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Small-scale Tea Growing and Processing in Hawaii

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Tea *(Camellia sinensis* L.) is one of the oldest and most popular beverages in the world. It has refreshing and revitalizing herbal qualities and ceremonial aesthetics that together embody the essence of simplicity, calmness, and tranquility. By legend, the origin of tea is attributed to a Chinese scholar and herbalist, Emperor Shen Nung, who lived around 2737 BC. It is said that one day Shen Nung was boiling water for an evening meal while resting under a wild tea tree. A slight breeze came and a few of the leaves gently fell into his simmering water. Upon tasting it, he found this brew refreshing and exhilarating. Thus tea was "discovered," and since then it spread throughout the world.

Chinese character for "tea"

Although China certainly had an ancient and colorful role in tea's history, many other countries embraced tea culture, including Taiwan, Japan, Vietnam, India, Russia, Australia, East Africa, South America, Indonesia, Iran, and Turkey. Tea culture and trade were adopted early by the Mongols and Japanese. In the 1500s it was brought to Europe, where it flourished, and by the 1700s it had become the most popular drink in England. The English developed a passion for tea, inventing the garden tea party, which incorporated all of the social etiquette of the English elite. In the 1800s, India, Russia, and the USA (Georgia) started tea plantations. Tea cultivation eventually spread to most of the subtropical regions of the world, and the range of cultivated varieties (cultivars) grown under different environmental conditions resulted in the merchandizing of highly regarded "estate brands." Tea's many processing and drying methods each have unique qualities appropriately set for special purposes or occasions. Some of these techniques have become part of national ceremonial tea customs, often associated with displaying the skills of a distinguished tea master.

Awareness is currently increasing about the physiological benefits of drinking tea, the different types of tea, and the uniqueness of high quality specialty teas. A tremendous variety of value-added components are related to tea culture and commerce, including ceramic teapots, cups, and bowls; serving trays and utensils; ceremonial customs, clothing, and fashion; furniture and architecture; personal hygiene products; confectionery products; and ready-to-drink beverages. Tea is sold in the world commodity markets and also has an expanding role in niche markets for specialty and organically grown products.

Tea was first introduced to Hawaii in about 1887. Since then, unsuccessful attempts to commercialize tea production on Kauai and in the Kona region of the island of Hawaii were attributed to the high cost of production in Hawaii compared to the lower costs in other tea producing areas. In the late 1980s, some of our sugar firms attempted to establish tea plantations, but these projects proved to be unsuccessful and were terminated. It seemed that Hawaii-grown tea would have difficulty competing in the world market at the commodity-grade level.

The most recent introductions of clonal cultivars of tea to Hawaii were in 1999–2001 by the Tropical Plant Genetic Resource Management Unit, U.S. Department of Agriculture, Agricultural Research Service, Pacific Basin Agricultural Research Center in Hilo, in partnership with the University of Hawaii, College of Tropical Agriculture and Human Resources, Cooperative Extension Service. Half-acre plantings were established at each of three locations on the island of Hawaii in Waiakea (600 ft elevation), Mealani (2800 ft), and Volcano (4000 ft). Preliminary observations of these research and demonstration efforts suggest the following:

- Tea grows very well at Mealani and Volcano and relatively slower at Waiakea.
- Most cultivars are ready for harvest in about 18–20 months after planting.

- Green, oolong, and modified green teas processed from tea leaves harvested at Mealani and Volcano are of excellent quality.
- Clonal tea plants are recommended over seedlings for their uniform growth, allowing the vegetative cycles to be more readily synchronized for mechanical harvesting.
- The pest and disease problems of tea are relatively mild at all three locations and can be readily managed by agronomic practices such as pruning and fertilizer management.
- There are observable differences in susceptibility to pests and diseases among the tea clones. Some of the pests are spider mites, aphids, and leaf rollers. So far the most serious disease is anthracnose and gray blight which occurs mainly during wet periods. No insecticides or fungicides were applied at any of the three field locations for over three years.

Much interest in tea growing in Hawaii was aroused by these three successful field plantings. In 1998, Dr. Francis Zee developed a simplified tea processing method using a microwave oven for quality determination. The tea processed using this method was excellent and comparable to high quality tea. As with most prospective diversified agriculture commodities in Hawaii, the potential growth of tea as an industry needs to be advanced concurrently by both research institutes and innovative growers. Our recent research has demonstrated that tea plants can easily be grown in Hawaii. Now, extension of these plantings to small-scale field demonstration trials throughout Hawaii is the next logical step. The idea of merchandizing a high quality tea grown and processed in Hawaii appears to be gaining momentum toward creating a niche market for a "Hawaiian Tea Blend" to be sold worldwide.

The purpose of this publication is to provide basic and simplified information on tea growing and to describe a microwave method of processing tea.

Environment

Camellia sinensis is an evergreen plant that can be grown in Hawaii from sea level to 6000 ft. It prefers acidic soil (pH between 4.5 and 5.0) with good drainage and aeration. Optimum shoot growth occurs at 65–77°F (18–25°C) and 75–85% relative humidity and with evenly distributed annual rainfall of 72–100 inches (1800–3000 mm). In tea growing regions, growers prefer elevations above 1500 ft (>500 m) and drier conditions with rainfall less than 80 inches (~2000 mm) and frequent morning and late afternoon fogs (relative humidity around 80%); plants growing under these conditions are claimed to have superior quality. Strong wind, frequent frost, and excessive rainfall are detrimental to the production of high quality tea.

A light fog in the Volcano area of the island of Hawaii contributes to the vitality of this experimental tea planting.

Tea types

Camellia sinensis is the plant that green, oolong, and black teas are made from. It is the processing of the young shoots—involving different degrees of withering, "fermentation," heat processing, and drying—that results in different types of tea. The "fermentation" process in tea making is not a true fermentation but rather is the various oxidation and enzyme reactions within the leaves induced by wilting and physical bruising. When the tea processing has resulted in a desirable fragrance and level of oxidation, the leaves are steamed or heated to stop the chemical activities before they are further shaped and dried to create the final product.

Un-oxidized (unfermented) tea

The un-oxidized teas are the least processed of all teas. The freshly harvested leaves are steamed immediately to preserve their flavor before they are dried and shaped.

The Japanese green teas, such as sencha and matcha, and the Chinese green tea lung-ching are examples of un-oxidized teas.

Partially oxidized tea

A range of Chinese teas are classified as partially oxidized, including paochong and oolong teas, which are 8–25% oxidized, and teh-kuang-yin and Formosa oolong, which are 50–60% oxidized.

Fully oxidized tea

The familiar black tea, red tea, or English tea is fully oxidized tea.

Tea cultivars

Many tea cultivars have been developed in the various tea growing regions; each region has its specially selected cultivars for the production of green tea, oolong tea, or black tea. For example, 'Chin-Shin-Oolong' and 'Chinhsuan' are used in Taiwan for processing into oolong and paochong tea. In Japan, 'Fujimidori', 'Tamamidori', 'Asahi', and 'Yabukita' are examples of clones grown and processed into green tea; the latter is the predominant green tea cultivar there. Clones 'TV2' and 'TV17' in India; 'S1' and 'S21' in Sri Lanka; 'Boh' 11, 17, and 44 in Malaysia; and 'Benikaori' in Japan are some of the tea cultivars used for black tea production.

In Hawaii, preliminary observations from the three recent plantings suggested the following clones for further testing.

'Bohea'

This vigorous plant has compact stature and small, somewhat oval leaves. It has good resistance to anthracnose, is slightly susceptible to leaf roller feeding, and is relatively easy to propagate by cuttings. 'Bohea' is suitable for processing into oolong tea (>65% oxidation, from plants grown at high elevation) or black tea (grown at low elevation). It has a sprawling growth pattern making it an excellent choice as an ornamental hedge.

'Yabukita'

This Japanese cultivar for processing into green tea and lightly oxidized oolong tea is suitable for testing in slightly drier areas and elevations above 1500 ft. It has elongated, serrated leaves, long internodes, and an upright growth habit. It is relatively easy to propagate by cuttings. It is moderately susceptible to leaf anthracnose, susceptible to leaf roller damage, and slightly susceptible to spider mite damage.

'Yutaka midori'

This is another Japanese cultivar for processing into green and oolong tea. Tea made from 'Yutaka midori' has a very gentle, mild, sweet flavor. This cultivar is suitable for testing at elevations above 1500 ft having a relatively dry climate. It has long internodes, good production, and is relatively easy to propagate by cuttings; it is somewhat susceptible to leaf anthracnose and leaf roller.

Other clones are being tested, and promising ones will be released for private testing.

Propagation

Seeds

Tea plants can readily be grown from seed, but the resulting seedling will vary from its parents. Seedling plants have uneven growth rates, sizes, and shapes and highly variable processing qualities. For these reasons seedlings are not suitable for commercial production, but they can be used for backyard enjoyment as hedges or potted plants and for home processing.

Tea seeds should be sown when fresh; do not dry them or store them for more than a few days. Immediately before planting, the seeds should be soaked in water for 24 hours, and all floaters should be discarded. They should be planted with their "eyes" horizontal and covered with about 1 inch (2.5 cm) of moist potting soil. Keep the pot in the shade and water it frequently. Most of the 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 about a foot tall with well established leaves.

Vegetative propagation

The standard means of vegetative propagation of tea clones is a single-leaf cutting. Success ranges from 40 to 80 percent. The cultivar, season, growth medium, type of cutting material, moisture, and temperature of the rooting environment can affect root development. Other

known or reported methods of tea propagation are air layering, tissue culture, and various grafting techniques including cotyledon-stage grafting.

Cutting preparation

Cuttings should be harvested from mother plants that are selected for propagation. The bush should be pruned and fertilized every 3–4 months to induce vigorous vegetative growth. The best rooting success is obtained with recently matured shoots containing slightly reddened bark adjacent to mature leaves with actively breaking axillary buds. The long, multiple-leaf branch should be kept moist by wrapping it in a damp sack for transport. All further cutting preparations should be done in the shade. Single-leaf cuttings are made from the branches with a pair of sharp pruning shears. Cuts should be made about ⅜ inch (1 cm) above each leaf node, leaving about 1½ inch (3–4 cm) of stem below the node. If the internodes of the branch are less than 1 inch, use a two-leaf section and remove the lower leaf to make a single-leaf cutting. Dip the cut end of the stem into a commercial rooting powder containing 0.3–0.8% indole-butyric acid (IBA) before inserting it into a planting medium.

Rooting medium

The medium used is critical for the success of rooting tea cuttings. It can be clean subsoil from the location, or artificial potting mix. It needs to be acidic and low in humus and have good drainage. Cuttings form callus and roots best when the medium's pH is below 5.0.

In some tea production regions, cuttings are planted into polyethylene sleeves about 3 inches in diameter and 10 inches deep filled with low-pH subsoil amended with ½ oz (14 g) of superphosphate; the soil should be pressed firmly into each sleeve. The filled sleeves can be kept from falling over by surrounding them with a frame. One cutting is placed in each sleeve, with the leaf and bud just above the soil level. Leaves should not overlap. Cuttings prepared in such a manner should be watered well, kept cool, and then watered about once every two weeks. The bed should be shaded with 90% shade-cloth and covered with a protective polyethylene cover stretched over hoops of wire or bamboo placed over the bed, with the sides and ends of the cover buried in the ground. Rooting should occur within 3–4 months. When the new plants have three or four mature leaves, the side of the bed cover is gradually opened to harden the plants. The shading is slowly reduced after the plastic is completely removed. At this stage, the plants can be fed weekly using an acidic foliar fertilizer at half strength. Proper watering is critical; do not let the plants dry out. Do not use manure or organic fertilizer until the plants are transplanted into the ground and fully established.

At the Tropical Plant Genetic Resource Management Unit, each IBA-treated cutting is placed into moistened 1½-inch (3.75 cm) commercial foam propagation cubes; three strips of 10 cubes each are placed in a 10½ x 21 inch plastic tray with a net bottom. The trays are placed in a mist room with fine overhead misting (20 seconds every 30 minutes around the clock), with electric mats providing bottom heat at 80°F. The enclosed mist room is shaded at 70%. Callus can be observed after about a month. Fine rooting can be seen on the bottoms of the cubes after 3–4 months. Once rootlets are visible, each cube is separated and transplanted into a 5-inch pot with a 1:1:1 mixture of perlite, vermiculite, and peat. The plants are maintained in 50% shade and gradually moved to full sun. They are fertilized immediately with a half-strength 30-10-10 liquid formulation, and then again every 2 weeks, rotating with a 10-30-20 liquid fertilizer. A slow-release 13-13-13 fertilizer is applied at 1 teaspoon (about 5 g) per pot three months after transplanting. Rooted cuttings can be planted in the ground after about a year.

Field planting

Tea fields can be on slopes or on flat terrain having adequate drainage. They can receive full sun, but tea is also known to thrive in foggy or misty environments. Planting should be done when the soil is well moistened in advance by irrigation or rainfall, and it is very important to maintain uniform soil moisture after transplanting. Drip irrigation systems have been demonstrated to be successful, and sprinkler irrigation is an alternative in low-humidity areas. The site should be prepared in advance either to establish a cover crop or apply mulch or weed cloth and to make planting holes. Planting holes should be 18 inches deep and 12 inches wide (45 x 30 cm); mix 1 oz (28 g) of superphosphate into the soil at the bottom of each hole and cover that with 2 inches (5 cm) of soil. The suggested planting distance is 20 inches (50 cm) within the row and 6 ft (180 cm) between rows (4800

Table 1: Optimal nutrient composition in leaves of tea, *Camellia sinensis*, reported in Taiwan.

Element	*Suitable range*	*Unit*
Nitrogen	4.00–6.00	%
Phosphate	0.25–0.40	%
Potassium	1.50–2.10	%
Calcium	0.25–0.55	%
Magnesium	0.15–0.30	%
Iron	90–150	µg/g
Manganese	300–800	µg/g
Copper	8–15	µg/g
Zinc	20–40	µg/g
Aluminum	400–900	µg/g

New leaves emerging after a pruning.

plants per acre). A general rule is that a field for green or black tea production can be planted more densely than a field for partially oxidized tea (oolong). Appropriate windbreaks should be used to protect newly planted fields.

Specially formulated slow-release and soluble foliar fertilizers are available for plants such as camellias that grow best in acidic soils, and these are recommended for tea if the soil is not already acidic. We suggest following label dosages applied three or four times per year after each harvest from the spring, summer, and autumn growth flushes. Dolomite may be of benefit when sparingly applied once a year in the summer. If you plan to establish an organic niche market, you will need to choose organic fertilizers and soil amendments. Pruned tea branches, when well composted, can also be applied as mulch at the base of the hedgerows.

Foliar nutrient analysis

Periodic analysis of leaf tissue nutrient content is the best means to ensure healthy growth of tea plants. The following suggestions and index tissue levels (Table 1) are adapted from a Taiwan tea industry extension bulletin.

- Sampling time: at each harvest.
- Sample type ("index tissue"): top shoot plus three leaves at the "one shoot–five leaves" stage.
- Sample size: 30 shoots randomly collected from ¼ acre.
- Samples should contain only normal growth without any mechanical, insect, or disease damage.
- Take separate samples for different cultivars, crop ages, field conditions, and management history.
- Separate normal samples from those with nutrient deficient symptoms.

Tea bush pruning

Nursery and young grove pruning

Nursery plants and young field plants have small root systems, so pruning should be limited to shaping and training. The primary focus of nursery and early field pruning is on the removal of growing points and the first node below to induce branching and formation of a bush with a wide and flat top surface.

Production pruning

In a producing bush, young flushing shoots are produced on the top of the bush; the stems and foliage below these shoots are the photosynthesis sources for the young growth. Because these older branches cannot continuously produce new shoots, it is important to generate a new layer of feeder leaves from the current flush. This can be done by allowing the new shoots to grow longer and harvesting only the top shoots and leaves to retain at least one or two sets of new leaves and nodes from

Some pests and diseases affecting *Camellia sinensis* in Hawaii.

Broad mite damage, view of upper leaf surfaces

Broad mite damage, view of lower leaf surfaces

Anthracnose (brown blight) damage

Chinese rose beetles and damage

Anthracnose is caused by fungus (*Colletotrichum* species)

Gray blight damage caused by fungus (*Pestalotiopsis* species)

Mexican leafroller damage

Red and black flat mite damage

Mexican leafroller caterpillar

Shoot infested with melon aphids

Mexican leafroller adult

Leaf infested with avocado scale

Tea bush ready for harvest.

The harvestable shoot tip.

the current flush. For example, in Taiwan, new shoots are harvested at the "one shoot–five leaves" stage, but only the shoot tip with two or three leaves are cut; the remaining two leaves are the source of a new flush for the next picking cycle (see photos above and on p. 7).

Maintenance pruning

With the harvesting method just described, the pruning surface (or "harvest table") broadens and rises as the season progresses, and for continued ease of harvest it eventually must be lowered by cutting it back. The continual harvesting of new shoots also produces a thick layer of old stems and knots on top of each bush; this eventually restricts new growth and 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. Before such a maintenance pruning, it is recommended that potassium fertilizer be applied to ensure rapid recovery.

Diseases and pests

Tea is a perennial crop that can remain productive for decades if managed properly. As with the development of any new commercial perennial crop, quarantine to prevent the introduction of diseases and pests is the first and most important precaution to ensure success.

Insect and mite pests

Worldwide, tea plants are attacked by more than 300 known pests. Crop loss estimates due to pests generally average from 5 to 15 percent. The main insect and mite pests of tea in Thailand, Vietnam, Taiwan, China, India, Sri Lanka, and Africa are leafhoppers, plant bugs, mites, aphids, thrips, and leafrolling and leaf-folding caterpillars. Unlike most crops, the tender young leaves and buds are the harvested portion of the plant, and pests that attack these parts are of particular concern to growers. Pests can cause direct crop loss due to feeding injury or indirect damage by adversely affecting the quality of the tea. Although many of the species of insects and mites attacking tea in other countries do not occur in Hawaii, some pest species do occur here, and recent surveys indicate that the same broad groups of insects attack tea in Hawaii. Arthropods collected on tea in Hawaii thus far include the melon aphid (*Aphis gossypii*), Mexican leafroller (*Amorbia emigratella*), light brown apple moth (*Epiphyas postvittana*), transparentwinged plant bug (*Hyalopeplus pellucidus*), twospotted leafhopper (*Sophonia rufofascia*), spiraling whitefly (*Aleurodicus dispersus*), red and black flat mite (*Brevipalpus phoenicis*), broad mite, also known as yellow tea mite, (*Polyphagotarsonemus latus*), avocado scale (*Fiorinia fiorinae*), mining scale (*Howardia biclavis*), and greenhouse thrips (*Heliothrips haemorrhoidalis*).

Melon aphids typically suck the sap of buds and young terminal leaves; the leaves become distorted and curled. Aphid colonies can build to large numbers quickly but usually are controlled by natural enemies. Aphids seldom cause enough damage to justify using insecticides. Regular harvesting keeps this pest under control.

Red and black flat mites feed on the cell sap, and attacked leaves turn bronze color. These mites feed on the underside of the leaves, especially near the petiole. The yellow tea mite can be a serious pest of cuttings and seedlings. Damaged leaves curl inward, and shoots become stunted and deformed. Naturally occurring predatory mites and other predators can often suppress mite populations if pesticides are absent, but sometimes mite populations build up in spring when natural enemies are low.

The Mexican leafroller and the lightbrown apple moth web together and feed on buds and young leaves; terminal leaves appear rolled or folded. *Bacillus thuringiensis* (Bt) can be applied for control of leafroller caterpillars.

The twospotted leafhopper, another polyphagous pest, also occurs in tea. Its damage to tea has not been determined, but symptoms of leafhopper feeding on other crops include tip burn, leaf chlorosis, wrinkling and cupping of the leaves, and burning of leaf margins. Likewise, the transparent winged plant bug has been collected in tea, but its feeding and damage symptoms have not been determined. In other crops its feeding causes leaf yellowing and early bud abscission.

Chinese rose beetle (*Adoretus sinicus*) is a polyphagous pest that can devastate young tea plantings. The larvae feed in the soil, and only the adult stage is above ground and damaging to tea plants. Adults feed at night, with the greatest feeding and mating activity in the first few hours after sunset. The adult beetle prefers to feed on mature foliage, a response to the high carbohydrate content of these leaves compared with young leaves, and the interveinal pattern of feeding—giving leaves a lace-like appearance—is distinctive. While older plants can outgrow feeding damage, young plants may be severely stunted or killed if all their foliage is consumed. The simplest means to protect young plantings or minimize damage from Chinese rose beetle is with a physical barrier, such as screen cages for individual plants or screen fencing for larger plantings. The beetle is a clumsy flier and will not fly up and into the open top of a hoop cage.

Other insects that occur in Hawaii and are known to attack tea elsewhere include green scale (*Coccus viridis*), red wax scale (*Ceroplastes rubens*), latania scale (*Hemiberlesia lataniae*), coconut scale (*Aspidiotus destructor*), black twig borer (*Xylosandrus compactus*), Hawaiian flower thrips (*Thrips hawaiiensis*), and red spider mite (*Oligonychus coffae*).

Quarantine

Import restrictions and inspections are our main weapons against the introduction of new tea pests. The tea industry should work proactively with USDA-APHIS and the Hawaii Department of Agriculture to identify pests elsewhere that may pose a threat to Hawaiian tea should they be accidentally introduced. Most of Hawaii's new tea varieties should be brought in as seed or clonal material rather than rooted nursery stock to minimize the chance for introduction of foreign disease and insect pests. Pests such as the *Helopeltis* plant bugs, the black citrus aphid (*Toxoptera aurantii*), the lesion nematode (*Pratylenchus loosi*), and several eriophiid mite species are serious pests in many foreign countries and could pose a threat to tea production in Hawaii if introduced. Once a complete list of serious foreign pests are identified, the possible countries of origin, a host-list for each pest, and potential modes of entry can be determined. To improve interception efforts at our ports of entry, informational material on the diagnostic signs of infestation for the pest and a method of inspection can be developed. Unfortunately, experience tells us that our worst pests in the future are often not "on the radar" because they are non-pests in their native environment. Despite this, increased awareness of exotic pests will help us in developing ideas for combating pest types, rather than individual species, in tea.

Diseases

Diseases of tea are numerous, with more than 130 potential pathogens affecting tea leaves. Commercially cultivated tea plants are potentially susceptible to a variety of fungal, bacterial, viral, and nematode problems, with fungi being the main problem. Leaf blights and spots are common diseases of tea grown in hot climates with heavy rainfall.

In almost all areas of the world including Japan, China, and Taiwan, anthracnose or brown blight (caused by *Colletotrichum* spp., including *theae-sinensis* and *gloeosporioides*) and gray blight (caused by *Pestalotiopsis* spp.) can be found. These diseases were recently isolated and identified in the tea fields of the Waiakea Research Station in Hilo. Symptoms of the disease begin as small oval spots on the leaves. As these lesions grow, they become gray or brown with irregular concentric rings and tiny black dots (the fungal fruiting bodies). The areas of dead tissue can sometimes be surrounded by a narrow, yellow margin. They can occur in the center of the leaf or begin at the leaf edge. As the lesions grow in size, the leaf tissue dries and falls off. In young plants, leaf drop occurs. These fungal infections can also be responsible for loss of leaves at the early stage of propagation from stem cuttings.

Tea cultivars show various levels of resistance to disease. At Waiakea, certain 'Yabukita' clones were more susceptible to anthracnose. Leaf blights and anthracnose are fungal diseases prevalent in humid environments, and they usually attack weakened or damaged shoots on bushes affected either by other pests, temperature stress, poor nutrition, or damage incurred during harvest. In most locations, these diseases are currently considered only minor leaf diseases, so it is not usually necessary to control them with fungicides. The damage can be reduced through proper tending and practices promoting plant health.

The following diseases are not reported in Hawaii. They are very damaging to tea, and all precautions should be taken to prevent their inadvertent introduction with importation of plant materials. Plant materials suspected to be infected should be completely removed and burned after preserving samples for diagnostic analysis.

Canker disease (*Macrophoma theicola* Petch) is one of the most serious diseases of the cultivar 'Chin-Shin Oolong', causing almost half the crop to die when it occurs. Symptoms develop rapidly (within a few days) on young growth and include wilting and loss of leaf luster, with gradual yellowing and drying of the leaves. The dead leaves remain on the branches; distorted lesions are found around infected areas with browning of bark and wood.

Blister blight (*Exobasidium vexans* Massee) is a fungal parasite that is of major economic importance in all tea growing areas of Asia. Blister blight attacks young leaves and stems and reduces both the quality and quantity of the harvest. It was also reported that the infected shoots show reduced activities of the enzymes polyphenol oxidase and peroxidase, which are responsible for tea flavor and character qualities. Blister blight is most prevalent at locations above 2300 ft (700 m) having prolonged cool, wet, and cloudy conditions. The fungal spores are sensitive to sunlight; high humidity and leaf wetness are required for their germination and infection. The spores are sticky and easily spread by animals, rain, wind, or mechanical means. The fungus can complete its entire life cycle in 11–28 days, resulting in a multiple-cycle disease with several generations of the pathogen being completed in one season. Initial symptoms are visible as pale green, yellow, or pink translucent dots on young leaves, gradually expanding to ¼–½ inch (6–13 mm). Some spots may reach 1¼ inches (3.3 cm) in diameter, with thickened blisters on the underside of the leaf causing leaf distortion. Most tea varieties are susceptible to this disease.

Tea hair disease (*Marasmius equines* Muler & Berk.), reported in China, Japan, India, Australia, Indonesia, and Taiwan, develops long, thin strands of black fungal mycelium wrapped around or hanging from infected twigs. Severe infection kills stems. This disease is prevalent in hot, humid areas. It is a serious disease in tea producing areas because removing and burning infected branches is the only way to control it.

Simplified small-batch tea processing using a microwave oven

A simplified tea processing method was developed for assessing the qualities of small batches of leaves processed into teas with different degrees of oxidization. For every 5 pounds of fresh leaves, about 1 pound of finished, dried tea is produced. The following procedure is modified for small-scale processing of about 1 pound of fresh tea leaves.

1. Pick tea leaves from the current growth; pick a single shoot tip with two or three tender leaves. The current growth should have at least five sets of fully expanded leaves before harvesting. Avoid bruising or crushing the leaves during picking and handling.
2. Sun-wilt the fresh leaves for 30–40 minutes. Pro-

vide 20–30% shade during this step under intense sun. Gently turn leaves at least twice during sunning for even wilting.

3. Move the wilted leaves indoors; gently toss them for 1 minute, spread them into a 1-inch layer, and rest them for an hour. After the first hour of resting, rub the leaves by the handful very gently for 1 minute, then rest them for an hour. Repeat this two to three times to induce oxidation, with 1 hour of resting between each handling. The leaves should now be flexible and wilted, with a light, flowery fragrance.
4. For summer harvests, increase the resting time by at least 30 minutes after each handling, and increase the number of resting periods to six or seven, i.e., twice as much as the lightly oxidized tea. This reduces the bitterness of the summer crop and increases the amount of flavor and color to produce a darker tea.
5. After the resting and withering period, the final tossing of the leaves is done in a woven basket with continuous gentle turning and tumbling of the leaves for 30–40 minutes. Afterward, the leaves are spread to a depth of 2–3 inches and rested for 2 hours in a cool and windless location with as little handling as possible. A strong, flowery fragrance should develop and peak sometime during or after the 2-hour resting period, depending on the humidity and temperature of the room. This is the most critical and subjective step in the processing. The tea maker's decision on when to move on to the next step is based on personal experience, knowledge, and preference.
6. Microwave the leaves in an open bamboo basket at the highest setting for 30–45 seconds.
7. Remove the leaves from the oven and toss them to let steam escape, then immediately repeat the heating; do this three to five times. Avoid generating excessively high heat—the idea is to have sufficient heat to stop the enzyme activities without "cooking" the leaves.
8. In a sheet of clean muslin cloth, gently rub and loosely roll the heated leaves for a minute. Then reheat them in the microwave oven. Repeat this rolling and heating process three to four times. The purpose of this is to physically rupture the cells in the leaves so that the flavor and fragrance can be readily released at brewing. Handle the leaves gently so they remain whole and are not broken into pieces.
9. At the last rolling, tightly knead the leaves into a solid ball by continuous rolling with downward pressure and tightening of the cloth. Do this for about 45 seconds to a minute, then gently break apart the ball into individual shoots. Reheat the shoots for 20–30 seconds and repeat the kneading. This process gradually and gently shapes and compacts the leaves into tighter curls; the more this step is repeated, the tighter the curls become. In commercial high-grade oolong tea, each one-tip-two-leaf shoot is processed into a sphere 3–4 mm in diameter. In our processing, we repeat the compacting process from three to six times.
10. Place the processed leaves in a food dehydrator until they are dried.
11. Pack the dried tea in an airtight bag or can and place the container in a cool, dry, dark place for 3–4 days to mellow. Without mellowing, the fresh new tea may be bitter and astringent.
12. Gently bake the tea in a toaster oven to finalize the fragrance. Preheat the oven to 250–300°C, turn it off, put the dried tea leaves on a foil-lined tray, and place it in the middle rack for 5–10 minutes. Repeat this process twice.

How to brew and serve tea

Use 1 part tea to 50 parts water; e.g., ⅒ oz (3 g) of tea leaves with 5 oz (150 ml) of water. Use hot water as it begins to boil for green tea and semi-oxidized tea. Use boiling water for black tea.

At this ratio of water to leaves, steep the tea for 5 minutes before decanting the broth completely into a serving container. This ensures an even concentration of flavor. Never let tea steeped in boiling water sit for longer than 5 minutes, as it may develop a strong, bitter flavor. The same leaves can be brewed five to six times, adding an extra minute for each subsequent infusion. The first brew has the best fragrance, and the second brew has the best flavor.

The infusion should be bright, clear, and shiny with a greenish-yellow to honey color. The fragrance should be mild, rich, and slightly flowery. The taste should be full, neither bitter nor insipid, and it should be slightly

sweet, with a lingering after-note of sweetness and flowery fragrance coating the back of the mouth and throat.

Brewing "espresso" or "Kung Fu" tea

Fill half to a third of a 6–8 oz clay teapot with tea leaves. Add boiling water and steep for 30–40 seconds, then decant the broth into a serving container before serving. Use small tea or sake cups. This infusion is intense in flavor and slightly insipid, but the coating, fragrance, and after-notes are strong and pleasant. Add 15–20 seconds to each following steep of the leaves.

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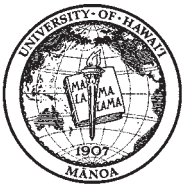

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