have found that storing their coffee as parchment is the best way to preserve bean quality. Parchment is milled to green only as needed for roasting.

The dry milling, sorting, and grading is contracted out to another company that has exacting quality standards and can keep each estate-grown coffee separate. The dry mill also has certified organic milling, which allows the Brocksens to document an unbroken processing chain for their certified organic coffees. Coffee is roasted only to fill orders, i.e., there is no stock of roasted coffee kept on hand. Each estate coffee has its own characteristics and careful records are kept for every batch to ensure an optimal roast. Due largely to their meticulous processing, the Brocksens' farmers have won four first prize awards at the annual Kona cupping competition, including two during the 2006–08 period. Most of their customers purchase via the Internet, finding the web site either through search engines or by word of mouth. They also do a direct mailing at Christmas time to customers who have made a purchase within the previous 18 months. They sell a holiday basket with a new design each year. Their coffee is also highlighted in a small number of high-end hotel gift shops.

Another source of new business is the Brocksens' farm tour. The 3-hour tour covers coffee and macadamia nut farm operations and coffee processing. At the end of the tour, they roast coffee for any tour participants who would like to purchase coffee to take home. The tour gives people the full experience of coffee from field to cup and many visitors have said that the farm tour was the highlight of their vacation.

### **Hula Daddy Kona Coffee**

Hula Daddy, owned and operated by Lee and Karen Paterson, farms 34 acres of coffee in Hōlualoa, North Kona,

Hawai'i. With experience farming in the Seattle area, the Patersons began growing coffee in Hōlualoa in 2002. Since the beginning, they have questioned conventional thinking about planting, growing, picking, processing, and storing coffee. Their coffee trees are grown from seed they collected from trees they felt gave a superior taste. They pay their pickers a premium to pick only red cherry and reject any coffee cherry that is green or brown. They also sun dry all of their coffee. They use a range of pulping processes including wet fermentation, dry natural, and pulped natural processing to develop complexity and body in the coffee. Approximately 25% of their coffee is removed during the sorting process and is sold to distributors or, if warranted, used for mulch.

Although they subcontract the dry milling, the Patersons do their own sorting and grading. This allows them to strictly control the quality of beans they roast. Approximately 25% of their coffee is removed during the sorting process and is sold to distributors or, if warranted, thrown away. As a result, they have received high praise from wholesalers who buy their green beans.

Although they subcontract the wet and dry milling of their coffee, they do their own roasting using a state of the art roaster. In December 2008, Hula Daddy coffee was awarded 97 points by Coffee Review, the highest score ever awarded



Parchment drying deck and master roasting class at Hula Daddy.

any coffee. About 80% of their coffee is sold as roasted product to consumers through their tasting room visitor center, web site, eBay sales, and local fairs such as the Hōlualoa Coffee & Art Stroll. People find their visitor center through rack cards found in retail centers throughout the Kona area, hotel concierge recommendations, and word of mouth. Their free tour includes farm operations and five steps of coffee processing, concluding with roasting. Visitors who are especially interested can get a coffee cupping exercise led by their roaster. The purpose of the tour is for visitors to leave knowing more about coffee production, quality, and brewing, while having a deeper appreciation for the Kona coffee industry.

## ECONOMIC ANALYSIS

In a University of Hawai'i cost of production spreadsheet (UH CTAHR 1998) the following observations are made: Operating costs are all the costs directly associated with growing and harvesting the coffee crop: fertilizing, weed control, pruning, insect, disease and rodent control, irrigation, harvesting, and marketing. In an example farm, using the Kona style of pruning (see "Basic crop management" above), the pruning (including chipping) activity is the largest growing cost, constituting almost 9% of the total growing costs. Total growing costs consume 20% of the gross income. Hired labor is the single most significant operating input. Harvest labor alone consumes almost 40% of the gross income.

## FURTHER RESEARCH

### Potential for crop improvement

Coffee crop improvement tends to focus on pest/disease resistance, yield, and quality. Coffee cup quality is another pursuit of crop improvement that may benefit Pacific island farmers financially. The focus on cup quality should aim to discover and create flavor attributes that are unique to a variety and growing environment.

### Improving potential for family or community farming

Cooperatives are perhaps the most successful mode of community coffee farming. They allow smallholder farmers to successfully process and market their coffee. Research into the feasibility and design of co-ops will greatly benefit the coffee growing potential of the Pacific islands. There is also a need to develop models for multiple cropping systems that buffer market and environment fluctuations and increase overall farm profitability.

### Genetic resources

The center of coffee genetic diversity is in Ethiopia. Major germplasm collections exist at the following institutions:

Jimma Agricultural Research Centre; Jimma, Ethiopia  
Lyamungu, Tanzania  
Foumbot, Cameroon  
Ma, Ivory Coast  
Riuru, Kenya  
FOFIFA, Ilaka-East, Madagascar  
IAC, Campinas, Brazil  
CENICAFE, Chinchina, Colombia  
CATIE, Turrialba, Costa Rica  
University of Trieste, Trieste, Italy  
CIRAD/IRD, Montpellier, France  
USDA, Puerto Rico

## REFERENCES CITED AND FURTHER READING

- Bittenbender, H.C., and V. Easton Smith. 2004. Growing Coffee in Hawai'i (Revised Edition). College of Tropical Agriculture and Human Resources (CTAHR), University of Hawai'i at Mānoa, Honolulu. <http://hdl.handle.net/10125/1912> [accessed October 9, 2009]
- Clifford, M.N., and K.C. Wilson (eds.). 1985. Coffee: Botany, Biochemistry and Production of Beans and Beverage. AVI Publishing Co., West Port, CN.
- Elevitch, C.R., T. Idol, J.B. Friday, V.E. Smith, and S.C. Nelson. 2009. Shade-Grown Coffee in Hawai'i: Results of a twelve farm study in Kona. Permanent Agriculture Resources, Hōlualoa, Hawai'i. <http://agroforestry.net/caf> [accessed October 9, 2009]
- Hawaiian Ecosystems at Risk project (HEAR). 2009. Invasive species information for Hawai'i and the Pacific. <http://www.hear.org> [accessed October 9, 2009]
- International Coffee Organization (ICO). 2004. Resolution No. 420. <http://www.ico.org/documents/iccres420e.pdf> [accessed October 9, 2009]
- Nelson, S.C. 2007. Coffee (*Coffea arabica*) Pest and Disease Image Gallery: Online quick reference for Hawaii's coffee farmers. University of Hawai'i at Mānoa, College of Tropical Agriculture and Human Resources (CTAHR), Department of Plant and Environmental Protection Sciences (PEPS). <http://www.ctahr.hawaii.edu/nelsons/coffee/coffee.html> [accessed October 9, 2009]
- Nelson, S.C. 2008. Cercospora Leaf Spot and Berry Blotch of Coffee. PD-41. College of Tropical Agriculture and Human Resources (CTAHR), University of Hawai'i at Mānoa, Honolulu. <http://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-41.pdf> [accessed October 9, 2009]
- Nelson, S.C., V.E. Smith, and M. Wright. 2005. Banana Moth as a Pest of Coffee. IP-21. College of Tropical Agriculture and Human Resources (CTAHR), University of Hawai'i at Mānoa, Honolulu. <http://www.ctahr.hawaii.edu/oc/freepubs/pdf/IP-21.pdf> [accessed October 9, 2009]



- Nelson, S.C., D. Schmitt, and V. E. Smith. 2002. Managing Coffee Nematode Decline. PD-23. College of Tropical Agriculture and Human Resources (CTAHR), University of Hawai'i at Mānoa, Honolulu. <http://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-23.pdf> [accessed October 9, 2009]
- Serracin, M., D. Schmitt, and S.C. Nelson. 1999. Coffee Decline Caused by the Kona Coffee Root-Knot Nematode. PD-16. College of Tropical Agriculture and Human Resources (CTAHR), Honolulu. <http://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-16.pdf> [accessed October 9, 2009]
- Steiman, S. 2008. *The Hawai'i Coffee Book: A Gourmet's Guide from Kona to Kaua'i*. Watermark Publishing.
- Thaman, R.R. 1993. Appendix. One hundred Pacific Island agroforestry trees. p. 216–266. In: Clarke, W.C., and R.R. Thaman. *Agroforestry in the Pacific Islands: Systems for Sustainability*. United Nations University Press, Tokyo.
- Thaman, R.R., and W.A. Whistler. 1996. *A Review of Uses and Status of Trees and Forests in Land-Use Systems in Samoa, Tonga, Kiribati and Tuvalu with recommendations for Future Action*. South Pacific Forestry Development Programme, Suva, Fiji.
- U.S. Dept of Agriculture, Foreign Agricultural Service (USDA FAS). 2009. *Coffee: World Markets and Trade*. Circular series FCOFF 1-09. USDA.
- U.S. Dept of Agriculture, National Agriculture Statistics Service (USDA NASS). 2009. *Hawaii Coffee*. Hawaii Field Office, Honolulu. [http://www.nass.usda.gov/Statistics\\_by\\_State/Hawaii/Publications/Sugarcane\\_and\\_Specialty\\_Crops/index.asp](http://www.nass.usda.gov/Statistics_by_State/Hawaii/Publications/Sugarcane_and_Specialty_Crops/index.asp) [accessed October 29, 2009]
- University of Hawai'i CTAHR (UH CTAHR). 1998. *The Economics of Producing Coffee in Kona*. AgriBusiness AB-11. <http://www.ctahr.hawaii.edu/oc/freepubs/pdf/AB-11.pdf> [accessed October 9, 2009]
- Pacific Island Ecosystems at Risk (PIER). 2009. Institute of Pacific Islands Forestry, U.S. Forest Service. <http://www.hear.org/pier> [accessed October 9, 2009]
- Wilson, K.C. 1999. *Coffee, Cocoa and Tea*. CABI Publishing.
- Wintgens, J.N, (ed.). 2009. *Coffee: Growing, Processing, Sustainable Production. A Guidebook for Growers, Processors, Traders, and Researchers* (2nd ed.). Wiley/VCH.
- on a per tree, per acre, and per farm basis. Growers can enter their costs and income into the spreadsheet. All results are dependent upon the initial assumptions and the user's data entered into the outlined spreadsheet cells. The various results are only as accurate as the data provided by the grower.

### Internet

Food and Agriculture Organization, online statistics database: <http://faostat.fao.org>

Hawai'i Ecosystems at Risk: <http://www.hear.org>

## OTHER RESOURCES

### Public assistance

“The Economics of Producing Coffee in Kona” (<http://www.ctahr.hawaii.edu/oc/freepubs/pdf/AB-11.pdf>) spreadsheet calculates the production costs, the returns to productive resources, and the economic profitability of coffee production

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

## Farm and Forestry Production and Marketing profile for Coffee (*Coffea arabica*)

**Authors:** Virginia Easton Smith, University of Hawai'i at Manoa, Cooperative Extension Service–Kona, 79-7381 Mamalahoa Hwy, Kealahou, HI 96750-7911, Tel: 322-4892; Email: [vsmith@hawaii.edu](mailto:vsmith@hawaii.edu)

**Dr. Shawn Steiman**, Coffea Consulting, 1418 Mokuna Pl, Honolulu, HI 96816. Email: [steiman@coffeaconsulting.com](mailto:steiman@coffeaconsulting.com); Web: <http://www.coffeaconsulting.com>

**Craig R. Elevitch**, Permanent Agriculture Resources, PO Box 428, Holualoa, HI 96725; Tel: 808-324-4427; Fax: 808-324-4129; Email: [cre@agroforestry.net](mailto:cre@agroforestry.net); Web: <http://www.agroforestry.net>

**Recommended citation:** Smith, V.E., S. Steiman, and C.R. Elevitch. 2010–11. Farm and Forestry Production and Marketing Profile for Coffee (*Coffea arabica*). In: Elevitch, C.R. (ed.). Specialty Crops for Pacific Island Agroforestry. Permanent Agriculture Resources (PAR), Holualoa, Hawai'i. <http://agroforestry.net/scps>

**Version history:** November 2009, February 2011

**Series editor:** Craig R. Elevitch

**Publisher:** Permanent Agriculture Resources (PAR), PO Box 428, Hōlualoa, Hawai'i 96725, USA; Tel: 808-324-4427; Fax: 808-324-4129; Email: [par@agroforestry.net](mailto:par@agroforestry.net); Web: <http://www.agroforestry.net>. This institution is an equal opportunity provider.

**Acknowledgments:** Many thanks for contributions and review from Skip Bittenbender, Heidi Johansen, Leopoldo Miranda-Castro, Gerry Ross, and Bruce Vogel. We gratefully acknowledge Trisha Bobnar, Melanie and Colehour Bondera, Kamilo and Sinouvi Faleofa, Una Greenaway, Churd and Chew Hanson, Gerry Herbert, Imagine Coffee, Kona Coffee Cultural Festival, Kona Joe Coffee, Kona Mountain Coffee, MauiGrown Coffee, Maxine and Larry Kunitake, Denver Leaman, Barbara and Kalehua Meheula, Bonnie and Bacci Perata, Nancy Redfeather, Leon Rosner, Gerry Ross, Janet Simpson, Paul and Deb Sims, Desmond and Lisen Twigg-Smith, Christian and Lisa Twigg-Smith, Deborah Ward, and Al and Donna Woolley for photo opportunities. Many thanks to Meg Spearman for her illustration.

**Reproduction:** Copies of this publication can be downloaded from <http://agroforestry.net/scps>. Except for electronic archiving with public access (such as web sites, library databases, etc.), reproduction and dissemination of this publication in its entire, unaltered form (including this page) for educational or other non-commercial purposes are authorized without any prior written permission from the copyright holder. Use of photographs or reproduction of material in this publication for resale or other commercial purposes is permitted only with written permission of the publisher. © 2009–11 Permanent Agriculture Resources. All rights reserved.

**Sponsors:** Publication was made possible by generous support of the United States Department of Agriculture Western Region Sustainable Agriculture Research and Education (USDA-WSARE) Program and the County of Hawai'i Department of Research and Development in partnership with the Big Island Resource Conservation and Development (RC&D) Council. This material is based upon work supported by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, and Agricultural Experiment Station, Utah State University, under Cooperative Agreement 2007-47001-03798.

