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Farm and Forestry
Production and Marketing Profile for

Tea

(*Camellia sinensis*)

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PAR

USES AND PRODUCTS

Tea is the most widely consumed beverage after water. It has a cooling, slightly bitter, astringent flavor. The three most common types of tea are black, green, and oolong. There are also some less common types such as white and yellow teas. There are also compressed teas (e.g., puerh) as well as numerous flavored and scented teas. All of these teas have in common that they use the leaves of the same plant, *Camellia sinensis*, but they are processed in different ways.

Usually, the tip (bud) and the first two (or sometimes three) leaves are harvested for processing. Different leaf ages produce differing tea qualities, because their chemical compositions are different. Green tea is steamed (Japanese method) or roasted (Chinese method) very soon after picking to stop the oxidation ("fermentation") process. The processed leaves still have their original green color. Oolong tea is semi-oxidized, it is left to oxidize but for a shorter time period than black tea. The color of oolong tea can vary from bright green to dark brown. Black tea is oxidized for the longest period of time, which results in a dark brown or black color.

White tea is made from new buds and young leaves plucked before they have fully opened, at which time they are still covered by fine white hairs. The highest quality white tea is made from "tea needles," buds that have not begun to open. Lower grades contain leaves as well as buds. White tea is produced by wilting and then very gently drying the leaves, undergoing minimal oxidation. The liquor of white tea is normally clear with a light green/yellow or slightly golden color.

The term "herbal tea" usually refers to an infusion or tisane of fruit or herbs that contains no *Camellia sinensis*, e.g., rose hip, chamomile, peppermint, rooibos, etc.

Other products from the tea plant

Tea seeds can be pressed to produce tea oil. Oil yield is around 15%. This oil can be used for human consumption as edible oil and many industrial applications. In the cosmetic industry, for example, it is used for making hair lotions and soaps. The oil cake and other residues are used as fodder and fertilizer. However, tea seed oil has high saponin content. Saponin has some medicinal value but it is also quite toxic and limits the use of seed cake as fodder.

Green, oolong, and black teas are also used as raw material for making industrial extracts such as dyes, detergents, and sterilization and medical agents.

Tea has also traditionally been used in some parts of the world as food. In Tibet, pieces of tea are broken from tea bricks, and boiled for several hours in water, sometimes with salt. The resulting concentrated tea infusion is then mixed with butter (sometimes cream or milk) and a little salt to make butter tea. In parts of Mongolia and Central

Top: Harvesting tea plants in Vietnam. Middle: Harvesting full-grown tree from the ground and from within the crown. Bottom: Experimental production at the USDA Agricultural Research Service's Volcano Station in Hawai'i.

Left: University of Hawai'i tea research trials at the Mealani Experiment station in Waimea, Hawai'i Island. Right: Tea service at tea farm in Volcano Village, Hawai'i.

Asia, a mixture of ground tea bricks, grain flours, and boiling water is consumed. In some areas of Japan, concentrated tea is mixed with grain flour, then formed into balls and eaten. In Burma (Myanmar) tea is pickled (fermented) and eaten in a dish called *lahpet*.

BOTANICAL DESCRIPTION

Preferred scientific name and author

Camellia sinensis (L.) Kuntze

Family

The tea plant belongs to the genus *Camellia* of the family *Theaceae*. There are 100–250 recognized *Camellia* species. The wide range in the number of recognized species reflects the considerable disagreement among taxonomists about the status of many *Camellia* species. Members of the *Camellia* genus are mostly evergreen shrubs and small trees native to south and east Asia.

Non-preferred scientific names

Older names (synonyms) for the tea plant include *Camellia thea* Link, *Camellia theifera* Griffith, *Thea bohea* L., *Thea sinensis* L., and *Thea viridis* L.

Varieties (subspecies)

Two main varieties (subspecies) of *C. sinensis* are used for tea production. Within these main varieties, there are thousands of cultivars and clones.

- Assam variety (*C. sinensis* var. *assamica*, also known as *C. assamica*) (J. Masters) Kitam, and
- Chinese variety (*C. sinensis* var. *sinensis*).

The Assam variety is native to northeast India, Burma, Vietnam, and southern China. Most of the commercial tea production in the world comes from this variety, including most of the important black teas (such as Assam and Ceylon teas). Teas from this variety taste more "malty" compared to the generally more flowery taste of teas from the Chinese variety. Tea tasters use the term malty to indicate a subtle, underlying flavor. Maltiness is a desired quality in Assam teas.

The Chinese variety is native to southeast China and was used to produce tea as long as 4,000 years ago. Its leaves are used to produce green tea and Chinese-type black tea.

Sometimes a third variety is distinguished, the Cambodian variety (*C. sinensis* var. *parvifolia*). Since its growth characteristics are intermediate between the Assam and Chinese varieties, it is usually considered as a hybrid of these two.

Common names

In Chinese dialects, pronunciation of the word for tea is divided into two classes based on phonetic similarity. In mandarin, tea is *ch'a*. In Xiamenese (Fujian province), tea is *tay*. Around the world, local words for tea are derived from either of these two pronunciations. The British spelled *tay* as tea, which became widely accepted in the English-speaking world. The French *the* and the German *tee* also have *tay* as their origin. In India and Sri Lanka the common name for tea is *cha* or *chai*.

Botanical description

Cultivated tea plants are usually pruned to a height of around 1–1.5 m to make crop maintenance and harvesting ("plucking") easier and to increase yields. However, in their natural state, tea plants will grow to small trees. The Assam variety can grow into a loosely branched tree about 15 m tall. It is a lowland plant, and requires high rainfall and good drainage. The Chinese variety grows to a much smaller size, reaching a height of 3–5 m.

Roots

Tea plants from seedlings have a strong taproot with a dense network of feeder roots. Most feeder roots are located in the top 30 cm of soil. Taproots reach a depth of 1.5–3 m and provide good anchorage for the plants. The taproot is also important because it stores starch from the sugars produced in the leaves. The more starch stored in the taproot, the faster the plant can recover from pruning and plucking. Tea plants grown from cuttings ("clones") generally lack a taproot.

Leaves

The leaves are 4–15 cm long and 2–5 cm wide. Leaves from the Assam variety are normally larger than those of the Chinese variety. Usually the new leaves are harvested for tea production. They are light green in color and have short white hairs on the underside. Older leaves are darker green.

Flower, flower buds, and leaves.

Flowers

The flowers are white with a yellow center, 2.5–4 cm in diameter, with 7 or 8 petals. The flowers are scented and occur singly or in clusters of two to four. Flowers are pollinated by insects and the wind. Tea is mostly self-sterile and almost entirely cross-pollinated.

Fruits and seeds

The fruits are 2–3 cm in diameter, brownish-green in color when mature, and contain one to four spherical or flattened, brown seeds. The fruit ripens in 9–12 months, after which the seeds fall to the ground. Seeds are only capable of germination for 2–3 weeks (Bonheure 1990).

DISTRIBUTION

Native range

The exact origin of the tea plant is unclear. The Chinese variety is probably native to southeast China (Yunnan), while the Assam variety is native to Assam (India), Burma, Indochina and southern China. Naturalized tea plants can be found growing in these areas, but it is often unknown whether these trees are remnants or offspring from past cultivation.

Current distribution

From its center of origin, tea has been introduced to more than 50 countries. However, only 10–15 countries are important producers on the world market, including China, India, Sri Lanka, Kenya, Turkey, Indonesia, Vietnam, Japan, Argentina, Bangladesh, Iran, Malawi, and Uganda.

In the Pacific Basin, commercial production is mainly limited to Papua New Guinea, but there is growing interest and production in other areas, such as Hawai'i.

ENVIRONMENTAL PREFERENCES AND TOLERANCES

Climate

Tea is mainly cultivated in tropical and subtropical climates, but commercial cultivation can also be found in more temperate areas, such as Portugal (Azores Islands), the U.S. mainland (South Carolina, Washington, Georgia, and California), and even the United Kingdom (UK) (Yorkshire and Cornwall).

Tea grows best under high and evenly distributed rainfall. In the tropics, it needs at least 1,500 mm rain per year with a dry season of less than 3 months. Young transplants may require supplemental irrigation. The upper limit to the amount of rainfall appears to be around 3,000 mm. In Sri Lanka, however, tea grows well in certain areas that annually receive more than 5,000 mm of rain.

The ideal temperature for growth is 18–30°C. Growth is limited by temperatures above 32–35°C and below 12–13°C. Strong winds, frequent frost, hail, and excessive rainfall are also detrimental to the production of high quality tea.

Tea requires long hours of sunshine for good production. The ideal day length for vegetative growth is 11¼ hours. This means that tea can be harvested year round within 15–18° of the Equator. Outside this area, dormancy will occur at a rate of 30 days for every additional 3–5° from the Equator (Ranganathan, undated).

Optimum shoot growth occurs between 75 and 90% relative humidity. When the air is too dry, shoots form dormant buds and the plant stops growing.

Tea can be grown from the lowlands to 1500–2000 m elevation above sea level. Many high quality teas are grown at

high elevations, where rainfall less than 2,000 mm. In these areas the plants generally grow more slowly which results in a better flavor.

Soils

Tea is grown on a wide range of soil types. Deep, well drained soils with good structure are essential for vigorous production. High organic matter content is also important.

A soil depth of 1.5–2.0 m is ideal, but in some regions (e.g., Vietnam), tea grows well on soils that are only 60–100 cm deep. With shallow soils it is important that soil moisture is maintained throughout the dry season.

Tea is generally grown on hillsides, but the slope must be less than 30 degrees. On steeper slopes special measures should be taken to avoid erosion (e.g., trenches for drainage, terraces), particularly with young tea plants whose root systems are still developing (Bonheure 1990). As a consequence of serious erosion and leaching, soils often tend to become low in bases and phosphorous, and have great variability in their nitrogen concentrations.

Tea is a calcifuge, which is a plant that does not tolerate alkaline (basic) soil. The most important chemical characteristic of tea soils therefore is soil acidity. The upper pH range in which tea will thrive is 6.0–6.5. The optimum pH for tea is 4.5–5.5.

Under alkaline conditions, iron becomes less soluble. As a result, calcifuges grown on alkaline soils often develop symptoms of iron deficiency, typically leaf chlorosis or yellowing between the veins.

On acidic soils, tea plants accumulate large amounts of aluminum and fluoride, especially in the mature leaves. This may in turn result in high concentrations of these elements in the tea liquor (the technical term for a tea infusion in water), which may have negative effects on human health (Wong et al. 2002). A more recent study, however, concluded that there were no adverse health impacts (Fungal et al. 2009). Liming the soil could reduce the uptake of both elements. For example, Ruan et al. (2004) demonstrated that increasing soil pH from 4.3 to 5.4 (using 1.65 g CaO per kg soil) significantly reduced fluoride uptake.

Indicator plants could be used to evaluate soil for tea cultivation. In east Africa, the most reliable indicators were found to be plants that also accumulate aluminum; e.g., plants from the family Melastomaceae and certain ferns (*Gleichenia* spp.). Staghorn (*Gleichenia linearis*) and *Melastoma malabathricum* are known indicator plant for aluminum soils occurring in Hawai'i, as is club moss or wawae'iole (*Lycodium cernuum*) (Moomaw et al. 1958).

SHALLOW HAWAI'I SOILS

Some areas of Hawai'i have shallow soils but otherwise excellent environmental conditions for tea cultivation. Successful plantings have been established using a backhoe with hydraulic hammer to break through layers of lava rock to form trenches. Another method is to build up soil directly over the natural or crushed surface lava. With both methods, a bed that is 30–60 cm deep should be built using combination of compost, soil, and amendments. Creating these beds well in advance of planting helps establish a healthy environment for microorganisms, proper pH, and rich organic matter. The tea roots can find paths through cracks in the lava to deeper pockets of loose soil where moisture and nutrients are available. Root channels provided from cover crops may assist with opening these paths.

GROWTH AND DEVELOPMENT

There are several ways to describe the different stages in the growth and development of the tea plant. The following is a description by Zeiss & den Braber (2001) based on the practice in Vietnam.

Young plant stage

This stage begins when the seed or cutting is planted and ends when the young plant is pruned for the first time. For plants grown from seed, this lasts until the end of Year 2 or the beginning of Year 3. For cuttings, this is often at the end of Year 1. The appropriate time of the first pruning is normally when the diameter of the main stem is greater than 7 mm, and the height of the plant is more than 70 cm.

Branch formation stage

This stage begins at the first pruning and ends at the last "formation" pruning, which is the last pruning made to shape the frame of the tea bush. Tea plants grown from seeds are usually pruned three times during the formation stage, while plants grown from cuttings are pruned twice.

Plants with many strong, healthy branches have high productivity and good quality. During the branch formation stage, the purpose of pruning is to develop a strong frame of branches. Pruning removes the buds at the growing tips or shoots. This stimulates the development of the side buds, which allows the frame to grow broader. The plucking table should be formed at a height of 70 cm. The width of the table should be such that the center is at arms reach from the path adjacent to the tea row. If the plant can be reached from two sides, the width of the plucking table is about 1.5 m.

Commercial stage

This stage begins after the last formation pruning and continues for as long as the tea is economically productive (often 40–50 years or longer). In this stage the main frame of the tea bush has already been established. However, the pluck-

Plucking table at an appropriate height of about 70 cm.

ing table continues to rise from season to season. The purpose of pruning therefore is to regularly reduce the height and renew the maintenance foliage, the layer of permanent foliage (usually 20–30 cm) directly above the pruning level. These leaves are essential for the tea bush to replenish its nutrient reserves. Plucking continuously removes new shoots and leaves from the plants and, as a result, large amounts of nutrients are being lost from the tea fields. Therefore, plants during the commercial stage need nutrients replaced, especially nitrogen, to continue producing new leaves.

Low vigor tea

When tea is not properly managed, the plants will start to show symptoms of degradation years before the end of their normal commercial productivity. In Vietnam, the moniker "aging tea" is sometimes used for this problem. However, the problem is probably caused more by bad management than by actual age, as many well maintained plantations planted 50 or more years ago are still healthy and productive.

The symptoms of degraded tea include (Zeiss and den Braber 2001):

- low yields
- increasing number of empty spots in the field due to plant mortality
- thin and weak branches
- increased disease infestations above and below ground
- increase in the proportion of unproductive (brown and woody) tissue on the tea plants.
- small and scarce buds and crown buds
- many shoots at the base of the bush, or sprouting up from ground level

When bushes in a tea field become degraded, it is often best to rejuvenate these bushes by heavy pruning close to the ground so that they grow a completely new frame of young branches. When many bushes in a field are degraded it is probably better to replant the whole field with new tea bushes when the financial resources are available.

AGROFORESTRY AND ENVIRONMENTAL SERVICES

As mentioned above, photosynthesis of the tea leaves declines rapidly as temperatures rise above 32–35°C. Without shade trees, yield of tea in warm seasons can be limited by high leaf temperature in many climates. In regions with extensive dry seasons, shade trees play an important role in providing and maintaining sufficient humidity.

Shade trees for mature tea plants are best planted within the rows of tea plants so as not to obstruct harvesting along the aisles between rows. Suitable shade trees have fine leaves that cast moderate shade (a 60–70% penetration by sunlight is said to be ideal) and a deep root system so as not to compete with the tea for nutrients. An example of such shade tree is *Grevillea robusta* (silver oak), which is widely used in India and Africa. Other popular shade trees include various *Albizia* spp., *Erythrina* spp., *Derris robusta*, *Gliricidia sepium*, and *Indigofera* spp. Some *Acacia* species are also commonly used (e.g., Vietnam), but many cast too much shade. All shade trees should be pruned periodically to manage shade levels.

The wood of certain shade trees (e.g., *Grevillea*, *Acacia*) can also be used as building material or fuel wood. The trees can be harvested when they reach a desired size and replanted. Some trees regrow after cutting at the base (coppice), and often this regrowth can replace the original shade tree.

While the tea plants are still too young to be harvested, it is possible to grow other crops ("intercrops") in the space between the tea rows.

These intercrops can:

- Help protect the soil against erosion.
- Help control weeds.
- Enrich the soil with nitrogen and other plant nutrients (when using a nitrogen-fixing green manure plants).
- Provide an early income in the case of annual crops or certain fast-producing perennials.
- Provide temporary shade for young tea plants in some cases.

Crop selection is site specific. In several tea growing areas, spice plants and herbs are integrated in the tea production. Cardamom and ginger are grown in Darjeeling and nutmeg and citronella in Sri Lanka. If tea is grown under shade, then vanilla or pepper could also be integrated into the tea plantations, with these crops using the shade trees as support for climbing (Sippo/FiBL 2002).

Vietnamese tea plantations are good examples of integrated polycultures. The hilltops are covered with natural forest and planted in *Acacia* and *Eucalyptus* trees, with tea agroforests on the slopes below, often including fruit trees such as lychee (*Litchi chinensis*), longan (*Dimocarpus longan*), and pummelo (*Citrus grandis*) on the lower parts of the slopes near homes. Before the lychee and longan close their canopies, annual crops, such as peanut, bean, and sweetpotato, are cultivated (VNAFE 2008).

In China and Sri Lanka, tea is intercropped with rubber, particularly to improve farmers' income in the years before the rubber can be tapped. Raintree (2005) describes the rubber–tea system in China in more detail: In the first year, the rubber trees are planted with spacing that results in the rubber providing 30% shade for the tea. Annual and short-term crops such as upland rice, maize, and peanuts are planted between the rubber trees. After harvesting the rice and maize, pineapple is planted. Peanut is harvested in Year 2 and the pineapples in Years 2–4. In Year 4, the spaces previously occupied by the pineapple is planted with the tea. At this time, the rubber trees are tall enough to provide enough shade for the tea. The rubber trees can be tapped starting Year 6, while the tea can be plucked from Year 7 onward (when the tea is more than 3 years old). The rubber/tea system operates effectively for 30 years, after which the rubber trees must be replanted and the whole system re-started.

A second system from China intercrops Paulownia trees with tea. This system is said to have appeared in Fujian province as early as in the Song Dynasty (960–1279 C.E.) (Li 2001). Paulownia is a key part of tree planting in east central China, especially in agroforestry systems. Paulownia wood is lightweight but strong and is widely used for making musical instruments, furniture, handicrafts (e.g., tea boxes) and plywood. Leaves can be used as fodder for livestock. A spacing of 10 m × 10 m for the Paulownia with the tea at 2.5 m × 1.5 m was found to be best, yielding 37% shade. Closer spacing had a negative effect on the growth of the tea (Li 2001).

Advantages and disadvantages of growing in polycultures

Growing tea in polycultures has many advantages but also a few disadvantages.

The main advantages include:

- Polycultures can give multiple yields, which allows the farmer to diversify production especially before the tea reaches full productivity.
- Properly planned shade trees and ground covers often improve tea production by supplying additional nutrients to the tea, improving the soil (adding organic matter), protecting the tea from too much sun, controlling weeds, and reducing erosion.
- Shade trees and other plants grown with the tea can suppress certain pests and diseases and attract beneficial insects.
- Shade trees provide a more pleasant working environment for the tea pluckers.

Disadvantages include:

- Shade trees and other intercrops may sometimes act as host to tea pests and diseases.
- Shade trees need continuous management in order to maintain an optimum level of shade.

Left: Young tea plants intercropped with vegetables. Right: Tea growing under native forest trees in Volcano, Hawai'i.

- Overly dense shade could result in a reduction of yield or an increase in the incidence of certain tea pests and diseases (e.g., blister blight).
- High shade levels can intensify color and flavor but catechin is reduced.
- Managing a polyculture system within different niche environments can be challenging.

PROPAGATION AND PLANTING

Tea plants are propagated both vegetatively (mostly by cuttings, but grafting and layering are also possible) and from seeds.

Traditionally, tea was propagated by seed. The plants resulting from multiplying selected mother plants from seeds were known in India as "jats." Since tea plant is a cross-pollinator and therefore produces highly heterogeneous offspring, plants grown from seed have uneven growth rates, vigor, and highly variable processing qualities. Therefore, in the main commercial tea production area in the world the use of cuttings has in recent times replaced the use of seeds for propagation. However, many small farmers in countries such as China and Vietnam still use seed and this is one of the reasons for the relative low average yields in these countries. Of course, seeds can be used if one is interested in having a few tea plants for backyard enjoyment as hedges or potted plants or even for home processing (Zee et al. 2003).

Cuttings

Described below is a generalized method for making cuttings. One could make cuttings to multiply a preferred cultivar or to multiply any individual plant with interesting characteristics.

First, mother bushes are carefully selected based on health, vigor, and yield. After pruning, these bushes should be left to regrow freely without plucking. Extra fertilizer should be applied. Bonheure (1990) recommends 80–180 kg nitrogen/ha (depending on the age of the bush) as well as phosphorus and potassium (at a rate which is half of the nitrogen applied). Sulfur could also be given, at 25% of the dose of nitrogen. Cuttings can be taken 4–9 months after pruning.

The best time to make cuttings is when the weather is cool and cloudy. Take cuttings from the new shoots. Cuttings should be severed with a sharp knife, hand pruners, or razor blade. The middle portion of the shoot, which is neither too soft nor too hard, makes the best cuttings. Cuts should be made 2–3 mm above each leaf node, leaving about 3–4 cm of stem below the node (about 2–3 nodes per stem section). The rooting medium can be clean subsoil from the location, or artificial potting mix. It needs to be acidic (pH < 5.0) and have good drainage. The cuttings are cared for in nurseries usually until they are 1–3 years of age (Zeiss & den Braber 2001). However, on at least one Hawai'i farm cuttings have been outplanted with a 90% success rate only 3 months after being started as cuttings (Jacobson, pers. comm.).

Based on methods observed in Japan, Yamasaki et al. (2008) developed a procedure for in-ground rooting of tea cuttings suitable for growing conditions in Hawai'i.

Seed

Use only fresh seed with a dark seed coat from mature fruit. Do not dry or store seeds for more than a few days because tea seeds quickly loose their viability. Immediately before planting, the seeds should be soaked in water for 24 hours, after which all floaters should be skimmed off and germinated separately, as they may have much lower viability than sinkers. Seeds should be planted with their "eyes" down and covered with about 2.5 cm of moist potting soil. Keep the container shaded and well watered. Most seeds will germinate within 4–8 weeks after sowing. Gradually move the plants into full sun to prepare them for transplanting. Transplant them into the ground when the plants are 20–30 cm tall with well established leaves, which usually takes 18–24 months from seed (Zee et al. 2003, Zeiss & den Braber 2001).

Outplanting techniques

Spacing

Tea is normally planted in single or double rows. Rows are separated by paths 1.2–1.8 m on center to allow access to the bushes for plucking and maintenance. When the tea is planted in double rows, the distance between the rows is somewhat larger then when the tea is planted as a single hedge. In India the spacing would be 1.2 m × 0.75 m for a single hedge and 1.35 m × 0.75 m × 0.75 m for a double hedge. These spacings give 10,800 and 13,200 plants/ha, respectively. In general, 10,000–20,000 plants/ha are planted in the main tea growing regions of the world. Zee et al. (2003) suggest a planting distance for Hawai'i of 50 cm (20 inches) within the row and 180 cm (6 ft) between rows, which will result in a density of some 12,000 plants per hectare. The type of spacing pattern selected depends on the terrain, (e.g., flat, hilly) and whether harvesting is carried out by hand or machine.

On sloping land, tea should be planted along the contour to help reduce erosion. During initial establishment of a tea plantation additional anti-erosion measures should be taken. Hedges of leguminous plants can be planted in between the rows of new tea plants. These hedges can reduce erosion and provide shade to the young tea plants. They will have to be pruned back regularly to ensure that their growth will not compete with the young tea plants. The prunings should be returned to the soil, as this will provide considerable amounts of organic matter (Bonheure 1990). When the tea is to be cultivated on terraces, the soil should be pro-

Left: Two leaf cutting. Middle: Misted propagation bed. Right: Plant ready to transplant into field. All photos taken at the Mealani Experiment station in Waimea.

tected against drying out by cover crops or mulches (Sippo/FiBL 2002).

Site preparation

The planting site should be prepared in advance. On grassland or land cultivated with crops, the preparation time needed is around one year (Bonheure 1990). Problematic weeds, particularly stoloniferous grasses such as imperata grass (*Imperata cylindrica*), should be eliminated, if possible, by manually uprooting the weed plants. Burning the vegetative cover for land clearance should be avoided, as it destroys the natural humus and degrades the soil. After clearing the land, planting fast growing cover crops such as *Vigna hosei*, *Indigofera spicata*, or Guatemala grass (*Tripsacum laxum*), can suppress the growth of unwanted weeds (Sippo/FiBL 2002).

Wind protection

Tea is quite sensitive to wind and therefore windbreaks are important in areas where tea would be exposed to wind. Windbreaks should be oriented perpendicular to the prevailing wind. Depending on the size of the field, a windbreak could consist of a system of main windbreaks on the field borders and secondary windbreaks within the field. The main windbreak ideally consists of several rows of trees, with 2–3 m distance between the trees in a row. Trees could be planted in a square or a triangular arrangement. The secondary windbreaks are formed by single rows of trees. The distance between the windbreaks should be less than 10 times the height of the trees on flat or gently sloping and even closer on steep slopes (Bonheure 1990). Useful trees for windbreaks are pine, cypress, *Grevillea robusta*, willow-leaved hakea (*Hakea saligna*), *Acacia* sp., *Eucalyptus* spp. and certain bananas.

Outplanting

Planting holes of 20–30 cm wide and 40–60 cm deep are recommended. The bottom and the walls of the holes should be broken up to avoid root spiralling where the soil is very heavy or compacted.

In South India, no fertilizer is applied at the time of planting; regular fertilizer applications begin only 2 months later. In some other regions, organic manure and rock phosphate or superphosphate are applied to planting holes at planting (Ranganathan & Natesan 1990). Bonheure (1990) recommends applying, if necessary, 30–60 g superphosphate per planting hole.

After planting, the field should be mulched. Mulch is useful in retaining moisture, keeping young roots cool, avoiding soil erosion, controlling weeds and providing nutrition for both the tea plants and the overstory vegetation. The mulch should not touch the plant stems, because it can lead to rot of the tender stem tissues or result in damage from soil insects. Young plants benefit from partial shade from green manure trees or other plants (Zeiss & den Braber 2001).

FOREST CULTIVATION IN HAWAIʻI

With careful planning, tea can be planted in degraded native forests in Hawaiʻi, often with minimal disturbance of existing native species or the forest structure. Assessing site conditions before planting is essential to ensuring a beneficial relationship between the tea and forest plants. Areas that are best suited have less than 40–80% shade, good soil drainage, and some open space so as to avoid excessive root competition. Compared to open field plantings in the same area, tea grown in a forest setting is slower to develop and yields less. However, forest-grown tea is rare and has unique characteristics in sweetness and flavor, giving it a certain market appeal that may compensate for diminished yields.

Attention to the health of the tea is crucial in both forest and open field cultivation. Since each environment has various factors that affect plant growth and yields, schedules and methods vary for mulching, pruning, fertilizing, and harvesting. Irrigation requirements are often greater for open field plantings because forest soils tend to stay moist for longer periods between rains.

Hawaiʻi's young volcanic soils are generally very favorable for tea cultivation. Soil depth, composition, and nutrient status, etc., vary depending on the site's history in volcanic activity, forest age, agricultural activities, and so on. Soil sampling and analysis are recommended for determining the pH and nutrient availability on a specific site.

Removing invasive species

Many native Hawaiian forests have been partially occupied by numerous invasive plant species that should be controlled for forest health. Common invasive plants found in Hawaiʻi forests are tibouchina (*Tibouchina* spp.), kahili ginger (*Hedychium gardnerianum*), Christmas berry (*Schinus terebinthifolius*), and strawberry guava (*Psidium cattleianum*). These compete heavily with native species for available soil nutrients and light.

There are many techniques for removing invasive species without herbicides that can be used for preparing a forested area. For instance, plants such as kahili ginger can be cut repeatedly over a season. This will weaken the roots making it easier to manually remove the plants. Strawberry guava trees may be girdled and eventually drop their leaves. Their roots weaken over time, easing the work of manual removal. For a faster process, machinery such as compact utility tractors can be used in certain forested areas. Gently guided, light machines can remove invasive species while not harming natives, such as the shallow-rooted ʻōhiʻa lehua trees. Some of the organic matter generated from forest clearing can be utilized for soil amending and mulch. These organic additions stimulate natural soil life and provide a healthy environment, helping to ensure successful introduction of tea plants.

Left: Four-year-old tea plants growing in native ʻōhiʻa lehua forest in Volcano, Hawaiʻi. The tea is growing in an ecological niche formerly occupied by invasive species. Right: Strawberry guava, a common invasive species, growing in native forest in Volcano, Hawaiʻi.

CULTIVATION

Variability and known varieties

There are hundreds of tea cultivars, each with their own unique characteristics and flavor profiles. Since propagation by seed does not give the required uniformity, commercial tea cultivars are all propagated vegetatively, yielding identical clones. In regions where tea has been grown for decades, it may be advisable to continue with normally accepted cultivars. Where tea cultivation is new such as in Hawai'i, the tea market will eventually determine the most appropriate cultivars.

Basic crop management

Soil and water conservation measures

Proper soil and water conservation measures are essential for successful tea cultivation. As mentioned earlier, tea rows should be planted on the contour on slopes. Trenching and mulching promote rainwater infiltration and make moisture available to the plants on a sustained basis. Trenching is done by digging small ditches between alternate plant rows and filling them with prunings of green manure plants, material, leaves, compost, and animal manure. The organic material must be cut into small pieces and should not be buried too deep. In digging the trenches, some of the tea roots are severed but this stimulates new growth. The trenches should be redone every 3–4 years. The disadvantage of this method is the high workload involved, especially in older plantations with narrow gaps between the rows (Sippo/FiBL 2002).

Nutrient supply and fertilizer management

A large amount of nutrients are removed through the continual plucking of tea leaves. For each 1,000 kg tea leaves, the equivalent of 45–65 kg N, 5–15 kg P_20_5, and 20–35 kg K_2O is taken away (Sippo/FiBL 2002; Bonheure 1990). The regular pruning of the tea bushes also removes large quantities of nutrients.

Fertilizer recommendations vary widely for different tea growing regions of the world. Rates depend on the age of the bushes, pruning cycle, yield, and soil fertility. Field trials are useful to develop recommendations for new tea regions. Once a plantation has been established, periodic analysis of leaf tissue nutrients should be carried out to monitor the health of the plants.

During the first 5–6 years of growth, tea plants need 40–200 kg/ha/year of N. Applications of P and K are normally given at 50% of the amount of N applied (Zeiss & den Braber 2001). However, where there is a severe deficiency of P or K, higher amounts are needed.

During the commercial stage, the tea plants require more nitrogen than in previous stages. Most recommendations are in the range of 80–300 kg/ha/year but the exact amount of nitrogen also depends on how much tea is harvested. As an approximate guide, use about 20–25 kg of nitrogen for each ton of fresh tea leaves harvested (Zeiss & den Braber 2001) In Sri Lanka, K is applied at rates of 60–80 kg/ha K_2O for yields of up to 1600 kg/ha or 90–180 kg/ha K_2O for higher yields (Ranganathan & Natesan 1990). Phosphate is applied as rock phosphate in most tea growing areas, while super-

Variety trials at the University of Hawai'i Mealani Experiment station in Waimea, Hawai'i Island.

Table 1. Common tea varieties grown in Hawai'i

Cultivar	Green	Pouchong*	Oolong	Black	Notes
'Bohea'	X		X	X	Vigorous, good resistance to anthracnose, easy to propagate, grown for black tea at low elevations
'Yabukita'	X				Slightly drier areas and all elevations. Elongated, serrated leaves, long internodes, relatively easy to propagate. Susceptible to anthracnose.
'Yutaka Midori'	X		X		Gentle, mild, sweet flavor. Suitable for all elevations and relatively dry. Relatively easy to propagate. Can be used to make matcha.
'Benikaori '				X	Good resistance to anthracnose. Good needle tea.
'Chin Shin Oolong'		X	X		From Taiwan, used for oolong and paochong tea.

Source: Compiled by Ben Discoe from UH CTAHR publications.
* Semi-oxidized Oolong

phosphate is used extensively in Africa. In South India, P is applied as rock phosphate placed at 15–25 cm depth once a year until the first pruning and once every 1–2 years thereafter, depending on yield level. Rates vary from 40 to 100 kg/ha P_2O_5 (Ranganathan & Natesan 1990).

Tea has relatively high requirements for calcium, zinc, and magnesium. In very acid soils, zinc deficiency may occur. Zinc deficient plants show small and chlorotic leaves, short internodes, and longer period of dormancy (Zeiss & den Braber 2001; Nelson 2006). If plants seem to be deficient in zinc, apply zinc sulfate at 8–30 kg/ha (Zeiss & den Braber 2001). Other options are zinc oxide and zinc chelate. Poultry and swine manure are good organic sources of zinc (Nelson 2006).

Soil pH should be maintained at about 5.0 by application of lime once per pruning cycle. The quantity of lime should be determined on the basis of soil pH, rainfall, and crop yield.

For organic tea production, compost, oil cake, and rock phosphate are the main inputs. Nitrogen is also supplied by regular pruning of shade trees and other leguminous trees and applying the prunings as mulch. Bone meal, fish meal, and wood ash can also be applied (Sippo/FiBL 2002).

Shade management

Adequate attention to shade tree maintenance will help provide optimum shade. Excess foliage and small branches should be cut a few times a year. Larger branches on the lower part of the shade tree should be removed. Overlapping branches can create overly dense shade. Leave the lopped branches in the field as green manure.

It is difficult to give details on the optimum range of shade. Generally, tea plants require about 50% diffused sunlight for optimal physiological activity. However, actual requirements for shading depend on the climate and the altitude of the area where the tea is grown and on general management. Detailed planting densities for shade trees are difficult to find in the tea literature. Sippo/FiBL (2002) mention a density of up to 500 shade trees per hectare depending on the site and the variety of tree. Zeiss and den Braber (2001) state a density of 200–300 per hectare for *Indigofera* shade trees in Vietnam.

In general, the higher elevation, the less shade is necessary (Sippo/FiBL 2002). This is because in the same manner as altitude, shade generally causes a decrease in ambient temperature and an increase in relative humidity.

When choosing which shade trees to use, it is important to consider species that are adapted to the local conditions. It is advisable to include some nitrogen-fixing species. Overall, select several species so as to avoid the problems of a monoculture. The ideal combination of shade trees for a particular locality should be based on local experience or, when that is not available, determined by on-site field trials (Sippo/FiBL 2002).

Care should be taken to choose fast and slower growing species at the start of cultivation Sippo/FiBL (2002). Since tea plants have an economic life of 40–50 years (even up to 100 years), shade trees should last this long. Slower growing species often have a longer lifespan and will provide shade in the later productive years of the tea bush. However, slower species may take several years (3–5 years is common) to provide adequate shade and therefore faster growing species are used during the early years. Once the slower growing species (the "permanent" shade) provide enough shade, the faster growing species (the "semi-permanent" shade) can be removed. In Bangladesh, *Albizia sinensis* and *A. moluccana* provide semi-permanent shade, while *A. odoratissima, A. procera, A. lebbeck* and *Derris robusta* are used as permanent shades (Ahmed and Bedroll Alam, undated). Many of these species are considered invasive in Hawai'i and other parts of the Pacific, so other non-invasive shade trees should be trialed for use in these regions.

Mulching

Mulching is very beneficial, particularly in the seedling and branch formation stages. Mulching can be done with bunch grasses, straw, crop residues, ferns, shade tree loppings, and other plant materials. Plants can be grown in vacant patches, field borders, etc., to be cut for use as mulch. The kind of material used for mulching will influence its effect. Material that quickly decomposes will protect the soil for a relatively short time period but will rapidly provide nutrients while decomposing. Materials that decompose more slowly release nutrients more slowly, but cover the soil for a longer time, which is especially important in areas where soil erosion is a problem.

A mulch cover enhances the activity of soil organisms such as earthworms. They help to create a soil structure with plenty of smaller and larger pores through which rainwater can easily infiltrate into the soil, thus reducing surface runoff. As mulch material decomposes, it increases the content of organic matter in the soil. Soil organic matter helps to create a stable crumb structure. Thus the soil particles will not be easily carried away by water. Therefore, mulching can play a crucial role in preventing soil erosion.

The plant material used for mulching should be free of seeds to avoid weed problems. If insufficient mulch material is available, consider planting ground covers or permitting useful weeds to grow between rows ("living mulches"). Beware that in dry weather, mulch could be a fire risk.

Weed control

Mulch and the use of ground cover crops greatly contribute to the reduction of weeds. Manual weeding, if feasible,

HAWAI'I CASE STUDY

A 10-year study by the USDA Pacific Basin Agriculture Research Center (USDA PBARC) and a handful of private tea farms in Volcano, Hawai'i has shown promising cup quality for tea cultivated in the native rain forest. The Volcano area covers 147.4 km^2 on the summit of the Kilauea volcano, with most of the farms located near Volcano Village at an elevation of about 1,220 m. Parts of Volcano Village lie within a *kīpuka* (an area surrounded by one or more younger lava flows). A 1790 eruption covered the area in a mineral-rich, 30–100 cm deep deposit of volcanic ash. Over time, the humus layer has built up to 18–25 cm thick, although some areas have soil, humus, and volcanic ash to depths of up to 4.6 m. Annual rainfall in the Volcano area is generally 2,500–3,200 mm with daily average temperatures of 11–22°C. Here, forests tend to retain the proper amount of moisture needed for growing tea and there is generally no need for additional irrigation.

Dr. Francis Zee of USDA-ARS (on left) conducts a trial harvest of tea at Volcano station.

Planting tea in degraded native and secondary non-native forests for hand harvesting allows for more natural planting configurations. If growers anticipate wanting to utilize machine harvesters, planting configurations should be designed for harvester access. Spacing of 50–60 cm between plants in single-row plantings has been successful in Volcano Village forests. Because of the slower growth rate in this environment, this spacing allows a table design for producing a substantial yield while allowing proper air circulation around the trunk area, encouraging a healthy root system. Planting holes dug to depths of 1–1.2 m allow for deep root growth. Breaking through the various soil layers to combine the humus and volcanic ash strata assists in nutrient availability and provides a favorable environment for root development. Tools that are commonly used for digging holes in this environment are a posthole digger, ʻōʻō bar (long metal digging pole), or a gas-powered auger.

A range of organic amendments can be mixed into the planting holes, including those rich in trace minerals such as azomite, jersey green sand, chicken manure, and agricultural blue-green algae (or other organic resources of nitrogen, potassium, and phosphates). Experiments in planting techniques with minimal soil disturbances are also being conducted.

Left: Holes prepared with gasoline-powered auger at 50–60 cm spacing in cleared forest understory. Middle: Digging holes with ʻōʻō bar and post hole digger. Right: Soil amendments and potted tea plant ready to go into the ground. Volcano, Hawai'i.

is always preferred to herbicides. Weeds can be pulled by hand or by using hoes or spades. Mowers can also be used to make the job easier. In the rainy season, weeds should not be pulled out but cut just above the ground so that their root systems stay in the soil and help reduce soil erosion during heavy rains.

Irrigation

In areas with sufficient, evenly distributed rainfall, irrigation may only be needed for keeping plants healthy and productive through dry spells and while establishing small plants.

In drier areas irrigation becomes necessary in periods when evaporation exceeds precipitation. The volume of irrigation water needed can be measured or estimated. Direct measurement requires sophisticated equipment. Therefore, tea growers usually rely on indirect measurements like monitoring soil moisture or estimates based on meteorological observations.

Both drip and sprinkler irrigation is being used in tea, with sprinkler systems being more common. Sprinkler systems are easy to operate but costly to install and to operate (cost for electricity). In the larger tea plantations in India the rotating-head sprinkler is the most commonly used system. Sprinkler systems are suitable where farmers' maintenance skills are limited and water supplies are adequate.

Mulch can greatly benefit tea plants, especially during establishment. These small plants in Ahualoa, Hawai'i are mulched with shredded tree trimmings and ginger stems.

Drip irrigation is suitable for areas where water is limited or costly, water is clean, and where good maintenance skills and parts are available. These systems are more efficient than sprinkler systems and allow for "fertigation," providing fertilizers with the irrigation water. Labor requirements for drip systems are lower than for sprinkler systems. However, the initial investment costs for drip irrigation are higher than for sprinkler systems.

In Vietnam, smallholder tea farmers normally water by hand with a hose connected to a pump that draws water from a pond or stream.

Horticultural techniques

Pruning

Regular pruning is essential in tea cultivation. Pruning shapes the plant so as to encourage a fresh supply of new shoots and increase yields. A variety of pruning systems and intervals are practiced, depending on the site and plucking system (Bonheure 1990, Zeiss & den Braber 2001).

Usually, the bushes are pruned back once every 3–4 years to a height that is comfortable for plucking (50–100 cm) and then heavily pruned every 10–20 years to a plant height of 30–40 cm. If possible, pruning should be carried out when the tea bushes are dormant or less active, such as in the dry season. Usually, special pruning knives are used for smaller branches and saws for thicker branches. Tools should be sharp so as to make clean cuts, which will help prevent diseases. Various types of Japanese portable power hedgers are used for flat or arched surface cuts.

Pruning of young plants (the "formative" pruning)

The primary focus of nursery and early field pruning is to induce branching and the formation of a bush with a wide and flat top surface (Zee et al. 2003). Pruning removes a large percentage of the leaves, which considerably reduces the plant's ability to produce the nutrients needed for its development. After pruning, new shoots develop to the detriment of the plant's nutrient supplies, particularly those in the roots. Young plants do not yet have a large root system and it is therefore possible in this stage to kill part or all of the plant's frame (Bonheure 1990).

The first formative pruning is done when the diameter of the main stem is at least 7 mm and the height of the plant is at least 70 cm. For cuttings this is usually at the end of Year 1 or the beginning of Year 2. For plants grown from seeds this is normally one year later. In the first pruning, the main stem

of the plant is cut 25 cm above the ground and the other stems at a height of 40 cm. A second formative pruning is done one year later, at a height of 45 cm (Fig. 1). After new shoots have grown 20–30 cm above the pruning level, break them off ("tipping") at a height of 60–70 cm ("tipping level") to form a flat canopy ("plucking table") (Fig. 2) (Bonheure 1990; Zeiss & den Braber 2001).

Production pruning

After the formation pruning, tea bushes are usually pruned every 3–4 years at a height of 4–5 cm above the point of the last pruning. This type of pruning is called Light Pruning. The main purpose of light pruning is to renew the wood, regulate the distribution of new shoots, reduce pests and diseases, and maintain a good frame height. The time period between one light pruning year and the next is called a pruning cycle. The length of a pruning cycle depends on the climate of the growing area, the planting material used, and the plucking method (Bonheure 1990).

One method to determine the best time for pruning is the root starch reserve test. Much of the sugar produced by tea plants is stored in the roots in the form of starch. The more starch stored in the roots, the better the plant is able to recover from pruning. To test how much starch is stored in the roots, cut the end of a root and apply some iodine on the cut. Iodine will react with starch by turning blue. The darker the blue color, the more starch in the root (Zeiss & den Braber 2001).

The "cut across" means that all the branches above the pruning level are cut while the frame under that level remains intact (Bonheure 1990). The best way to make a pruning cut is as follows: Always cut the branches at an angle of 45° to allow any water to shed, hastening development of a pruning scar, thus avoiding any disease infestation. The pruning cuts should be made so that the high side of each wound faces outwards from the center of the bush. It is said that by making such cuts, the new shoots also will grow toward the outside of the plants, creating a bigger plucking surface. Since the center of the plant always grows faster than the outside, it is also recommended to prune the center of the bush a little lower than the outside, creating a hollow shape (Zeiss & den Braber 2001).

If tea is grown on hillsides, the tops of the bushes should be cut parallel with the slope of the hill (Fig. 3), ensuring that all branches are the same length, which gives uniform growth for the whole plant. If tea is pruned level, branches on the higher side of the bush will be closer to the ground than branches on the lower side. Branches that are too short will develop fewer new leaves and shoots and production will be reduced (Zeiss & den Braber 2001).

In between successive pruning years, tea bushes are sometimes given lighter forms of pruning called "skiffing." This would be done, for example, when the plucking table rises too quickly or when the tea bush is damaged by hail, frost, or severe insect damage (Bonheure 1990).

Maintenance pruning

The plucking table gradually broadens and rises as the seasons progress, and for continued ease of plucking, it eventually must be lowered by cutting it back. The continuous removal of new shoots also leads to a layer of thickened stems and knots on top of each bush, which eventually restricts new growth and reduces production. This condition is overcome by maintenance pruning that removes all stems and leaves down to the primary frame of the tea bush. This is done at intervals that vary from region to region and different techniques are being used appropriate to specific growing conditions (Zee et al. 2003).

Height Reduction Pruning is done by bringing down the height to 60–70 cm above the ground, while Medium Pruning reduces the height of the bush to 45–50 cm above the ground. After these treatments, plants are brought back to the normal pruning cycle within about 4–5 years (TRA 2008).

Heavy pruning is done at 15–45 cm above ground level for complete rejuvenation of the tea bush. Collar pruning, an even more severe measure, removes all above ground parts, leaving only 10 cm or less of trunk. In India, this kind of pruning is largely avoided since it often results in heavy mortality, especially in poor soils (TRA 2008).

Prunings should be left in the field. In some areas, they are put on top of the pruned bushes to protect them from the sun. Often, the pruning material is left on the ground in between the tea bushes. The material breaks down easily and becomes incorporated into the soil organic matter.

For Light Pruning, there is generally no need of a period without plucking ("resting the bush") before pruning. However, bushes with poor vigor should be rested starting 3 weeks before pruning. For bushes that are very weak or for Medium Pruning, the bushes should be rested 5–8 weeks before pruning. For Medium and Heavy Pruning, additional doses of phosphate and potassium should be given. In India, a temporary shade of *Indigofera teyesmanii* is planted a year before Medium or Heavy pruning in areas with inadequate shade (TRA 2008).

Plucking (harvesting)

For high-quality tea only the bud and the two (or at most three) youngest leaves should be plucked. The seasonal growth of these buds and leaves is called flushing. A plant will produce a new flush every 7–10 days during the growing season (Bonheure 1990).

To understand how plucking needs to be carried out, it is important to know how tea plants grow. Growth consists

of two phases, the productive period (the "flushing" period) and the dormant or "banjhi" period. Dormant buds, or banjhis, gradually swell and then start to grow longer. They first produce one or two small, non-serrated bracts. These bracts drop soon after opening. Then two kinds of pre-leaves are formed, first the "janams" and then the fish leaves. The janam leaves also often fall off, leaving a small scar. Fish leaves are smaller than normal leaves and usually have a smooth edge. Photosynthetic activity in fish leaves is higher than in normal leaves. Finally, 4–8 normal leaves appear, the exact number depending on the growing conditions of the plant. Then a new dormant bud appears, which after 8–15 days starts a new cycle of leaf production (Bonheure 1990; Zeiss & den Braber 2001).

Standard plucking is done at the level of the fish leaf (see picture). Too light plucking leads to a loss in yield and the formation of a very irregular plucking table. If the plucking is too hard (i.e., reaching the janam leaves), this will result in the formation of numerous twigs, a reduction in the weight and size of the shoots, and therefore a considerable loss of yield (Bonheure 1990).

Good plucking practices include (Bonheure 1990):

- Only pluck adult shoots (one bud + 2 leaves or one bud + 3 leaves).
- Never adopt a fixed plucking schedule. Pluck the tea as soon as around 30% of the shoots are ready for harvesting. This system will increase tea yield and quality, reduce insects pests (e.g., green leafhopper), but will require more labor and good planning.
- Never pluck the shoots below the plucking table.
- Keep the plucking table flat and parallel with the ground.
- Do not pluck on rainy days; wet tea will take too long to dry which affects the quality.

The plucking table produced by pruning generally results in a greater density of shoots in the center of the plucking table compared to the sides. While this central area only represents around 10% of the total surface of the table, it provides 60–65% of the yield.

Harvesting is a skilled job, in many countries traditionally carried out by women and done by hand. To pluck the shoots, the leaves are carefully pinched and twisted when removed from the tea bush. Handfuls of shoots are then placed into baskets carried by the pluckers. After the tea is harvested in the

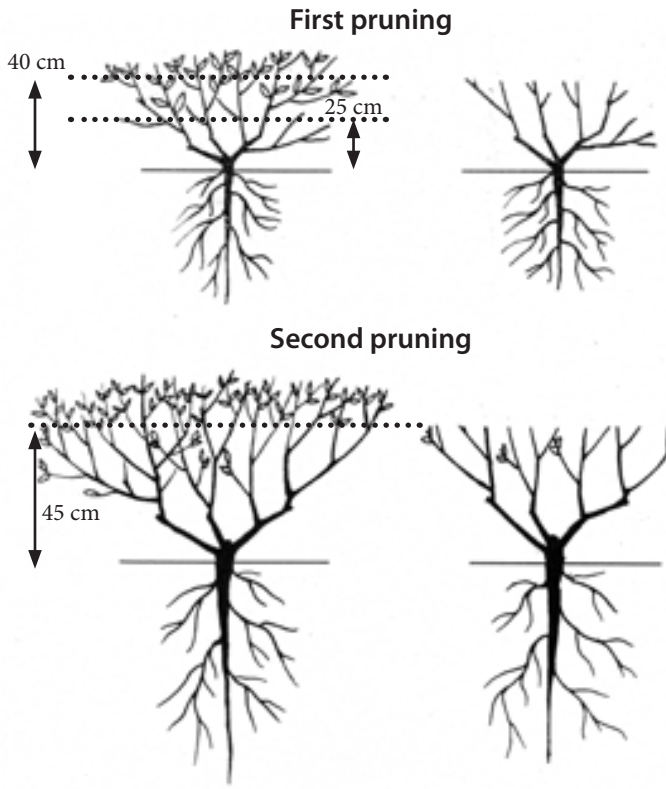


Figure 1. In the first pruning, the main stem of the plant is cut 25 cm above the ground and the other stems at a height of 40 cm. A second formative pruning is done one year later, at a height of 45 cm (adapted from Bonheure 1990).

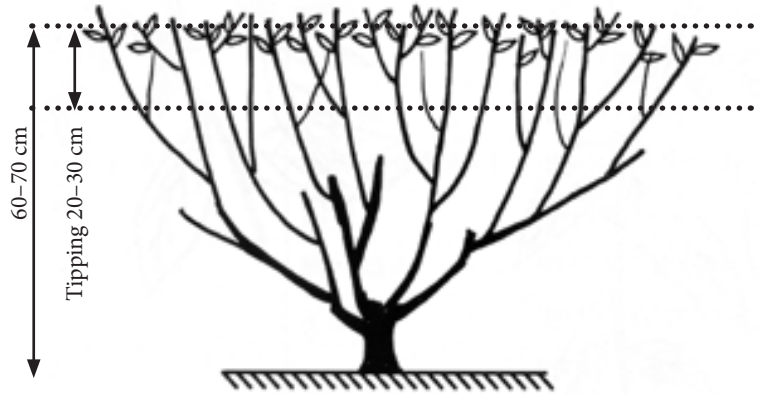


Figure 2. After new shoots have grown 20–30 cm above the pruning level, break them off ("tipping") at a height of 60–70 cm ("tipping level") to form a flat canopy ("plucking table") (adapted from Bonheure 1990).

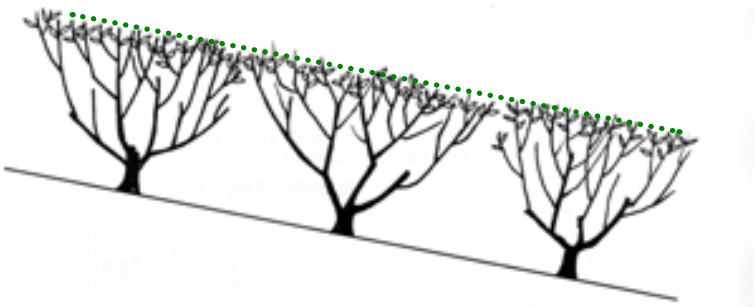
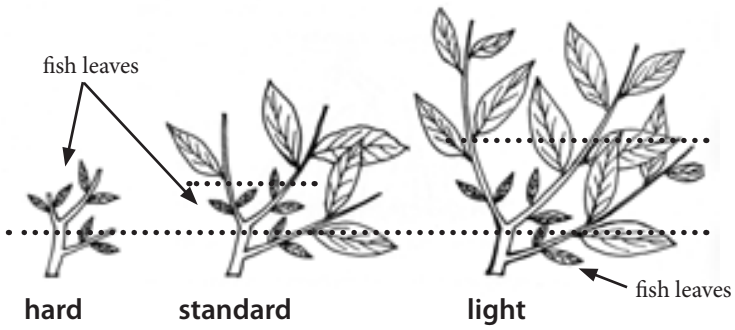


Figure 3. Pruning should keep the plucking surface parallel to the slope (adapted from Bonheure 1990).

fields, it is brought directly to the tea factory where it is further processed (Bonheure 1990).

In many countries with larger plantations (e.g., Japan, Taiwan, Africa, U.S., China, Australia, Korea, Russia), plucking machines are used. However, machine plucking is hard on the plants and usually does not result in high-quality teas.



Hard, standard, and light plucking (adapted by Zeiss and den Braber 2001 from Bonheure 1990).

PESTS AND DISEASES

Susceptibility to pests/pathogens

More than 1,000 species of arthropods and nearly 400 pathogens are known to affect tea worldwide. Losses due to pests and diseases are estimated to be 15–20%. As the tender young leaves and buds are the harvested portion of the tea plant, pests that attack these parts are of particular concern to growers. Pests can cause direct crop loss due to feeding injuries or indirect damage by negatively affecting the quality of the tea.

Although tea pests vary between regions, they usually belong to the same groups, notably mites, leafhoppers, mosquito and other plant bugs, aphids, thrips, leaf rolling and leaf folding caterpillars, and stem boring insects. Recent surveys in Hawai'i indicate that the same broad groups of insects attack tea in Hawai'i (and potentially also other parts of the Pacific region). The following species were identified (Zee et al. 2003, Hamasaki et al. 2008):

- melon aphid (*Aphis gossypii*)
- Chinese rose beetle (*Adoretus sinicus*)
- Mexican leafroller (*Amorbia emigratella*)
- transparent winged plant bug (*Hyalopeplus pellucidus*)
- twospotted leafhopper (*Sophonia rufofascia*)
- spiraling whitefly (*Aleurodicus dispersus*)
- red and black flat mite (*Brevipalpus phoenicis*)
- broad or yellow tea mite, (*Polyphagotarsonemus latus*)
- avocado scale (*Fiorinia fiorinae*)
- mining scale (*Howardia biclavis*)
- greenhouse thrips (*Heliothrips haemorrhoidalis*).

Pests such as Helopeltis mosquito bugs, black citrus aphid (*Toxoptera aurantii*), the lesion nematode (*Pratylenchus loosi*), and several eriophyid mite species are serious pests in many tea growing areas and could pose a threat if introduced to tea production in Hawai'i and other areas in the Pacific. Quarantine measures are the main defense against the introduction of new tea pests (Zee et al. 2003).

The most common diseases in tea can be grouped as root rots, leaf diseases, and branch diseases. Leaf blights and spots are common in hot climates with heavy rainfall. Anthracnose or brown blight (caused by *Colletotrichum* spp.) and gray blight (caused by *Pestalotiopsis* spp.) are common and also found in Hawai'i (Zee et al. 2003, Keith et al. 2006).

The following diseases are not reported in Hawai'i but are very damaging to tea in other parts of the world and all precautions should be taken to prevent their accidental introduction (Zee et al. 2003):

- Branch canker disease (*Macrophoma theicola*)
- Blister blight (*Exobasidium vexans*)
- Tea hair disease (*Marasmius equines*)

Plant materials suspected to be infected should be removed from the field and burned after preserving samples for diagnostic analysis (Zee et al. 2003).

Identification guides for Hawai'i pests (Hamasaki et al. 2008) and diseases (Keith et al. 2006) are available, which may be useful for other areas of the Pacific as well. Zeiss & den Braber (2001) and Zee et al. (2003) also have good images and descriptions of many pest and diseases species.

Pest and disease prevention

Pest and disease management practices should focus on prevention rather than control. Within a balanced ecological system, the pests and diseases are controlled by the use of resistant clones, balanced nutrient supply, natural enemies, and by appropriate cultural operations. If insects and diseases occur, non-toxic biological methods are preferred.

The University of Hawai'i CTAHR tea program has been demonstrating that no pesticides are necessary. No insecticides or fungicides have been used at the CTAHR tea experimental plots for over 9 years. Good cultural practices and maintaining adequate plant health can sustain a balance of predators and pests that minimizes pest damage.

Healthy plants

Poor pruning and plucking practices will weaken tea plants and cause them to become more prone to pest and disease infestations. Bringing plants into bearing too fast will result

PLANTING TEA AT LOWER ELEVATIONS IN HAWAIʻI

Hawaiʻi's weather patterns do not include seasonal typhoons, allowing tea cultivation to take place at elevations that are lower than in other tea-growing regions of the world. There is some experience with both *C. sinensis* and *C. assamica* cultivation from 275 m down to 30 m and even lower elevations throughout Hawaiʻi. It is too early to say what kinds of processed teas will be favorably produced from these low elevation teas.

In the past, many lower elevation agricultural lands were used for industrialized sugarcane production, which left the soils heavily degraded. Many aggressive weeds thrive in these conditions. Some tea growers in such areas use commercial weed mats to suppress weed growth around their plants. These mats add extensive heat to the immediate environment, raising temperatures to levels that can stress plants and affect their growth and health. Additional irrigation may be needed to offset the heat and accompanying evapotranspiration.

Depending on the specific location, wind can be a challenge for young plants. Windbreaks are helpful in protecting young plants before they get established and can provide partial shade to relieve plants exposed to the higher temperatures of lower elevations.

Permanent living ground covers and cover crops that are nitrogen-fixing can replace unwanted weeds. Perennial peanut (*Arachis pintoi*), clover (various genera), and Sunn hemp (*Crotalaria juncea*) have worked well for growers. Sunn hemp can grow high enough to also act as a windbreak. Tea plants that have matured and been pruned properly often shade out weeds so that no weed mats are required.

There are a number of pests that can effect tea production in Hawaiʻi. One insect not prevalent at the higher elevations but a problem at lower elevations is the Chinese rose beetle (*Adoretus sinicus*). It feeds on the older leaves and not on the new growth or harvestable flush. Mature plants usually recover readily from the leaf damage, but periodic feeding can be devastating for young plants. Chinese rose beetle has an interveinal pattern of feeding, leaving a lace like appearance. The Chinese rose beetle can be combated with barriers around young plants such as stretched cloth or a tall cover crop such as Sunn hemp. Planting decoy plants that the beetle prefers to tea such as certain bamboos can help reduce damage. Installing solar powered night lights that switch on at dusk can disrupt their nocturnal cycle and hence reduce feeding damage.

Top left: Assam cultivar growing at 275 m (900 ft) in Hakalau, Hawaiʻi. Top right: Rose beetle-laced tea foliage. Bottom: Young tea plants being established with irrigation between rows of Sunn hemp for organic matter production and wind protection.

in plants with poorly developed frames that cannot sustain long-term production.

Always make sure to use sharp, clean pruning tools that make a clean cut. Irregular cuts heal slowly and collect water, and can get infected with pathogens more easily. Mechanical plucking also can increase disease infestation since it damages leaves that remain on the plant.

Good fertilizer management is also important, making sure that nutrients are balanced rather than focusing only on nitrogen. Tea plants growing in soils deficient in potassium are more susceptible to diseases such as grey blight and Anthracnose. Applying too much nitrogen fertilizer increases tea's susceptibility to certain diseases such as blister blight.

Use of resistant clones

There are specific clones that are tolerant of a variety of tea diseases such as Anthracnose (e.g., 'Benikaori' and many pure Assam varieties) and blister blight (e.g., 'SMP-1' and 'SA-6' from India, 'TRI-2043' and 'DT-1' from Sri Lanka, 'GMB' numbers 6, 7, 8, 9, and 10 from Indonesia, and many Chinese-type varieties).

Protect and enhance populations of natural enemies

Insect and mite pests have many natural enemies, including predators, parasites, and diseases. The preservation of natural enemies is important for pest control. To protect predators, it is essential to limit the use of chemical pesticides as much as possible. In Vietnam, for example, it is believed that increased use of broad-spectrum pesticides has resulted in the growth of green leafhopper and mosquito bug populations.

Provide natural enemies with the shelter they need by planting cover crops between the rows, or permitting beneficial weeds to grow there. Mulching between the rows may also help encourage higher populations of predators.

Manage the tea microclimate

Growing tea underneath shade trees tends to reduce problems with certain insect pests such as leafhoppers. Mulching also helps to increase soil moisture retention and reduce leafhopper populations. On the other hand, mosquito bugs (*Helopeltis*) prefer moist conditions and mild temperatures. For that reason, mosquito bug populations are often higher under heavy shade. Blister blight also often develops under heavy shade and modifying the microclimate through the thinning of shade trees can control this disease. Adequate spacing is important to reduce disease development, as it will permit air circulation and reduce humidity and the duration of leaf wetness.

Plucking frequency

Several insect pests such as green leafhopper and mosquito bug lay their eggs in the young leaves and buds. The frequency of plucking therefore plays an important role in limiting leafhopper populations by reducing the availability of suitable sites for egg laying. Plucking every 10–15 days removes insect eggs and young insects before they can grow large enough to cause a lot of damage. Pluck out all the damaged buds as well, even if they are so badly damaged that they cannot be used. Plucking the damaged shoots will stimulate the growth of new shoots. Appropriate timing of the harvesting period can also minimize pest infestations.

Manage alternative host plants

Several tea pests, e.g., mosquito bugs and mites, feed and reproduce on many plant species. In case of a pest problem, it could be useful for growers to search for these pests on other plants in and near their tea fields. If necessary, these alternative hosts can be removed.

Field monitoring and decision making

Pest control decisions should be based on field monitoring. Decisions should not only be made on the pest or disease incidence, but also on (Zeiss & den Braber 2001):

- The age of the tea bushes
- How the pest or disease incidence has developed over time
- The number of natural enemies
- The number of days before the next harvest; and
- The weather forecast.

Control methods

If the only option remaining is to spray a pesticide, avoid pesticides that kill natural enemies, such as broad-spectrum types and pyrethroids, and pesticides with high human toxicity. Growers can try botanical pesticides such as neem oil for certain pests (Zeiss & den Braber 2001).

Although pesticide application could give some temporary relief, it should be noted that pest and disease problems are often a symptom of some problem in the growth or development of the plant. The only long-term solution is to identify the root causes and address them.

Plant quarantine

Importation of tea germplasm from other regions can introduce new serious tea diseases and pests. If tea germplasm is to be brought in, this should be done in cooperation with state or federal agricultural agencies.

DISADVANTAGES OF THIS CROP

It usually takes 4–5 years for tea to reach full production and there is little income from tea plants during the initial years. Intercropping could provide some income during this period, for example when fast-producing fruit trees are planted with the tea. Planting nitrogen-fixing pulses such as soybean

or cowpea has the double benefit of providing an income and improving of the quality of the soil.

The initial investment for a tea plantation itself could also be a problem, particularly for smallholders when no credit facilities exist. In certain areas irrigation may be required, which increases investment costs. Tea production and processing is labor intensive. This could be a serious limitation in areas where labor resources are scarce or expensive.

Producing a good quality tea is often said to be more of an art than a technique and there is quite a steep learning curve for horticulture and processing in new areas. Considerable time and effort is required to learn all the steps in producing and processing the tea.

Finally, export opportunities for new production areas may be limited due to high international competition and the domination of the international trade by a few large companies. However, there is potential for high-quality or specialty teas (including organic and fair trade teas) and for both local and export markets.

Potential for invasiveness

Tea is not considered to be invasive.

COMMERCIAL PRODUCTION

Postharvest handling and processing

Main types of tea

Black tea is fully oxidized and undergoes five basic manufacturing stages: withering, rolling, oxidation ("fermenting"), firing, and sorting. Two different processing methods are used, the Orthodox method and the CTC (Cut, Tear, Curl) method. The basic difference between these methods is in the rolling/cutting process. In the Orthodox method, the withered leaves are twisted gradually in slow rollers, while in CTC, the leaves are shredded by mechanical cutters. Orthodox teas look like twisted flakes and are rich in aroma while CTC teas are more powdery and are rich in color. Although many countries still prefer Orthodox teas, the trend is toward CTC processing (AIT 2002).

The purpose of withering is to remove the surface moisture (and partially the internal moisture) of the freshly harvested green leaves and to get the correct physical condition of the leaves, which will allow them to be rolled without breaking. The withering process begins by evenly spreading out the shoots in thin layers on trays or fine meshed screens, called the withering troughs. A volume of 12–30 kg of leaves per square meter is recommended (Bonheure 1990). Withering takes place in open-air rooms utilizing the effect of natural airflow or in special facilities with controlled heating and ventilating equipment. Withering is done at 20–25°C. During withering, the moisture content of the green leaves is reduced to 55% (hard withering) in the Orthodox production method and 70% (light withering) in the CTC method. Withering takes about 6 hours for light withering and about 12–18 hours for hard withering (AIT 2002).

The purpose of rolling is to break the plant cells. During this process, plant enzymes are released and begin a chemical reaction when exposed to oxygen. Rolling is mostly done mechanically but some high-grade teas are still rolled by hand. In the CTC method, leaves are not rolled but shredded to release the plant enzymes. The shredded (pre-conditioned) leaves then pass through a CTC machine (AIT 2002).

After rolling, the tea leaves are prepared to go through to the next stage of processing, oxidation, commonly referred to as "fermentation." Oxidation determines the characteristic color and aroma of the tea. Normally, shorter oxidation gives teas rich in flavor and aroma while longer oxidation gives more color. Great skill is needed during the oxidation phase because it can dramatically affect the finished product, particularly in timing and air circulation (AIT 2002). This stage also makes it uniquely different from green tea, which is not oxidized. Green tea skips this process and proceeds directly to the "firing" or drying ovens to reduce the moisture content.

The Orthodox method usually uses a natural oxidation process, in which the rolled leaves are spread out in thin layers on tables or perforated aluminum trays for about 3–4 hours. Mist chambers or humidifiers are used to moisten the oxidation area. In CTC production, the tea leaves are fed into a rotating oxidation drum, where blowers supply air. This process takes only about 45 minutes (AIT 2002).

Once the desired oxidation is achieved, the dried leaves are fired to halt the oxidation process and to reduce the moisture content of the tea to 2–3%. Hot air is passed through the oxidized leaves in dryers. Temperatures of 90–160°C (depending on the type of dryer) are required for about 20–30 minutes to complete the process. Firing determines the final product quality of black tea (AIT 2002).

After firing, the tea is sorted into different grades by passing it over a series of vibrating screens of different mesh sizes. This system produces a number of grades with evenly sized particles. The smallest sizes are "dust" and "fannings," while higher quality grades are "broken leaf" and "whole leaf" grades. Teas are then packaged according to particle size and appearance. Each grade has a specific name (see Table 2).

Oolong tea is partially oxidized tea, only 10–80% of the oxidation as compared with black tea. In Taiwan, one of the first steps in the processing of oolong tea is to toss the leaves in large bamboo baskets to bruise the outer leaf edges. This bruising causes the leaves to oxidize. After tossing, the fresh leaves are exposed to air. The leaves react with oxygen and

begin to turn brown on the edges. They are then rubbed to further augment oxidation. The oxidation process continues for a predetermined time based on type of oolong tea to be produced. The longer the leaves are oxidized, the closer to black tea the result will be. Oolong teas that have only a short oxidation are closer to green tea.

Next, the leaves are fired to halt oxidation. The leaves are then rubbed several times to enhance flavor, aroma, and texture, and then re-fired. Upon cooling, the leaves are rolled and fired one last time. The final steps in the process include drying, grading, and packaging.

As opposed to black tea, no single accepted method has been developed for grading oolong teas. In China, oolong tea is graded "Fanciest" or "Extra Fancy" for the best teas, while the lowest grade of oolong tea is referred to as "Common."

Green tea is unoxidized. Processing consists of wilting, followed by either steaming (Japanese method) or roasting (Chinese method). The oxidation process begins naturally once the leaves are bruised through plucking and handling during transportation. Steaming or roasting should occur soon after harvest so as to stop oxidation of the plucked leaves. Next, the leaves are rolled and then dried to a finished product, or rolled and dried alternately until finished, depending on the type of green tea being manufactured. After this process, a final drying takes place followed by sorting.

Manufactured green tea can be classified according to the same sorting grades as black tea, i.e., whole leaves, broken leaves, dust and fannings, etc., but this system is not applied universally and some traditional green tea producing countries such as Japan and China prefer to use their own grading systems.

Table 2. Tea grades in Orthodox process

Whole leaf grades	
FTGFOP	Finest Tippy Golden Flowery Orange Pekoe
TGFOP	Tippy Golden Flowery Orange Pekoe
GFOP	Golden Flowery Orange Pekoe
FOP	Flowery Orange Pekoe
OP	Orange Pekoe
Broken leaf grades	
BOP	Broken Orange Pekoe
BP	Broken Pekoe
P	Pekoe
FBOP	Flowery Broken Orange Pekoe
GBOP	Golden Broken Orange Pekoe
BOPF	Broken Orange Pekoe Fannings
Dust and Fannings	
Fannings	
Dust	

White tea is a very special product in China, mainly produced in Fujian Province, but now beginning to be found in western China other parts of the world. It is made either from "tea needles," the newest, still folded buds at the end of shoots, or from shoots that consist of the tea needles and one or two young leaves. After the leaves are plucked they are withered in the sun before transferring them indoors for more controlled withering. The total withering time is up to 3 days. After withering, the leaves are graded and then baked (not fired) at temperatures of less than 40°C to remove excess moisture. Baking time must also be precisely controlled.

White teas are graded according to the variety of the tea used, the degree of maturity of plucked leaves, and the appearance of the buds and leaves (e.g., all very straight buds of the same length together, all buds with a slight bend together, etc.). Further distinction can be made based on the size of the leaves used (the youngest leaves are generally considered to have the highest quality flavor) and the region of origin. The two highest grades of white tea are "Silver Needles" and "White Peony."

Other types of tea

Besides the four main types described above, there are other types of tea that are less common on the world market:

Yellow tea is a rare tea from certain parts of China (notably Anhui). One of the aims of making yellow tea is to remove the grassy aroma of green tea while retaining its health qualities. The processing is similar to green tea, but making yellow tea is much more difficult and time-consuming. The leaves are first roasted, as for green teas, but then the damp leaves are wrapped in special paper or cloth. At intervals the tea is fired again and re-wrapped to cool and oxidize slightly. This process continues for up to 3 days and finishes with a slow roasting. Yellow teas generally have a very yellow-green appearance (both dried leaves and liquor) and a smell different from both green and white teas. On today's markets, many yellow teas are fakes and made using normal green tea processing techniques.

Puerh (Pu-erh, Pu'erh, Puer) is an aged tea that since December 2009 has been awarded "Protected Identity" status by the Chinese government. This means that the designation "puerh" can only be used for teas produced in Yunnan province's eleven prefectures and must be made from leaves and leaf buds of *Camellia sinensis* according to a defined methodology. Although aged teas are produced in other places (other Chinese provinces, Vietnam, Korea, etc.), these can no longer be called puerh. It is Yunnan's special geology and geography, soil, and large-leafed *assamica* varietal tea plants and trees (many of which are up to 2,000 years old) that give puerh teas their unusual and individual character.

Puerh teas are made from unoxidized green tea. The made tea, called "maocha," is steamed and compressed into cakes of all shapes and sizes or left loose. These are then stored in special temperature- and humidity-controlled conditions during which time the tea gradually oxidizes and ferments until, after a number of years, the tea develops a mellow, smooth, sometimes slightly earthy character. Good puerhs require a minimum of 7–10 years to be ready for drinking and are often stored for much longer (50 or more years) to reach full maturity. Such teas are known as "raw" or "green" puerh (*sheng* in Mandarin Chinese).

Because the traditional method of manufacture takes so long, in the 1970s producers created a quicker way of achieving the same mellow earthiness in their puerh teas. This method involves making the green maocha in the same way as for traditional puerhs. The maocha is dampened with water (that usually contains bacteria that provoke enzymatic fermentation in the tea), heaped under covers, and stored in damp conditions for a few months until it develops the composted character that is similar to that of traditionally aged puerhs. These teas are known as "cooked" or "ripened" puerh (*shu* in Mandarin).

Scented and flavored teas can be made using white, green, yellow, oolong, black, or puerh teas as a base. Additional flavorings include flowers, fruits, herbs, and spices, and the blend often also includes flavoring oils or granules to ensure a well balanced and enduring aroma and flavor. Additional flavorings can be natural or artificial.

Some traditional teas are scented in the country of origin. For example, Jasmine, rose petal, lotus, and osmanthus teas are blended in the factory (usually in China, Taiwan, Vietnam, Cambodia, etc.). The tea is made first and stored until the harvest of the relevant flowers is completed. The tea is then heaped in layers with the flower blossoms (sometimes several different batches of flowers) and left over several days until the tea has absorbed the aroma of the blossoms. In the past, traditional lotus tea was made by wrapping small pinches of made green tea inside unopened lotus blossoms. The flowers were left overnight and the tea was retrieved the following morning. Today, pollen is removed from the lotus flower stamens and mixed with the tea.

Other blends are created by tea wholesalers that are situated in the countries of consumption (or in Germany where several of the large benders are located). Earl Grey tea, probably the most popular flavored tea worldwide, is flavored with oil of bergamot, a small citrus fruit that looks rather like a pear but tastes like an orange. The variety of flavored blends is endless but popular varieties include vanilla-flavored, fruit-flavored, and spiced black teas, and mint and citrus flavored greens.

Instant tea

Although still lagging far behind instant coffee in popularity, the production of instant tea has been growing in recent years. Both hot and cold water soluble instant teas are available in the market. These products often come with added flavors, such as lemon or other fruits, vanilla, or honey. Similar products also exist for instant iced tea. In producing instant tea, the liquor (tea brew) is concentrated and dried to form a powdered or granular product.

Bottled tea

After a slow start since its introduction in the 1980s, bottled teas have gained more popularity in recent years. There are now many brands on the market, with a wide range of types and flavors. Some bottled teas are made by brewing tea leaves in hot water, while others use powdered or instant teas or cold extraction. The teas are bottled in glass or plastic or even in carton packs or bags. Often, bottled teas are pasteurized or sterilized, which reduces the need to use preservatives.

Bubble tea

Originating in Taiwan some 10 years ago, one of the latest emerging trends in the tea market is bubble tea. The two main ingredients of this cold beverage are tapioca balls and milk tea. Round tapioca balls (the "bubbles" that give this product its name) are boiled in the tea flavoring.

Chai

Chai, which is the word for tea in many parts of the world, is generally made with rich, black tea, heavy milk, a combination of spices (e.g., cardamom, cinnamon, ginger, cloves, and pepper) and some form of sweetener. It is a centuries-old drink originating in South Asia but it is now becoming increasingly popular worldwide. In the U.S., chai has caught on and is being sold as, "tea latte" a popular alternative to its coffee namesake.

Blending

Almost all commercial teas sold in the West are blends. Blending may occur with teas from within one tea planting area (e.g., an Assam blend) or with teas from different areas (e.g., English Breakfast tea, which is a traditional blend of Assam, Ceylon, and African teas). The aim of blending is to obtain a consistent taste since the characteristics of pure teas always fluctuate due to changes in weather, rainfall, soil, and season. Some popular brands are blends of 20–30 different teas. Some people say that blending does not only give a consistent taste, but also a better price since more expensive, better-tasting tea may mask the inferior qualities of cheaper teas with which they are blended.

Methods of processing at a community or farm level

Tea processing, whether for white, green, oolong, or black teas, can be effectively done at the small family farm level. As demand increases, larger manufacturing facilities may prop up depending on the specific market sector developed and interest with investors. Although simple technologies exist for small-scale black tea processing (Sato et al. 2007) and several high-quality black teas use hand rolling and other manual processing, commercial black manufacturing is done in large factories. Setting up such a factory requires major investment in equipment and facilities and also requires a relatively large production base to achieve economy of scale. In general, such factories are owned by large companies. Very few farmer cooperatives have made the step to invest in a black tea processing factory.

Green tea production at a household level is very common in Vietnam and China. In Vietnam, only a simple dryer (Fig. 4) and sometimes a roller are used. Zeiss & den Braber (2001) gives a detailed description of green tea processing as practiced by smallholder farmers in Vietnam.

Processed green tea is also used as an ingredient in ready-to-drink teas, soft drinks, ice cream, biscuits, and candies. Some of these products, for example cookies or biscuits, could also be made at household or farm level and could be a nice complement to a good quality tea made at the community or farm level.

Product quality standards

There are no quantitative standards available for tea quality. The quality of tea is typically tested at the factory and/or by buyers at auction. The evaluation of the final product depends solely on the tea taster who judges characteristics of the liquor (flavor, aroma, color) as well as the leaf color, shape, and size of the samples. The teas are qualified using specific descriptive terms created by the tea industry. These terms include:

Body: A liquor that is full and strong
Brassy: Bitter taste.
Brisk: A pleasing and slightly tangy taste from a well oxidized and well fired tea.
Crisp: Taste quickly disappears on the tongue, a very desirable characteristic.
Flaky: Leaf that is fragile and flat due to poor processing technique
Malty: Thick mouth-feel flavor, desirable.
Tippy teas: Tea harvested from young leaves; having golden buds.

To prepare the samples for tasting (also called "cupping") a standardized procedure is followed. Sets of special tea tasting cups are used consisting of a lidded brewing cup with strainer and a bowl. ISO standards require that brewing cups are either 150 ml or 310 ml. White ceramic is used to facilitate color assessment. Cups and bowls are placed in a row, with one set per sample. A small quantity of the dry leaves is placed next to each cup. A precise measure (normally 2 g/100 ml) of the tea sample is put in the cup and just-boiled water is poured over it. This means that for the 310 ml brewing cup, 5.6 g of tea is used with 280 ml water. The cups are then covered with the lids and the tea is steeped for a fixed amount of time (6 minutes). The liquor is poured into the bowl for tasting. The remaining tea leaves are set on top of the brewing cups so that their color and aroma can be observed.

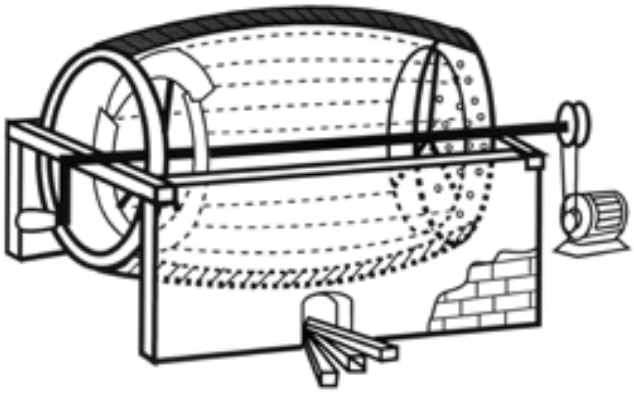


Figure 4. Typical dryer used in Vietnam (Zeiss & den Braber 2001).

First, the dried tea leaves are examined. Then the infused leaves are checked for color and aroma. Finally, the liquor in the cup is evaluated for color and taste. Aroma plays a major role in the sensory experience. The taster inhales the bouquet of freshly brewed tea before tasting. Using a spoon, the taster slurps the tea into his mouth without swallowing. This allows that the tea with a large amount of oxygen is passed over all the taste receptors on the tongue and other parts of the mouth and so provides an even taste profile. The liquid is then usually spat out into a spittoon before moving on to taste the next sample.

Product storage requirements and shelf life

Since tea quickly absorbs moisture, it is packed after grading in airtight containers. Packaging can either be in tea chests (wood based) or specialized packaging such as foil bags or multi-layered bags that include a layer of foil. In India, only bulk packing (in wooden chest or bags) is done at the factory level and trading companies pack tea for local or export markets, whereas in Sri Lanka and Vietnam, the packing (for example, tea bags) is done at the factory level (AIT 2002).

The shelf life of tea varies with storage conditions and type of tea. Properly stored black tea may keep for 2 years, but green tea loses its freshness usually in less than a year. Puerh teas improve with age and are kept for up to 50 years.

Cupping workshop with China researcher at Hawai'i farm.

Tea stays freshest when stored in a dry, cool, dark place in an airtight container. Storage life for all teas can be extended by using desiccant or oxygen absorbing packets, and by vacuum sealing. Improperly stored tea may lose flavor or become moldy. Tea also quickly acquires flavors or odors from other foods and should therefore be stored in proper containers, preferably away from strong smelling food.

Recommended labeling

A well designed packaging and label are important to attract new customers and to make the product stand out in a specific marketing niche. For any market, the legal labeling and packaging requirements should be followed. For value-added purposes, it could be useful to include on the label the type of tea used, the production location, special horticultural practices applied (e.g., grown under shade), organic certification, or any special processing methods used.

SMALL SCALE PRODUCTION

The cultivation of tea is attractive for smallholder farmers since tea cultivation requires little investment and the risk of crop failure is limited. In many parts of the world, tea is produced by smallholders, even in countries with large tea plantations. For example, in Sri Lanka there are over 206,000 tea smallholdings, responsible for 44% of the country's production (AIT 2002). In Kenya, 88,000 ha (or 65% of the national total area under tea) are managed by smallholders. In Vietnam most tea is produced by smallholders. The province of Thai Nguyen (the largest green tea producer in Vietnam) has a total production area of 14,500 ha, cultivated by a total of 66,000 households. Annual production of (fresh) leaf was 75,000 metric tons (MT) (den Braber 2003).

Since every 5 kg of fresh leaves gives only 1–1.25 kg of processed (green or black) tea, volumes produced on a small farm are normally quite modest. Small-scale processing of black and green teas can be done (Sato et al. 2007) but the required manual labor will make this kind of processing only economically feasible for high-value specialty teas.

Whether the tea is hand or machine processed, the art of making tea is dependent on the skills and experiences of the tea master. As has occurred in many tea growing regions of the world, a specialty tea in Hawai'i is waiting to be born as a result of Hawai'i's unique and rich island cultural heritage.

Processing of green or oolong tea could be economically feasible even on the household level, particularly where good quality teas can be grown. Some farmers (e.g., Vietnam, Taiwan) make a good living from their individual production since their tea fetches a price that is 30–50% higher than the price of an average quality tea. For larger commercial processing, farmers may do better operating a cooperative processing unit or selling to a large factory.

As with coffee, tea is usually exported at an early stage of production. The tea companies in the importing countries normally do the final blending and packaging, which is the most lucrative part of the tea trade. Tea producing countries themselves benefit little from the value adding. In Europe, 30–50% of the retail price of a tea is to cover the blending, packing, packaging materials, and promotion costs (Stamp 2001).

Several producers have tried to add value to their products by selling processed tea in tea bags or consumer-ready packaging units but the export of these ready-for-use products is often difficult due to poor market information and the lack of funds for specific marketing activities (Stamp 2001).

Nutrition

Pure tea beverages do not have much nutritional value, contain no sodium, and almost no carbohydrates, fat, or protein. They are virtually calorie-free. Tea drinking helps maintain a proper fluid balance in the body. Since tea is made with boiled water, it is often safer to drink tea in areas where there is no clean water.

Tea was probably first used in China for its medicinal values and it is still used in traditional Chinese medicine. The last 10–20 years has seen an increase in studies into the health benefits of tea, particularly green tea. For the most part, studies conducted on green and black tea has shown similar results.

Tea leaves contain more than 700 chemical compounds, among which flavanoids, amino acids, vitamins (C, E, and K), caffeine, and polysaccharides are closely linked to human health (U.S. Tea Association 2008). Fresh tea leaves contain about 4% caffeine. One of the key compounds in tea is L-theanine, which is largely responsible for tea's pleasant taste and calming effects. This amino acid is found almost exclusively in tea plants where it constitutes 1–2% of the dry weight of the leaves. Much research also focuses

on (tea) flavanoids, as they are believed to have antioxidant properties. Antioxidants work to neutralize free radicals, which scientists believe, over time, damage certain cell components such as genetic material and lipids, and contribute to chronic disease. Tea extracts are known to have an antibacterial activity and are therefore being investigated for the preservation of processed food and the treatment of persistent bacterial infections.

Some negative effects of tea on human health have also been reported. The high level of fluoride in tea has been linked to the high incidence of fluorosis in parts of China where people consume large quantities of tea from tea bricks (which is particularly high in fluoride).

Import replacement

In countries where green tea is produced traditionally, such as China and Vietnam, farmers often use the processed tea for home consumption. However, where black or oolong teas are the main type of tea consumed, home processing is impractical.

It is unlikely that local production will be able to fully replace imports in the Pacific area (e.g., Hawai'i). However, high quality regional production could replace some imports and boost the local economy as a specialty crop. Production of local specialty teas could further lead to the development of value-added products related to tea (tea pots, etc.) or tea-related agritourism.

YIELDS

Yields of tea vary widely among producing countries, depending on soil type, climate, and tea maintenance techniques. Total yields can vary greatly depending on the horticultural practices of the plantation in addition to whether the tea is hand or mechanically harvested. Very good plantations in India are producing 3,500 kg/ha/yr (which corresponds to some 16 MT fresh leaves/ha), while many smallholders in Vietnam do not produce more than 400 kg/ha/yr. Comparing national averages, Kenya in 2007 produced 2,000 kg/ha/yr, while India produced 1,700 kg/ha/yr and China just 1,000 kg/ha/yr (FAOSTAT).

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Value-added products such as tea-flavored candies, novel beverages, and culinary flavorings can help make tea operations economically feasible in the Pacific, where land and labor costs are high.

The introduction of green revolution technologies, such as chemical fertilizers and pesticides, has in general resulted in considerable yield increases since the 1950s. However, it seems that in several tea regions these yield increases have reached their limit due to chemical, physical, and biological impoverishment of soil fertility under intensive tea production (Panigrahi 1993, quoted in Senapati et al. 2001).

Recommended planting density

The most common planting densities are 10,000–15,000 plants/ha. Density is an important factor for yields. Lower densities favor greater individual bush productivity, whereas with higher densities individual yields decrease but total yields from the whole field is higher (Bonheure 1990).

The plant density should be adapted to the site conditions (slope, altitude, soil, etc.) and account for the incorporation of shading trees. Higher plant densities are appropriate when slopes are not too steep, on soils rich in nutrients, and when the risk of drought is low. However, close planting has the disadvantage that the individual tea plants will grow less vigorously and have lower yields, especially as the bushes age (Zeiss & den Braber 2001).

MARKETS

Commercial production worldwide

In 2008, world tea production reached 3.85 million tons, which meant a slight decrease compared to 2007 caused by drought in several major production areas, but still an increase of 5.5% compared to 2006. Black tea production totaled some 2.5 million MT, and nearly one million MT of green tea were produced. FAO estimates that, while production of both green and black tea will continue to grow, over the next decade green tea production will grow faster than black tea (4.5% annually for green tea compared to 1.9% for black tea) (FAO 2008).

Table 3 gives production figures for the period 2006–2008 for the main production countries. China and India are by far the largest producers, but this production is mostly consumed domestically. The largest tea producer in the Pacific region is Papua New Guinea, which produced some 9,000 MT in 2008.

Total world exports reached 1.65 million MT in 2008, which had an estimated value of US$3.76 billion (FAOSTAT). The main exporting countries are Kenya, China, Sri Lanka, India, and Vietnam.

Local markets

Local market sales should have high potential, especially for high quality, specialty ("boutique," "gourmet," or "origin") teas. Themed travel, including visits to tea gardens, is a new trend in tourism, not only in the more traditional tea growing countries (China, India, Sri Lanka) but also in the U.S. Examples are the Bigelow plantation in South Carolina and the Tea Hawaii and Company, which grows tea on a five-acre estate in Volcano, Hawai'i Island (Tea and Coffee 2008a, b).

Export market

Tea is one of the world's major agricultural export commodities. Many countries produce tea almost entirely for export. Total world export is around 50% of total production and tea consumption at present roughly equals production.

Like many other commodity markets, the tea industry is highly concentrated. It is said that about 85% of the world export is handled by only a few, large multinational companies (Stamp 2001). It is difficult for new countries to develop their place in the world export market. However, because the dominant multinational companies still mostly limit themselves to conventional tea, there still remain many possibilities on the specialty markets (high quality, organic, fair trade, etc.) for small or start-up companies and new production areas.

Tea consumption on a per capita basis is highest in northwest Europe (UK, Ireland) and the Middle East and North Africa (Turkey, Morocco, Iran, Egypt). The principal tea importing countries are Russia, United Kingdom, Pakistan, and the U.S. Other large importers include Morocco, Japan, and Germany. Globally, 1.47 million MT of tea were imported in 2006, an increase of nearly 6% over 2003. Growth has been especially strong (over 10%) in the U.S., Pakistan, and Morocco (FAOSTAT).

Specialty markets

The consumption of premium whole leaf teas (as opposed to tea bags) is rising, especially for green teas. This is thanks to an overwhelming emphasis on green tea in many articles promoting health benefits of tea consumption (Andersen 2005). This opens up new opportunities for small producers who are otherwise not able to invest in equipment for making tea bags or more complicated processing.

Over the last few years there has also been a general increase in the demand for niche products such as high quality gourmet, fair trade, and organic teas. Together with an increased interest in quality, there has also been a trend toward healthy and ethical products (Andersen 2005).

With the increased consumer demand and interest for high quality tea, the number of sales channels for such teas has also grown. High quality teas are no longer only sold by specialty shops, but can now also be found through the Internet, in tea salons, and even some supermarkets. The consumption of premium whole-leaf teas is also rising, especially green teas. This is largely a result of the promotion of the health benefits of green tea (Andersen 2005).

Organic tea production

The number of organic tea producers and the volume of organic tea traded on the world market has increased substantially over the last few years, although production is still quite small compared to the volume of conventionally produced tea. In 2003, an estimated 13,000 MT of organic tea was produced, from a total world production area of 16,000 ha. India has the largest area under organic production, followed by China.

Several factors contribute to the increase in organic tea production and consumption. Tea producers themselves have become more aware of the health impacts and environmental problems (erosion, pesticide residues, etc.) associated with intensive tea production. Consumers are becoming more concerned about pesticide residues and other health and environmental issues that have resulted from modern farming methods. Furthermore, drinking organic tea fits well with the general "health" trend in drinking tea seen by the continuing increase in the consumption of green tea. There is also much evidence that organically grown teas are generally of better quality due to the avoidance of artificial additives (Sippo/FiBL 2002). However, little reliable data about the organic tea market and the benefits of organic tea are available.

Table 3. World Tea Production 2006–2008 (in metric tons and as percentage of total world production)

Country	2006		2007		2008	
	Quantity	%	Quantity	%	Quantity	%
China	1,047,350	29%	1,183,000	30%	1,257,385	33%
India	928,000	25%	949,220	24%	805,180	21%
Kenya	310,580	9%	369,600	9%	345,800	9%
Sri Lanka	310,800	9%	305,220	8%	318,470	8%
Turkey	201,900	6%	206,160	5%	210,000	5%
Vietnam	151,500	4%	164,000	4%	174,900	4%
Indonesia	146,850	4%	150,200	4%	150,850	4%
Japan	91,800	3%	94,100	2%	94,100	2%
Argentina	72,100	2%	76,000	2%	76,000	2%
Iran	59,200	2%	60,000	2%	60,000	2%
Bangladesh	58,000	2%	58,500	1%	59,000	2%
Malawi	45,500	1%	46,000	1%	46,000	1%
Uganda	34,300	1%	44,900	1%	42,800	1%
World Total	3,649,170	100%	3,902,880	100%	3,845,700	100%

Data from de FAOSTAT, except for Turkey 2008, which is estimated (FAO database, accessed April 16, 2010)

CULINARY USES

One of the challenges tea growers face is to harvest the tea flush at its peak valued for fine tea. During the long periods of rain when harvesting is delayed, the flush can continue to develop beyond its peak. Rather than harvesting overmature leaves for an inferior tea or losing a crop, growers may consider harvesting them for culinary usage.

Culinary uses can be an important subsistence and value-added product. Top: Tea saimin. Bottom: Tea salad.

Most of the organic tea produced is exported to Germany, the UK, and the U.S. Sippo/FiBL (2002) estimates that organic tea consumption (black and green tea) for these market destinations is estimated at 600–800 MT per year in Germany, 1,000–1,500 MT in the UK, and 2,000 MT in the U.S. All other European countries consume less than 100 MT of organic green or black tea per year.

Because a large number of certified producers entered the organic tea market in the last few years, there is currently an oversupply. This situation has led to a drop in prices for producers, while consumer prices for organic tea have remained quite stable. This means, despite the existing oversupply, international traders are profiting (Sippo/FiBL 2002).

Fair trade

The world market for fair trade tea is growing rapidly. While in 2004 a total of 1,964 MT of certified fair trade tea was sold globally, sales increased to 5,413 MT in 2007 (Fairtrade, n.d.).

Consumers interested in fair trade products are often also interested in buying organic products. In general, fair trade products that are also organically certified seem to have an advantage over products that are solely organic or fair trade (Andersen 2005).

Sustainable agriculture

The Rainforest Alliance provides sustainable agriculture certificates for a number of crops, particularly coffee. A certification program for tea started in 2007. Also in 2007, UTZ Certified expanded its certification program for sustainable and environmentally friendly production to tea. Although few plantations have so far received these certifications, there is growing interest in buying tea with sustainable agriculture certification among large tea trading companies.

Branding possibilities

Local branding gives smaller plantations or farmer groups opportunities to develop niche markets for their products. Some teas are very unique for a specific location and can be sold at high prices. Popularity is enhanced where consumers are sensitive to the idea of local products or specific cultural aspects of production. Combining local tea products with other local specialties is a good strategy for expanding sales. In Hawai'i, local tea growers are combining their product with locally made chocolate truffles, baked goods, and honey. Introducing local teas through restaurants specializing in local cuisine is another interesting option.

Potential for Internet sales

Because tea is light weight and lacks special shipping requirements, it is well suited for Internet sales. Tea also stores well. In fact, tea is increasingly being sold through the Inter-

HAWAIʻI MARKETING

Hawaiʻi has a great potential to establish itself as a tea-producing region. The tea produced presently in Hawaiʻi is still evolving. Growers are experimenting with minimally, partially, and fully oxidized teas. Each location, field management program, cultivar, and processing method brings out various characteristics, creating unique teas. Marketing location-specific teas will foster numerous possibilities including local consumption, visitor markets, and international and domestic export.

Many value-added products such as candies, wines, pickled products, and sauces are in development. Small-scale cultivation specializing in fine quality teas with continual new product development will provide an industry that can stay competitive. Because of the uniqueness of Hawaiʻi teas, growers sell at local farmers markets, direct via the Internet and telephone orders, and offer on-farm tours where products are available for purchase.

Product selection is based on growers' personal preferences, ability to educate consumers, and filling customer demand. In understanding how to market Hawaiʻi-grown tea in the niche specialty tea industry, it is helpful for growers to learn about industry standards and what tea merchants' needs are for sustainable marketing. Hawaiʻi growers who have established themselves commercially know what their fields and gardens can produce in a year and how much can be manually processed with consistency in quality. This acquired knowledge will help Hawaiʻi in setting quality standards specific to Hawaiʻi that can be accepted in the world market.

Since growing, processing, and developing value-added products require different skill sets, the future of Hawaiʻi-grown tea may be in growers producing high quality tea leaves, with processing services provided by experienced small-scale processors who have researched and developed processing techniques that best serve Hawaiʻi-grown tea.

Left: Candy and tea products from Hawaiʻi. Right: Honey wine infused with tea produced in Volcano, Hawaiʻi.

net either by conventional retailers and specialized Internet tea retailers.

EXAMPLE SUCCESSES

Volcano Tea Garden, Volcano, Hawaiʻi

Mike Riley's Volcano Tea Garden has 0.2 ha planted in tea at 1,100 m elevation in Volcano, Hawaiʻi. The south-facing slope is favorable to tea cultivation, as is the well drained volcanic soil. Mike was introduced to tea many years ago by Dr. Francis Zee on a visit to the University of Hawaiʻi's Waiakea Agricultural Experiment Station in Hilo and was immediately hooked. Since then, he has been gaining experience growing, processing, and tasting tea.

Where there were native trees on Mike's farm, they were preserved by carefully clearing out the invasive species around them and planting tea in the open space. Mike's experience is that tea will thrive in up to about 50% shade, so he believes it would be a shame to eliminate native forest to grow tea.

Mike does his own plucking and processing, specializing in oolong and black teas. Due to the ideal growing conditions, visiting scientists have told Mike that his operation is capable of producing some of the finest oolong teas in the

world. He is currently hand processing to oolong and black teas, employing traditional techniques similar to the way tea was processed in China 1,000 years ago. The process is very time-consuming, requiring at least 5 hours per pound of tea produced. This yields an artisan tea in very limited quantities. The teas wholesale at $350/kg and retail at $880/kg. His production sold out last year, and a similar demand is expected this year.

Mike believes his teas sell because they are unique on the market and they have the Hawai'i name. Experts from large tea companies have visited Mike's farm and see the potential markets for Hawai'i-origin teas, and other advantages, including rich, volcanic soil, unpolluted air, and lack of many of the pests and diseases that have impacted tea in most large-scale tea-growing regions of the world.

Johnny's Garden, Hakalau, Hawai'i

John Cross has been growing 0.4 ha (1 ac) tea at 275 m elevation in Hakalau, Hawai'i since 1994. His plant materials originally came from a large collection at the University of Hawai'i Wailua Experiment Station, which included hundreds of Assam-type seedlings. C Brewer, a large agricultural producer, planted 100 select individuals from Wailua in Pepe'ekeo, but determined that the crop was not feasible for them to produce on a large scale. From these 100 individuals, John selected two that were healthiest and that possessed lots of silvery sheen, which is anecdotally associated with high quality tea. John believes that the cool nightly wind from the top of Mauna Kea downward across his farm toward the ocean is important for the accumulation of sugars and subtle flavor characteristics.

Because John has a full time job, he continues to maintain his tea plants, but has an agreement with a processor who harvests and processes his tea. John's primary motivation for this arrangement is to stimulate the tea industry in Hawai'i, by making the product available in a slowly growing market. His tea is processed to black tea marketed as Hawai'i Grown Makai Black.

John's biggest challenges have been contending with rose beetle damage (especially during the first year of establishment) and weed control, which includes handwork at the base of the tea plants. Constant pruning to train plants into a picking table has also been an issue. However, these challenges have been worth the effort to develop a new crop that will help farmers and be an asset to the Hawai'i visitor industry.

ECONOMIC ANALYSIS

Expenses of production

Cost of production is difficult to generalize since tea producing operations vary greatly among producing countries. One main difference is the scale of production, whether it is a household level or large-scale plantation. In countries such as India and Sri Lanka, corporate tea producers often provide services to their staff and laborers that their governments cannot offer. Apart from salaries, they pay for medical care, fuel, education, housing, and other benefits to staff and laborers. As a result, labor costs are relatively high for these companies. For example, in Sri Lanka the cost of production was US$1.37 per kg produced during the 2003/2004 season. Of this amount, 44% was for salaries and other ben-

Left: Volcano Tea Garden's planting under scattered native trees and shrubs. Right: Mike Riley (on left) hosts university visitors who are interested in the potential for tea production in Hawai'i.

John Cross discusses tea cultivation with a university researcher from China.

efits of the field workers, 16% for manufacturing (factory labor and fuel), and 6% for field materials and tools, such as fencing, control of pests and diseases, manure, etc. In India, the cost of production is US$1.62/kg, while the production costs in other major tea producing countries is lower, such as in Kenya US$1.16/kg, Vietnam US$0.96/kg, and Indonesia US$0.58/kg.

The initial investment for a new tea plantation can be high. For the establishment of a green tea plantation in Australia, capital costs were estimated to be some US$10,000/ha. These costs included fencing, equipment, irrigation, mulching, planting by hand, windbreaks, and tea plants at 18,000 per hectare (Monks, n.d.).

During the first 3–5 years, until the tea is mature and can be harvested, further investments are required, including fertilizers, pesticides, costs for weeding, irrigation and the application of fertilizers and pesticides, as well as crop maintenance. Only after this period, will tea harvests begin to recover this initial investment. Aside from the production costs, the cost for the processing and the processing equipment should be considered.

Expected income per plant

In most of the major tea exporting countries, with the exception of China and Vietnam, tea is sold through an auction system. There is no single world market price for tea and tea prices show strong fluctuations based on season, production volumes, impact of weather, etc. For example, major droughts in Kenya, Sri Lanka, and India reduced tea output, creating a shortfall in world production. As a result, tea prices increased sharply in early 2009.

Tea prices differ based on quality but also based on production country, even for the same quality of tea. The following example from the Mombassa Tea Auction, the principal auction for teas in Africa, will illustrate this point: In 2006, the average price offered was US$1.93/kg, US$1.66/kg in 2007, and US$2.18/kg in 2008. Looking more closely at 2008, the price was highest in August–September (US$2.56–2.60/kg) but then dropped sharply to US$1.70–1.76/kg at the end of the year. In 2008, the price was highest for teas from Kenya (US$2.30/kg) and Rwanda (US$2.24/kg) but teas from Zambia fetched only US$0.70/kg while the price of teas from Tanzania, Malawi, and Mozambique were also far below the average (ATB 2009).

Table 3 gives some details on comparative prices for different types of processed tea in Vietnam during 2009. It should be noted that these prices might not apply to teas from other countries, as explained above. Export prices for similar grades of tea from Vietnam are often 20–30% lower than from other countries due to differences in quality.

The price Vietnamese farmers received in early 2009 when selling fresh leaves to a factory was US$0.14–0.17. When farmers process the tea themselves into green tea, they receive US$1.75–2.65/kg when sold to the local market, or even higher prices for the best qualities.

FURTHER RESEARCH

Potential for crop improvement

Suggestions for further research on crop improvement include variety trials and the selection of appropriate shade tree species. The evaluation of high yielding tea cultivars for adaptability is a priority for Hawai'i. Biochemical analyses to confirm benefits of selected cultivars have potential to strengthen marketing. Finally, it would be of value to conduct genetic fingerprinting to document the identity of named or released cultivars.

Table 3. Value of different teas in Vietnam, June 2009.

Type of tea and grade	Price (US$/kg)
Black tea Orthodox (Bulk)	
Dust, Fannings	0.50–0.90
PS/BPS, FBOP	0.80–1.80
OPA, P, OP	1.20–2.50
Black CTC (Bulk)	
PD, BOP, BP1, BF1	1.10–1.80
Green tea (Bulk)	
Dust, Fannings	0.30–0.70
PS/BPS, FBOP	0.70–1.50
OP	1.30–2.00
Specialty teas	
Jasmine Green tea	3.00–5.00
Organic black/green tea	4.00–6.00
Oolong tea (Taiwanese type)	15.00–30.00
Lotus tea	50.00–60.00

Source: Hiep Thanh Tea Company, Vietnam–June 2009

HAWAI'I ECONOMICS

Due to high land and labor costs, the economics of production is much different in Hawai'i compared with most tea-growing regions. Currently, artisan teas produced in Hawai'i are retailed at $0.33–2.50 per gram. It is estimated that in order to cover costs, the minimum price a Hawai'i farmer must receive for hand harvested and processed teas is about US$0.45 per gram or greater (Discoe, pers. comm.).

Improving potential for family or community farming

To increase tea production and processing at the family or community level, training in tea growing and processing is needed. A tea curriculum at UH Hilo or Hawai'i Community College would help promote and further a Hawai'i tea industry. Verifying benefits of natural horticultural methods that do not harm the environment and are not detrimental to human health can support the adoption of tea as a healthful drink. Developing components for "Hawai'i grown" standards and labeling can strengthen tea as a specialty tea crop for small family farms. Finally, producer organizations such as the Hawai'i Tea Society should be given financial support to sponsor promotion, farmer workshops, and festivals.

Genetic resources where collections exist

The UH CTAHR Mealani experiment station has a (small) collection of tea varieties from different locations in Asia.

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INTERNET RESOURCES

General

Coffee-Tea: http://www.coffee-tea.co.uk/

Hawaii Tea Society: http://hawaiiteasociety.org/

Tea Notes: http://www.ahualoa.net/tea/growers.html

United Kingdom Tea Council: http://www.tea.co.uk/

Upasi Tea Research Foundation: http://www.upasitea-research.org/

Shade trees

Agroforestry Net: http://agroforestry.net

World Agroforestry Centre: http://www.worldagroforestry.org

NFT Highlights from FACT Net: http://www.winrock.org/fnrm/factnet/factnet.htm

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

Farm and Forestry Production and Marketing Profile for Tea (*Camellia sinensis*)

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