Pest Management Strategic Plan
for
Potted Orchid Production in Hawai‘i

Summary of a workshop held on
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Cover Photo: Oncidium orchids in two-inch pots. (Photo by Tessie Amore)

Executive Summary

The Hawai‘i orchid industry produces crops that are sold as either cut flowers (including lei flowers) or potted plants. This PMSP focuses on two important groups of potted orchids. Dendrobiums and oncidiums are among the most widely grown in terms of the number of farms and the quantity of potted plants sold. Hawai’i is an ideal region for producing a large number of orchid varieties due to its diversity in climate, temperature, rainfall, and sunlight. The climate for growing orchids in Hawai’i varies greatly from location to location, so proper site selection, growing structures, and design for an orchid nursery are important for good plant growth and management of pests.

Workgroup members identified thrips, mealybugs, mites, and blossom midge as invertebrate pests of particular importance. Thrips are the most prevalent insect pest of orchid flowers in Hawai‘i. Moreover, the several different species of thrips that plague orchids in Hawai‘i, present special problems for their identification and, therefore, control.

Environmental conditions in the tropics are frequently conducive to disease development; plant pathogens proliferate in Hawai‘i’s mild climate. While several diseases of potted orchids are described in the literature, there have not been many reliable, confirmed identifications of pathogenic fungi, other than *Fusarium.* This PMSP discusses the various diseases of orchids, but focuses on *Fusarium.* Two bacterial pathogens, *Erwinia* and *Burkholderia*, have been isolated from diseased and dying dendrobium plants and confirmed as pathogens. The prevalence of other diseases, especially those caused by unidentified viruses is not known.

Growers have learned to identify the key pests and their associated damage. Growers have established monitoring procedures and action thresholds, and use that information and their experience to decide on the implementation of various control measures.

There are trade issues related to pest management for potted orchid production in Hawai‘i. Certain pests are of quarantine significance. If an outgoing shipment of orchid flowers or potted orchids is intercepted with one or more of the quarantine pests, the shipment will be confiscated and subsequently destroyed. Additionally, much of the planting material for Hawai‘i’s orchid growers comes from sources outside the state, including foreign sources. Growers do not have the means to monitor conditions under which these materials were produced, and are vulnerable to stocking their nurseries with infected or infested planting materials. Importing orchids with pathogens or pest insects increases the cost of pathogen or pest insect control on those plants and may place other crops or plants in Hawai‘i at risk.

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Work Group and Contributors

A work group consisting of growers, agricultural consultants, regulators, university Extension agents and specialists, and other technical experts from Hawaiʻi Island and Oʻahu met on September 30, 2010, in Hilo, Hawaiʻi, to identify the needs of potted orchid producers across the state. This exercise resulted in the following document, which includes critical needs, general conclusions, and tables listing typical activities and efficacies of various management tools for specific pests.

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Top Pest Management Priorities in Hawai‘i Potted Orchid Production

(***not listed in order of importance***)

Research

- Control tactics for thrips
- Control tactics for bush snails
- Control tactics for coqui frogs
- Control tactics for little fire ants
- Control tactics for mealybugs
- Control tactics for mites
- Control tactics for *Fusarium* diseases
- Reliable field detection kit for viruses

Regulatory

- There are no regulatory issues that were identified as priorities for Hawai‘i’s potted dendrobium and oncidium orchid growers

Education

- Outreach about of the importance of not importing diseases via propagating material
- Correct identification of insects, diseases and viruses
- Educate growers about chemical use and resistance management

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Special Critical Need

- For control of *Fusarium* rot, and other diseases of orchids, reliable sources of disease-free planting material are needed.

General Production Information

Potted Orchids in Hawai‘i

The Hawai‘i orchid industry produces crops that are sold as either cut flowers (including lei flowers) or potted plants. This PMSP focuses on two important groups of potted orchids. Dendrobiums and oncidiums are among the most widely grown in terms of the number of farms and the quantity of potted plants sold. In 2008, 61 farms, which occupied 2.5 million square feet of production area, produced and sold potted dendrobiums. Potted dendrobiums and the Oncidiinae were among the top 20 diversified agriculture products in the state. In 2008, the Hawai‘i Field Office of the National Agricultural Statistics Service (NASS) reported the wholesale value of potted dendrobium sales of over $4 million and over $3 million for potted Oncidiinae. In 2008, export sales of almost $2 million and $3.7 million for potted dendrobiums and Oncidiinae were reported. 2008 was the last year for which the NASS Hawai‘i Field Office reported individual statistics for potted production of the Oncidiinae. In 2011, potted dendrobiums remained one of the Hawai‘i’s top 20 diversified agriculture products. However, beginning in 2007, sales for Hawai‘i’s floriculture and nursery industry as a whole have declined for five consecutive years.

Variety of Potted Orchid	Wholesale value 2008	Out-of-State sales 2008	Wholesale value 2012	Out-of-State sales 2012
	1,000 dollars			
Dendrobium	4,111	1,900	3,017	1,000
Oncidiinae	3,087	3,720	* Included in “other”	
Other potted orchids	6,453	5,765	* 7,374	* 5,400

Production of dendrobiums and Onciniidae to be sold as cut flowers is not a focus of this document. However, most of the pest management strategies are very similar for the cut orchids as they are for the potted orchid industry.

Other orchids are also grown in Hawai‘i, for either cut-flower production or to be sold as potted plants. Such orchids include Phalaenopsis, Vanda, Cattleya, Cymbidiums, Miltonias, Paphiopedilums and vandaceous types. The combined wholesale value of Hawai‘i’s potted and cut flower orchids was over $15 million in 2008 and over $14 million in 2012.

Production Regions

Hawai'i is an ideal region for producing a large number of orchid varieties due to its diversity in climate, temperature, rainfall, and sunlight. The climate for growing orchids in Hawai'i varies greatly from location to location. Hawai'i's island geography—with its rapidly rising mountains, the surrounding Pacific Ocean, and the prevailing northeast trade winds that travel over 2,000 miles of warm ocean waters—has a significant effect on temperature and rainfall patterns in any given locale. In general, the northeast facing sides of the islands—the windward sides—are cooler and wetter because of the warm, moist convection currents that come from the ocean, rise up along the mountains and cool as they increase in elevation resulting in condensation, cloud cover, and precipitation. In contrast, the west and southwest facing sides of the islands—the leeward sides—are warmer and drier because of the drier air that has advanced over and then descends down the mountains. Thus, the average rainfall distribution varies considerably, ranging from less than 10" to over 120" per year.

Hawai'i's mild climate year round, the result of the ocean's stable temperatures, provides essentially two noticeable seasons. Summer, which runs from May through October, is characterized by daytime temperatures between 80 and 90 degrees Fahrenheit and day lengths as long as 13-1/2 hours. The warmest months are August and September. Winter, which runs from October through April, is marked by daytime temperatures in the 70's and 80's with day lengths as short as 11 hours. The coolest months are February and March. Night temperatures will drop slightly below the daytime temperatures usually by only several degrees. Elevation plays an important part in temperature ranges; every thousand feet increase in elevation results in three degrees decrease in temperature.

Potted orchids are commercially produced on five of the main Hawaiian Islands. The bulk of the production is on the "Big Island" of Hawaiʻi (or Hawaiʻi Island). Orchids are also grown on Oʻahu and in much smaller quantities on the islands of Kauaʻi, Maui, and Molokaʻi. This is similar to the state's floriculture and nursery production industry as a whole, for which, in 2008, Big Island growers produced 43% percent of the state's sales. Oʻahu produced 39% and Maui County (which includes Molokaʻi) and Kauaʻi contributed 14% and 4%, respectively, to the value of the sales of floriculture and nursery products. 2008 is the last year for which county estimates were published.

HAWAIʻI ISLAND (THE "BIG ISLAND")

Orchids are grown in East Hawaiʻi in Hilo, and in Kapoho, Kalapana, Kurtistown, Mountain View, Glenwood and Volcano in the Puna district. On the West side, they are grown in Kealakekua and in the State Agriculture Park in Keāhole.

OʻAHU

Potted orchids are grown in Waiʻanae, Waimānalo, Kāneʻohe, Nuʻuanu, and Mānoa.

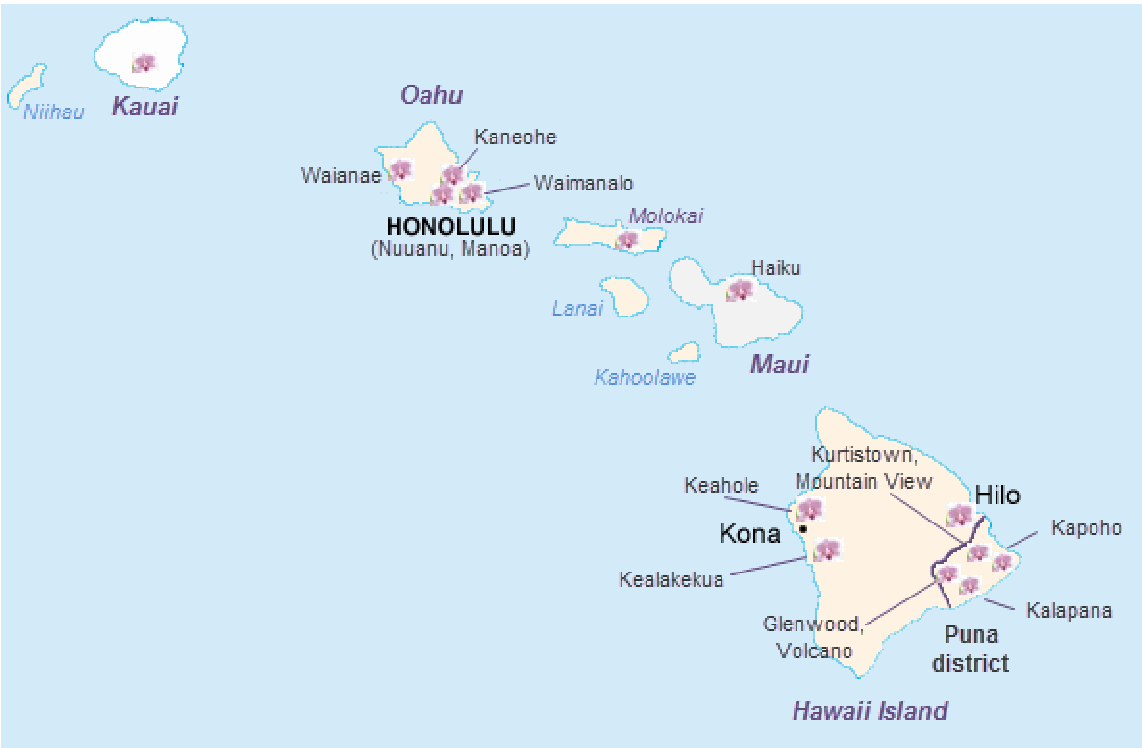
MAUI COUNTY

There are several orchid growers on Maui. Some may be considered hobby growers, but others supply the big box stores. The Haʻikū area is the most prominent of the orchid growing areas on Maui. Maui orchid growers produce a wide range of genera and species, such as warm temperature tolerant nobile dendrobiums.

Moloka‘i does not have significant potted orchid production. (However, there are some growers of vanilla on Moloka‘i.)

KAUA‘I

There are only a small handful of potted orchid growers on Kaua‘i found mostly between Kapa‘a and Kīlauea on the northeast side of the island.



Potted orchid growing areas of Hawai‘i

Cultural Practices

Dendrobium and oncidium cultural practices are very similar and these different orchids are often grown side by side. For brevity, references to "dendrobiums" in this document apply to oncidiums, as well. Any differences between these two groups of orchids are identified.

SITE ESTABLISHMENT (PRE-PLANT)

Site Selection

A nursery should be situated in an area that is conducive to good plant growth. Dendrobiums and oncidiums grow best when night temperatures do not drop below 65°F and day temperatures are between 75°F and 85°F. Under the cooler temperature conditions experienced at higher elevations in Hawai'i, these orchid plants are less productive and flower sprays are weaker than those grown near sea level. Another consideration for site selection for an orchid nursery is that, while land may be cheaper in wet areas, disease management will always be more expensive in moist environments.

Design and Construction of Structures

In Hawai'i, dendrobiums are grown in structures where roofs and side walls are covered with shadecloth to provide a protective environment for crop production. Such structures reduce the intensity of bright sunlight and provide some protection from strong winds, heavy rains, and large pests such as birds. The most common shadehouse structures in Hawai'i use a rigid framework of posts and cables to support panels of shadecloth. Knitted shadecloth material is recommended over woven material because of its superior strength and flexibility. In high-rainfall areas it is advisable to use structures covered with polyethylene film in addition to shadecloth to minimize disease establishment and spread. The shadecloth must either be embedded into the ground or be attached to a separate piece which seals the base of the shade house. Otherwise, the structure will be easily invaded by mice, birds, insects and other pests.

Greenhouses are rigid structures with transparent, solid coverings which may be fiberglass, fiberglass-reinforced plastic, polyethylene plastic film or glass. Growers producing dendrobiums in wet areas should seriously consider solid-covered greenhouses. The main advantage of solid greenhouse coverings is that they allow for total protection from rain. Plants remain dry throughout the night, and irrigation is provided at the discretion of the grower. This results in a significant reduction in the incidence and severity of diseases. The benefits include healthier plants and lower expenditures for fungicides and the labor to apply them. Fiberglass and fiberglass-reinforced plastic are suitable greenhouse coverings, but polyethylene plastic film is recommended because it is economical and equal to other coverings for rain protection. Polyfilms, however, are prone to degradation from ultraviolet radiation and, therefore, do not last as long as rigid sheeting. Polyfilms require replacement approximately every three years. Glass is seldom used because its initial cost is high and it requires a heavy structure to support its weight. (*Note*: "true" greenhouses, which are completely enclosed by non-porous materials, are not used in orchid production in Hawai'i. Here, growers use various types of shadehouses, as described above.)

The growth and yield of dendrobium plants are best when light is at the optimum level. Therefore, another reason to attach shadecloth to greenhouses is to create the appropriate light level. In Hawai'i, the shadecloth selected ranges between shade levels of 30% and 65% of full sun. The shadecloth selected must be of a sufficient density to protect the plants from excess light during the brightest periods, which generally occur at mid-day in summer. However, this density of shadecloth provides too much shade in the morning and late afternoon and at most other times of the year. Therefore, in Hawai‘i, growers usually select lower shade levels (higher sunlight transmission) to provide adequate light; during periods of high light intensity, supplemental shade is added, either seasonally or daily. Some operations have workers manually pull the shadecloth in the afternoons. With greenhouses, the grower has the additional option of using retractable shade. Some motorized systems are available that can provide near optimum light levels for more hours of the day and for more days of the year.

Freestanding greenhouses and gutter-connected greenhouses are both suitable for dendrobium cultivation. There is better air movement through a freestanding greenhouse because the ratio of perimeter area (side walls) to cubic volume is greater than with gutter-connected greenhouses. Another advantage is that compliance with Worker Protection Standards (WPS) is simplified in freestanding greenhouses where pesticide application is confined to clearly separated areas. It is also easier to establish isolation areas in physically separated houses. Gutter-connected greenhouses, however, may allow for more efficient use of labor because there is less “travel time” between houses. The large spans of gutter-connected greenhouses offer more possibilities for automated movement of materials and harvested products. They also make more efficient use of land because there are fewer roads and aisles between houses.

In addition to providing protection from rain and excess light, the area of the nursery where young plants are maintained should have a fog or mist system to create a high relative humidity. This is important for plants which have been transplanted from flasks. Good air movement is essential. The position of benches (spacing between rows, direction of rows, etc.) should provide for good air movement to keep foliage as dry as possible, following irrigation. Fans may be installed if natural air movement is inadequate. This should be the most sanitized area of the farm, because the humid environment favors disease development and because the plants that are housed here are at the stage when they are most susceptible to infection.

All growers should consider the types of orchid genera that they will be growing and their requirements. They should allow for some parts of the structure to be protected from rain (fiber glass or other types of solid cover). They should also plan to provide different shade levels and a separate area for sick or suspect but valuable plants (a quarantine area). Reasonable and intelligent diversification is important to successful nursery production.

A dry barrier of gravel without weeds or plants should surround the greenhouse to discourage entry of pests such as snails, slugs, toads, frogs, mice, and other small animals. These animals can move nematodes, and bacterial and fungal pathogens into clean fields or onto clean benches. The barrier should be at least 5 feet wide because nearby weeds will harbor many pests and make control difficult.

For growers producing potted plants for export, the crops must be grown on raised benches. Hawai‘i Department of Agriculture’s (HDOA) standards for export certification require that benches must be at least 18 inches tall so that splash from the ground cannot reach the plants. However, most nurseries have benches that are 30 inches tall which is better for employees who handle plants. If a new planting area was previously covered with vegetation, the ground is cleared completely and covered with weed mat and/or a thick layer of gravel. The ground in the shadehouses or greenhouses should be absolutely clean. There should not be algae, moss, ferns, weed, fallen leaves, flowers or other debris.

Unless windbreaks are necessary, trees and other plant growth around the shadehouse should be kept to a minimum. Minimizing surrounding vegetation allows for good air circulation and adequate light and discourages insect breeding.

PROPAGATION

Orchids can be propagated from seed and by vegetative means.

Seed-propagated

Seedling populations are variable, because each seedling is unique and not a clone. The extent of variability is dependent on the parent plants that were crossed. The variability in a species population is usually less than in a hybrid population. Crossing complex hybrids with multiple genera in their ancestry—as with many Oncidiinae alliance intergeneric hybrids, or Cattleya alliance intergeneric hybrids—may result in extreme variability in the seedling population. This variability among the seedlings in the progeny population presents opportunities for breeders to select improved, or simply new or different varieties which are then cloned and introduced to the market.

The dendrobium breeding program in the department of Tropical Plant and Soil Sciences (TPSS) at the University of Hawai‘i at Mānoa (UHM) provides dendrobium orchid seed pods of its outstanding varieties from amphidiploid parentage to Hawai‘i’s orchid industry organizations for propagation by private laboratories. Amphidiploids are primary hybrid tetraploids with a complete diploid genome complement from each species parent. This condition causes the amphidiploid to breed as if it were a species, with the resulting narrow genetic diversity normally associated with a species population. When an amphidiploid is crossed with a species or another amphidiploid—a technique called “genome breeding”—the hybrid progeny population is relatively uniform from seed. TPSS’s dendrobium breeding program used genome breeding technologies to develop their dendrobium varieties. The dendrobium breeding program has developed, named and released about 10 cutflower varieties and over 15 varieties for potted plant production to date. Seed pod culture from the UHM breeding program assures virus-free and true-to-type seedlings, and high-yielding plants.

Seedling populations which result from seed pods culture from the amphiploid parent plants of the UHM breeding program present several advantages to growers, specifically:

- Uniformity in plant and flower characteristics from seed.
- Virus-free plants (virus is transmitted through tissue culture, but not through seed).
- Inexpensive propagules (for most genera, the cost of cloning is 3 to 5 times the cost of seedling production).
- Large populations can be produced quickly, since orchid fruits contain many thousands of seeds. One thousand flasks of seedlings can be ready in 6 to 8 months from sowing, whereas 1,000 flasks of clones will take 2 or more years to produce due to the slower increase of tissue from the original explants.
- High-yielding plants.

Clone-propagated

For commercial production purposes, most orchids are cloned by tissue culture techniques. This has distinct advantages over propagation by divisions or other clonal (vegetative) means. Tissue culture is rapid and large numbers of plants can be propagated; this keeps the cost per plant low. Because plantlets are clones of the mother plant, they are true-to-type, except for occasional mutations. Plantlets from tissue culture start out free from fungal and bacterial diseases. They will, however, be virus infected if the cloned mother plant was virus infected. Therefore, it is important to index plants for the presence of virus before cloning.

Many commercial orchid growers from Hawai'i bring plants or divisions of their selected varieties to laboratories in Asia (predominantly Thailand and Taiwan) to be tissue cultured. The tissue culture process is labor intensive and the low labor rates in these countries allow these foreign laboratories to produce finished flasks of seedlings much more cheaply than the laboratories in countries with higher labor rates, but sometimes the quality of their work is inconsistent.

Several foreign laboratories are not solely service laboratories but are also associated with a nursery or a breeder and, thus, they may serve as sources of new varieties that are grown in Hawai'i nurseries. These laboratories make many more orchid cultivars available to growers beyond those that are provided by UHM. Because growers are constantly looking for newer and better cultivars, purchasing from overseas is very common.

Plant cultures, whether seedling cultures or tissue cultures, are grown in a laboratory where the growing medium and conditions can be modified by adjusting hormones, nutrients, temperature and light, to initiate roots and shoots as needed. The professional tissue culture technician manipulates these variables as he or she attempts to fill orders to meet the growers' rotating planting schedules. In practice, this is not easy to accomplish, particularly if the orchid variety is new or unfamiliar to the laboratory technician.

Divisions

Oncidium orchids are often propagated vegetatively by divisions of their bulbs. As plants age and have developed multiple bulbs from one plant in a pot, growers will separate older bulbs, peel off their old roots and leaf sheaths, let those bulbs cure for a few to several days, then replant them. This is not the best propagation method because it has a higher chance of spreading existing diseases, but it is cheap. Growers need to take special care to remove those that are infected and take only the cleanest bulbs for propagation. Oncidiums are also commonly clonally propagated in a lab which can provide clean plantlets. Growers buy these directly from the lab, or in a plug stage from others who grow them from the flask stage.

CARE OF YOUNG PLANTLETS IN THE NURSERY ENVIRONMENT

All cultivated dendrobium orchids, whether seedlings or clones, are started in glass flasks or autoclavable plastic containers. The flask environment provides the plantlets with ideal conditions for early growth. Nutrients and water are provided to the plantlets in measured amounts via an agar growth medium in a humid and sterile environment. Given appropriate light in the laboratory, generally about 200–300 foot-candles, the plantlets will thrive until the nutrients are depleted. Before depletion of the nutrients in the agar medium, plantlets should be either reflasked with new nutrient media or be or taken out of the flask to grow.

The proper care of plantlets from flasks through the community pot or "compot" stage is critical to their optimum growth, development, and productivity.

When flasks are received from a lab, they are placed in the nursery in a higher light intensity condition for 2–3 weeks to "harden off" the seedlings before they are deflasked. A common practice is to put the flasks in the same area where the community pots or plug trays will be placed, so that the light level before and after deflasking is the same. Flasks must not be exposed to direct sunlight for even a brief period. Direct sunlight exposure will raise the temperature inside the flask and may kill the plantlets.

Each flask is sealed with a rubber stopper. The area of contact between the glass and rubber is the seal that maintains sterility inside the flask; the stopper must not be disturbed until it is time to deflask the plantlets. When this seal is broken, fungal and bacterial pathogens and mites can enter and multiply quickly, often weakening or killing the young plants.

The optimum time for deflasking varies between cultivars and is largely determined by the post-transfer cultural practices and environmental conditions provided to the community pots or plug trays. Some growers have excellent success with plantlets that are only 1⁄2 inch tall and having one or two small roots, while others prefer plantlets to be nearer to two inches tall with three or four roots of one inch or longer. If there are pathogens present, the smaller plants are at greater risk of mortality. The plantlets should be healthy, with thick green leaves and active roots. A healthy and vigorous plantlet will establish more quickly than a weakened plantlet in its new environment.

Also, growers must take great care when removing plantlets from their flasks because an injured root or a cracked leaf weakens the plant and is a point of entry for even weak pathogens. Young plants should be placed on highly sanitized benches.

If the plantlets remain in the flask too long they will deplete the medium of nutrients and begin to decline. Inadequate nutrient uptake by the roots causes the lower leaves to begin to turn yellow, indicating that mobile nutrients are being taken from them to nourish the youngest developing leaf. Such plantlets are slower to establish in community pots. Deflasking should be done prior to the appearance of chlorosis or yellowing. If chlorosis does appear, plantlets should be removed and compotted at once, regardless of size.

MAINTENANCE OF GROWING PLANTS

To produce top-quality, disease-free community pots and plug trays, the choice of media, the microclimate around the young plants, and sanitation are critically important.

The medium must be pathogen-free and have a good balance of moisture-holding capacity, drainage and aeration. The tender young roots require moisture, but also need good drainage and aeration to prevent anaerobic conditions which will suffocate root tissue and promote the growth of certain bacteria, algae, and other micro-organisms. Available materials include "orchid bark" (usually fir bark, packaged in coarse, medium or fine grade), peat and perlite mixes, coconut chunks (coir), tree-fern (*hapu'u*) fiber, sphagnum moss, perlite, Styrofoam, and charcoal. (In Japan and Taiwan, it is common for commercial growers to use sphagnum moss, only.) Orchid bark is the preferred medium of some commercial growers and UHM researchers. (At UHM, researchers used tree-fern fiber until 2010; supplies of tree-fern fiber have since become unreliable.) All of these materials should be sterilized with steam at 180°F for a minimum of 30 minutes. (60 minutes is recommended.) The prudent grower will allow the media to cool, stir it, and repeat the process.

The agar medium is completely washed from the plantlets by a minimum of two washings. Many growers wash three times to ensure complete removal of the agar medium. This practice minimizes incidence of disease. After washing, the plantlets may be dipped in an approved fungicide solution.

Some growers bring in plantlets from Thailand which have already been deflasked and washed and are ready to be placed in for compots or 2-inch plug trays.

Plantlets are graded by size after washing. Plantlets of similar size are placed together in the same compot or plug tray. When plantlets of different sizes are planted together, the finished products will not be uniform. Then, excessive drying will increase mortality among the smaller plants which need more frequent, but shorter exposures to misting than their larger neighbors.

This is the stage of plant development when seedlings are most susceptible to infection. Compots and plug trays are placed pot-to-pot or tray-to-tray, on sanitized wire-covered benches. The surfaces of all benches are disinfected between crops, and only new pots and trays are be used. Recycled media should never be used for such tender plants.

Newly deflasked oncidiums. (Photo by Tessie Amore)

The daily weather determines the frequency of misting or watering. During long, warm, dry days, new compots may require several mistings daily. Older and deeper rooted plants require less misting, but heavier watering. It is not necessary for growers to have misting irrigation systems. For young plants, growers can achieve the same results by using a nozzle on a "fine" setting or by using a gentle shower type of nozzle.

Young plants just out of flasks need not be fertilized immediately upon planting. Because plants taken out of flasks do not have a well-developed cuticle, the growers' main objective at this stage is to let the plants harden off without burning them. Over-fertilizing results in high salinity and plantlets which have been injured by over-fertilizing are more susceptible to diseases. After the plantlets have hardened off (approximately 2–3 weeks), a dilute (about 1⁄4-strength) solution of liquid fertilizer is applied once a week. As the young plantlets harden off, shade is decreased and misting discontinued and replaced by several hand-waterings per day. As plants adjust to the higher light levels, and after new roots and leaves appear, the concentration of liquid feeding can be increased.

The young plant nursery area should be observed daily for any signs of disease. A single plantlet showing suspicious symptoms in a compot is cause to discard the entire compot. Growers should not try to salvage other plantlets in that compot. Adjacent compots are removed to an isolation area. If a plantlet in a plug tray displays symptoms indicative of possible disease, it is discarded, along with all adjacent plantlets, and the tray is removed to the quarantine area. The area of the bench from which the possibly infected compot or plug tray was removed is surface-sanitized.

Most cultivars and seedling crosses of dendrobium require 4–6 months growing time in compots or plug trays before they can be sold or transferred into the next size pots.

Dendrobium compot. (Photo by Tessie Amore)

TRANSPLANTING INTO INDIVIDUAL POTS

Plants are usually transferred from the compots or plug trays to approximately 4-inch pots (the diameter across the top). Slowly growing cultivars may be transferred to smaller pots. When transferring, the entire population should be moved together to a sanitized bench and kept apart from older, more mature plants. Young plants should never be placed in close proximity to adult plants, which are likely to harbor infectious organisms. Segregating plant populations by size also allows the grower to be more precise in meeting the water and fertilizer needs of the plants.

Dendrobiums in 2-inch pots. (Photo by Tessie Amore)

MEDIA, FERTILIZERS, AND IRRIGATION

Dendrobiums and oncidiums require well-drained media and, therefore, also require slow-release fertilizers because many of the commonly used media have low nutrient holding capacities. Nutrients in ratios of 1:3:1 or 1:2:1, in terms of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O), respectively, are recommended. Often, a slow-release fertilizer is used in a 1:1:1 ratio that is supplemented with MagAmp for increased phosphorus levels. This is supplemented further with foliar fertilizers which are sprayed onto plants to provide minor elements needed for optimum growth. Frequency of slow release fertilizer application depends on the type, whether it is a 3, 6, 9, or 12 month release type of fertilizer. In Hawai‘i, it is recommended to apply these fertilizers about a month earlier than the label states because the high rainfall and high temperatures result in a faster rate of nutrient release.

The preferred potting medium in some parts of Hawai‘i for plantlets ready for transplanting is screened basaltic gravel, known locally as “blue rock.” The roots will penetrate and occupy the spaces between aggregates, so growers first remove the smaller stones and fine particles that will impede drainage and aeration of the roots. Basaltic gravel is readily available, inexpensive, durable, and has high porosity. However, it is very heavy and has a low nutrient-holding capacity. Potted dendrobiums shipped out of state are often grown in much lighter media, such as peat and perlite mixes. Shredded coconut husks, cubed coconut husks, Styrofoam, and other light materials are also used for these plants. Another suitable medium is volcanic cinder, which is lighter than blue rock, has greater surface area due to its irregular form, and provides adequate drainage and aeration for short-term production purposes such as potted plants. Volcanic cinder is more widely used on the island of Hawai‘i, where it is available locally. Again, all media should be pasteurized before use.

Well-drained media also helps to prevent root fungal organisms and fungus gnats from proliferating. They are both often associated with very wet media that does not dry well.

Because most potted orchid plants are grown under a solid cover, plants need to be irrigated. The frequency of irrigation depends on the crop grown and the outside weather and season. During the hot, dry summer months, plants may need daily irrigation, or at least 3 times a week. During the cold, wet winter, plants may need as little as one irrigation cycle per week. To minimize disease establishment, plants should be irrigated in the morning and left to dry out before nightfall. Adequate plant spacing and good air exchange also facilitates leaf drying and lessens disease incidence.

PLANT GROWTH REGULATING HORMONES

Certain plant growth regulators have been used in commercial production of potted floral crops to produce shorter and more compact plants and therefore a better balance between plant and container sizes. Other plant growth regulators have been used to force the initiation of dormant or uninitiated floral buds to produce flowering outside of the normal flowering season or to create a plant with more flowers than normally expected. For growth-regulating hormones labeled for use on potted orchids in Hawai‘i, see Appendix 1.

POST-HARVEST (SHIPPING)

Potted dendrobiums generally ship very well and tolerate the shipping period without damage. There have been problems resulting from the shipment of plants that have low levels of disease. These are usually plants with a few spots caused by *Phyllosticta* or other fungi. In the greenhouse, adequate light levels allow the plant to produce biochemical products that keep pathogens confined. The production of these defensive biochemicals is dependent on photosynthesis. During transit, the plants are in boxes, and, therefore, in the dark, where no photosynthesis occurs, and fungal growth occurs rapidly. The packaging maintains the relative humidity high, a condition which favors pathogen growth. In a few days, many leaves become chlorotic and often drop from the cane (pseudostem). These plants are unmarketable.

There are no postharvest treatments that will eliminate fungi from the plant. Thus, for growers of potted plants, production of healthy and uncontaminated plants is the key to problem-free shipping.

There are also invertebrate and other animal quarantine pests which may cause rejection by shippers or authorities at destinations such as California and Guam. Heat treatments are applied just prior to transport to kill coqui frogs and some snails. Visual inspection prior to shipping is critical in order to ensure pest-free products.

Integrated Pest Management (IPM) in Potted Orchids

Ideally, growers have learned to identify the key invertebrate pests and their damage symptoms, and they have established an economic threshold for each pest. They monitor for these pests and use the monitoring data, action thresholds and their experience to reach decisions on the application of control measures.

SCOUTING FOR INVERTEBRATE PESTS

Growers can identify the key invertebrate pests, the damage symptoms and activity patterns of each pest and other evidence of their presence such as cast skins and droppings. They inspect canes, foliage, spikes, flowers, roots, and media for non-flying pests such as aphids, beetles, caterpillars, mites, mealybugs, weevils, bugs, snails, slugs, and mice. Counts of flying insects, such as whiteflies, thrips, and blossom midges are obtained from sticky-cards which are suspended within and above the plant canopy. All dendrobium growers should construct or purchase a modified Berlese funnel to monitor thrips. Some pests may be more active in the cooler times of the day, while others may be more easily spotted when it is warm. At night, growers use a flashlight to examine plants, containers, benches, and the ground for snails and slugs whose slime trails are easily seen in a flashlight beam. Growers devise their own scouting schedules and design data-recording sheets. Data and observations for each pest and beneficial organism are recorded to determine whether a population is increasing or declining.

Several "indicator plants" may be distributed about the nursery. An indicator plant is a plant found to be more attractive than orchids to a particular pest. *Aglaonemas* and *Chamaedorea* palms, for example, are particularly attractive to mealybugs and are appropriate indicator plants for these pests. Also, growers should check *Aglaonema* for stem and leaf rots commonly caused by *Fusarium*, and *Chamaedorea* for stem and leaf blights commonly caused by *Phytophthora*. Growers should purchase healthy indicator plants and watch them closely for movement of insects and mites onto these plants. These indicator plants are examined frequently (weekly) for early signs of insect, mite and disease infestations.

Growers must be vigilant and monitor for ants. These active and tiny insects burrow into the shadehouses, rapidly make large nests in these structures and facilitate the movement other pests such as aphids. In some environments, root mealybugs are common on weeds. Thus, no weeds should be allowed to grow near or in the greenhouses.

SCOUTING FOR DISEASES

For plant diseases, growers inspect plants at least weekly for any signs of rotted shoots or young leaves, yellowed or spotted leaves or flowers, blemishes on sheaths, browning of roots, or development of black rots on aerial shoots. In general, young tissue is much more susceptible to disease than mature tissue. Growers note the presence of these and other potential disease symptoms and increase monitoring of plants in the area. Temperature and humidity are also monitored and growers remain alert for conditions that favor specific disease pathogens. For example, cool, damp conditions are conducive for development of diseases caused by *Botrytis* and *Colletotrichum*, while warm, moist conditions are conducive for diseases caused by *Phytophthora*, *Erwinia*, and *Pseudomonas*. When a particular set of conditions exists, growers monitor frequently with increased vigilance for early symptoms of the specific diseases, and, if possible, cultural practices are adjusted to reduce the potential for disease development. Early identification of disease problems also allows growers to take action to prevent pathogen movement through the farm.

CULTURAL CONTROL PRACTICES

The goal of cultural control practices in an IPM program for orchid production is to maintain an environment that is not conducive to disease, insect or other pest infestation. The most important consideration for disease prevention is the elimination of the pathogen. Moisture must be controlled to reduce and prevent diseases caused by bacterial, fungal, and nematode pathogens.

Pathogen spores need water to germinate and thus plant wetness is a huge factor in disease formation. Moisture also favors epidemics by enhancing the growth, spread, and infectivity of many pathogens. Protecting the plants from rainfall is especially important in high-rainfall areas. Providing good airflow by the use of fans or creating good ventilation can also help in reducing the incidence of diseases.

Young plants are the most vulnerable to diseases. Therefore, starting with an insect pest-free, weed-free, and pathogen-free growing area is of utmost importance. IPM practitioners use only clean pots, media, and benches. When orchids are removed from flasks, they should be kept together and not mixed with older plants. Any plants that are suspected of hosting diseases, insects, or other pests should be discarded or moved to a quarantine area separate from all pest-free areas. As plants are repotted, they should be transferred to clean benches or growing areas which are clear of other plants. Newly repotted plants should not be integrated with older plants or placed on benches wherever spaces may happen to be available.

Use of clean propagation material is another critically important cultural practice. The seed-propagated dendrobium cultivars developed at the Department of Horticulture (now Tropical Plant and Soil Sciences) at UHM, are initially free of all diseases, including viruses, although they are not virus-resistant. Growers must employ practices that maintain the plants free of viruses. When growers choose to propagate plants by tissue culture, they should first determine that the candidate plant is free of viruses.

Increasing plantings with vegetative propagules such as aerial shoots or other plant parts poses a high risk of introducing viruses, fungi, bacteria, insects, and other pests to the production area and should be avoided.

In production areas, strict sanitation is critical. Fallen leaves, old flowers, dead or dying canes, weeds, and other host plants can be reservoirs of viruses, fungi, bacteria, insects, mites, and other pests. Growers should follow a weekly schedule to remove such reservoirs from their production areas and eliminate them from the property.

Trade Issues

IMPORTING ORCHIDS

Much of the planting material for Hawai‘i’s orchid growers comes from overseas sources. The single largest source of orchid imports is Thailand. Japan, Taiwan and China are additional sources of much smaller amounts of orchid planting material. (The Philippines had been, but is no longer a source of orchid planting material for Hawai‘i’s growers.) The importation of orchids into Hawai‘i is regulated by both the Animal and Plant Health Inspection Service (APHIS) of the United States Department of Agriculture (USDA) and HDOA. Permits from both agencies are required for importing orchid plant materials from foreign sources, and a permit from HDOA is required for importing from the continental US. Both agencies must inspect incoming shipments, and HDOA holds shipments from certain points of origin in quarantine. For obligate pathogens like rust, plant quarantine inspection services have been very effective and Hawai‘i is one of the few areas in the world that is rust-free.

EXPORTING ORCHIDS

The exportation of orchid plants from Hawai‘i to the continental US is regulated by HDOA’s Plant Quarantine Branch (PQ), which also inspects orchid nurseries regularly to ensure that they meet export requirements of the Burrowing and Reniform Nematode Certification Program.

International movement of orchid plants to and from Hawaiʻi are subject to provisions of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) regulations.

Nursery Certification Program. Export Certification requirements can be obtained from HDOA-PQ. These requirements include: weed-free greenhouses, minimum height of benches, absence of all insects and mites, absence of all pathogenic nematodes, a record of the number of plants covered by the Certificate, the area covered by the Certificate, and other items. The nursery must be certified by HDOA before plants or flasks are purchased from another certified source or plants started from imported seeds. All plants grown by a nursery before becoming certified cannot be included in the nursery's nematode-free certified plant inventory.

QUARANTINE PESTS

Certain pests are of quarantine significance. If a shipment of cut orchid flowers or potted orchids is intercepted with one or more these pests, the shipment will be destroyed.

- **Mealybugs** found on roots and are a major cause of quarantine rejections for exported potted orchids.
- **Melon thrips and western flower thrips**
- **Whiteflies**
- **Ants**
- **Scales**
- **Blossom midge**
- **Black twig borer**
- **Orchid weevils**
- **Slugs and Snails.** Slugs and snails are among the major pests of dendrobiums, causing feeding damage to leaves, roots, and flowers and quarantine rejections in export shipments. In recent years, a native snail (*Tornatellides* sp.), and the introduced snails *Liardetia doliolum* and the orchid snail (*Zonitoides arboreus*) have become of quarantine significance on ornamentals, including dendrobiums. (The orchid snail is widely distributed on the continental US and in other parts of the world.) These snails occur primarily on roots in the media and on leaves and are tiny (1⁄8 to 1⁄2 inch) and therefore may go unnoticed.
- **Coqui frogs**
- ***Fusarium* spp.**
- **Viruses**
- **Weeds**
- **Burrowing nematode** (*Radopholus similis*) is also a quarantine pest. Burrowing nematode has not been reported as a pest of potted orchids.

Pest Pressures and Control Measures

The remainder of this document is a pest-by-pest analysis of pest management in potted orchid production in Hawai‘i. Key management practices and their alternatives (current and potential) are discussed. Differences between production regions within and throughout the islands are discussed where appropriate. Pests are listed in order, by approximate economic importance, with pests causing the most economic damage listed first.

(*Note*: only the chemical controls that are actually used, or for which relevant information has been provided, are specifically discussed below. For all pesticides labeled for use on potted orchids in Hawai‘i, see Appendix 1 and Efficacy Tables, Appendices 2 - 5.)

Invertebrate Pests

Workshop participants identified **thrips**, **mealybugs** and **mites** as invertebrate pests of particular importance for in-depth discussion at the workshop. A workgroup member who was not present at the workshop identified **blossom midge** as another pest of critical importance to potted orchid production. Other invertebrate pests are included in this document, however, there are no “Critical Needs” specified for these other invertebrate pests.

Thrips: western flower thrips (*Frankliniella occidentalis*), melon thrips (*Thrips palmi*), dendrobium thrips (*Dichromothrips dendrobii*), banded greenhouse thrips (*Hercinothrips femoralis*), greenhouse thrips (*Heliothrips haemorrhoidalis*), Hawaiian flower thrips (*T. hawaiiensis*), vanda thrips (*D. corbetti*), and yellow flower thrips (*F. shultzei*)

Severity of crop damage
Controlled: 0- 25%
Uncontrolled: 100%
Region(s) where pest is a problem: all islands
Affects dendrobiums or oncidums or both: both
Crop stage(s) affected: flowering and seedlings
Crop stages at which controls are applied: flowering and seedlings
Economic thresholds
Local market: not marketable if flowers are damaged
Export: zero tolerance for the continental US and foreign countries

Thrips are the most common insect pest of orchid flowers in Hawai‘i.

The rasping-piercing-sucking mouthparts of thrips damage the seedlings and the leaves or flowers of dendrobium orchids. Greenhouse thrips and banded greenhouse thrips cause silvering of leaves, which eventually turn brown. Dendrobium thrips and vanda thrips attack flower buds and spikes, and young terminal leaves. The buds are deformed and die; the terminal leaves die. Western flower thrips, yellow thrips and melon thrips infest open blossoms. Because thrips are tiny, small populations on open blossoms are often not noticed. The feeding of large populations of thrips cause irregular white streaks and blotches on the flowers.

Thrips life stages include egg, two immature larval instars, prepupa, pupa, and adult. Immature larval stages and adults are the feeding stages of thrips. Eggs are oviposited into plant tissue. With most thrips species, immature thrips migrate off the plant and pupate in the media, plant debris, or other protected places. Melon thrips and western flower thrips can complete their entire life cycle in as little as 11 and 13 days, respectively.

The first step in effectively managing thrips is early detection. All dendrobium growers should construct or purchase a modified Berlese funnel to monitor thrips.

APHIS identifies melon thrips as a quarantine action pest with zero tolerance into the continental US. Western flower thrips and yellow flower thrips have immature stages that appear similar to melon thrips. Because immature thrips are almost impossible to distinguish between species, quarantine inspectors will reject dendrobium blossoms infested with immature thrips that appear similar to melon thrips.

Monitoring and identifying thrips:

With the Berlese funnel, low population levels of thrips can be detected, and this is the time when control measures must be implemented. All infested flowers and plants are removed, placed in trash bags and disposed of. An insecticide is applied both to leaves and the ground. Foliar application targets immature and adult thrips, and ground application targets the pupal stage of thrips.

Proper identification of the pest to be controlled is key in any pest control program. This is especially true for thrips and their chemical controls. There are several different species of thrips that plague orchids in Hawai‘i. A particular pesticide that is labeled for thrips can be very effective against one type of thrips, but be completely ineffective against another. That is why the correct identification process is critical. For example, the banded greenhouse thrips can be easily controlled with a number of broad-spectrum insecticides while melon thrips and western flower thrips have become resistant to many of these insecticides. Growers cannot afford the potentially very high combined costs of the chemical, the labor costs for application and potential damage from the actual pest when they apply a chemical that is ineffective against their particular thrips species.

Chemical controls:

Chemical control of thrips is very difficult because almost all stages are found inside flowers or buds, and thrips are resistant to or tolerant of many insecticides. Moreover, once thrips become well established, their pupae in the soil may escape treatment. Successive, carefully timed insecticide sprays are needed if this occurs.

- Imidacloprid (Mantra, Mallet, Marathon, Majesty, Lada, Benefit, Imigold, Malice, Widow)
  Imidacloprid may be applied by either drench or foliar methods.
  - Efficacy: good
  -Advantages: controls other sucking insects; efficacy is long-lasting. (*Note*: good efficacy and long-lasting effects justify the high purchase cost.)
  -Disadvantages: very expensive to purchase (however, the cost per application is reasonable); foliar application is incompatible with IPM programs (harsh on beneficials); resistance-management issues

- Bifenthrin (Talstar, Wisdom, Onyxpro, Bisect, Menace, Up-Star, Attain, Bifen)
  - Efficacy: good (against dendrobium & vanda thrips, greenhouse thrips)
  -Advantages: not expensive
  -Disadvantages: resistance-management issues; harsh on beneficials; incompatible with IPM programs; persists in water; Restricted-Use Pesticide

- Novaluron (Pedestal)
  Novaluron is an insect growth regulator (IGR) and, therefore, is only effective against immature stages of thrips. For melon and western flower thrips, novaloron is used in rotation with chlorpyrifos.
  - Efficacy: good - excellent
  -Advantages: compatible with IPM programs; also effective against whiteflies (immatures)
  -Disadvantages: moderately expensive; resistance-management issues; only effective on immatures

- Chlorfenapyr (Pylon)
  - Efficacy: excellent
  -Advantages: compatible with IPM programs; also effective against mites and foliar nematodes
  -Disadvantages: very expensive; only registered for use in “true” greenhouses (which are not used in orchid production in Hawai’i)

- Spinosad (Conserve, Entrust, Seduce)
  For melon and western flower thrips, spinosad is used in rotation with chlorpyrifos.
  - Efficacy: poor – good (good only in areas where resistance has not developed)
  -Advantages: less expensive than some other products; no known environmental issues
  -Disadvantages: thrips are highly resistant in certain locations/regions where spinosad products were used regularly and farms are very close to each other.

- Pyridalyl (Overture)
  - Efficacy: unknown (not commonly used); may be effective against melon & western flower thrips
  -Advantages: unknown (not commonly used)
  -Disadvantages: only for use in true greenhouses; slow-acting; needs research on applicability for an IPM program

- Abamectin (Avid, Ardent, Lucid, Timectin, Abba)
  For melon and western flower thrips, abamectin is used in rotation with chlorpyrifos. Some phytotoxicity (bud blasting or deformed flowers) has been observed following Avid applications when conditions are hot.
  - Efficacy: poor - good (greenhouse thrips, melon & western flower thrips)
  -Advantages: generic products are less expensive; no known environmental issues; also effective against mites and whiteflies

-Disadvantages: resistance-management issues in certain regions; bad smell is an issue for workers; slow-acting; needs research on applicability for an IPM program; possible phytotoxicity

- Cyfluthrin (Decathlon)
  - Efficacy: poor - good (dendrobium & vanda thrips, greenhouse thrips)
  -Advantages: inexpensive
  -Disadvantages: incompatible with IPM programs; resistance-management issues in certain regions; toxic to fish

- Methiocarb (Mesurol)
  - Efficacy: good (melon & western flower thrips)
  -Advantages: compatible with IPM programs; inexpensive; also effective against snails and slugs
  -Disadvantages: resistance-management issues; Restricted-Use Pesticide toxic; worker safety issues

- Malathion
  Malathion is used as a drench application for pupae.
  - Efficacy: poor – fair (dendrobium & vanda thrips, greenhouse thrips)
  -Advantages: inexpensive
  -Disadvantages: incompatible with IPM programs; resistance-management issues; bad smell and other worker issues; negative impacts to non-target organisms; water contamination issues

- Chlorpyrifos (Dursban, Vulcan, DuraGuard)
  Chlorpyrifos is used as a ground treatment to target pupae. For melon and western flower thrips, chlorpyrifos is used in rotation with novaluron, spinosad or abamectin.
  - Efficacy: good
  -Advantages: inexpensive; is also effective against mealybugs, black twig borer and orchid weevil
  -Disadvantages: incompatible with IPM programs (persistence issues); water quality issues, Restricted-Use Pesticide

- Dimethoate
  - Efficacy: fair
  -Advantages: inexpensive
  -Disadvantages: incompatible with IPM programs (broad spectrum); resistance issues; bad smell is an issue for workers

- Acephate (Orthene, Precise)
  - Efficacy: fair (melon and western flower thrips)
  -Advantages: systemic action
  -Disadvantages: some phytotoxicity has been observed

- Dinotefuran (Safari)
  - Efficacy: not reported

-Advantages: compatible with IPM programs; no resistance issues yet
-Disadvantages: very expensive

- *Beauveria bassiana* (Botanigard, Mycotrol)
  - Efficacy: unknown (newly registered product)
  -Advantages: compatible with IPM programs; no resistance issues yet
  -Disadvantages: none reported

Unregistered chemical:

- Endosulfan (Thionex SLN HI-070006); use terminated July 31, 2012
  - Efficacy: excellent
  -Advantages: moderate cost; is also effective on coqui and greenhouse frogs
  -Disadvantages: incompatible with IPM programs; worker safety concerns (unacceptable risk in California); water quality issues; effects on non-target species, including beneficial insects; Restricted-Use Pesticide; (All US registrations of endosulfan have been cancelled.)

Biological controls:

Because thrips are very difficult to control with insecticides, growers are encouraged to take advantage of their natural enemies. These are not a sole tactic, but an aid to pest control. These are not available for release. Growers should avoid use of ineffective insecticides which may impact natural enemies.

- Pirate bugs (*Orius* spp.)
  Pirate bugs are natural enemies of melon and western flower thrips. Research is currently being conducted on the effectiveness of pirate bugs in field situations.

- Predatory mites
  There are some naturally occurring predatory mites which may help control populations of melon and western flower thrips.

Other pest management aids (cultural controls & others):

- Sanitation (despiking and removal of infested spikes)
  When thrips have been detected, all infested flowers and plants are removed, placed into trash bags and destroyed.
  Efficacy: fair
  -Advantages: helps to keep thrips populations low
  -Disadvantages: low thrips level may not manifest in much visual damage; growers reluctant to destroy flower spikes and plants that generate income; high labor requirement

Potential pest management tools and unregistered/new chemistries:

- Entomopathogenic fungi. *Paecilomyces fumosoroseus* and other entomopathogenic fungi are potential tools to manage thrips, in addition to the newly-licensed biopesticides which contain *Beauveria bassiana*.

Critical Needs for Management of Thrips

- Research
  - Pirate bugs (*Orius* spp.) as a possible biological control method for control of thrips
  - Entomopathogenic fungi (such as *Beauvaria bassiana* and *Paecilomyces fumosoroseus*) as a possible biological control method for control of thrips
  - Effects of watering regimes on thrips management
  - Efficacy of newer products registered for thrips management
  - Continued development of an IPM program in potted orchids

- Regulatory
  - Expedite the approval of the importation of *Beauvaria bassiana* for use on orchids. *Update*: The Hawai'i Board of Agriculture approved *Beauvaria bassiana* for use in Hawai'i in May, 2011.

- Education
  - Continue to educate growers on identification of thrips species
  - Educate growers about water pH and its effect on pesticide efficacy
  - Continue to educate growers on effective IPM practices
  - Communicate with growers about the availability of information on the Hawai'i IPM web site
  - Educate growers about pesticide resisstance and chemical rotation

Mealybugs: longtailed mealybug (*Pseudococcus longispinus*), obscure mealybug (*P. affinis*), dendrobium mealybug (*P. dendrobiorum*), Jack Beardsley mealybug (*P. jackbeardsleyi*) and banana mealybug (*P. elisae*)

Severity of crop damage	
Controlled:	≤5%
Uncontrolled:	100%
Region(s) where pest is a problem:	all islands
Affects dendrobiums or oncidums or both	both
Crop stage(s) affected:	all stages
Crop stages at which controls are applied:	all stages
Economic thresholds	
Local market:	zero tolerance; damaged plants are destroyed
Export:	zero tolerance

Mealybugs have piercing-sucking mouthparts, feed on sap, and secrete honeydew. Feeding on dendrobiums results in deformed flower spikes. Mealybugs are also found on roots and are a major cause of quarantine rejections of potted orchids intended for export.

Adult mealybugs can either lay eggs or give birth to live young, referred to as crawlers. If eggs are laid, they usually hatch in less than 24 hours. Crawlers are highly mobile and are the dispersal stage of this pest. Once the crawlers find a suitable site, they settle down and begin to feed. The entire life cycle ranges from 2 to 4 months and adults live from 27 to 57 days, depending on the species.

Mealybugs are difficult to control because they are protected by white, waxy secretions and aggregate in cryptic habitats such as leaf axials and roots. Early detection is the key to successful mealybug management.

Chemical controls:

For foliar mealybugs, insecticides are applied weekly until the mealybugs are brought under control. Thorough spray coverage is essential to bring this pest under control. Insecticide drenches are somewhat effective for root-infesting mealybugs; prevention is strongly preferred

- Imidacloprid (Mantra, Mallet, Marathon, Majesty, Lada, Benefit, Imigold, Malice, Widow)
  Imidacloprid may be applied by either drench or foliar methods.
  - Efficacy: good (drench application); fair (foliar application)
  -Advantages: controls other sucking insects; if applied as a drench, not much impact on beneficial insects (which do not feed on the plant).
  -Disadvantages: very expensive; foliar application harsh on beneficials; foliar application is incompatible with IPM programs; resistance-management issues

- Bifenthrin (Talstar, Wisdom, Onyxpro, Bisect, Menace, Up-Star, Attain, Bifen)
  - Efficacy: good
  -Advantages: not expensive; single or few applications required (fewer than required for less-effective chemicals; more applications of less effective alternatives hasten resistance development to those chemicals)
  -Disadvantages: resistance-management issues; harsh on beneficials; chemical of last resort in an IPM programs; persists in water; Restricted-Use Pesticide; some products are for greenhouse use only

- Cyfluthrin (Decathlon)
  - Efficacy: good
  -Advantages: inexpensive
  -Disadvantages: incompatible with IPM programs; resistance-management issues; toxic to fish

- Malathion
  - Efficacy: poor – good
  -Advantages: inexpensive
  -Disadvantages: incompatible with IPM programs; resistance-management issues; bad smell and other worker issues; negative impacts to non-target organisms; water contamination issues

- Chlorpyrifos (Dursban, Vulcan, DuraGuard)
  - Efficacy: good
  -Advantages: inexpensive; is also effective against thrips, black twig borer and orchid weevils

-Disadvantages: incompatible with IPM programs (persistence issues); water quality issues, Restricted-Use Pesticide

- Dimethoate
  - Efficacy: fair
  - Advantages: inexpensive
  - Disadvantages: resistance issues; bad smell is an issue for workers; incompatible with IPM programs (broad spectrum)

- Dinotefuran (Safari)
  - Efficacy: good
  - Advantages: compatible with IPM programs; no resistance issues yet
  - Disadvantages: very expensive

- Buprofezin (Talus)
  - Efficacy: good
  - Advantages: compatible with IPM programs; no resistance issues yet
  - Disadvantages: very expensive

- Imidacloprid + Cyfluthrin (Discus)
  - Efficacy: good
  - Advantages: no resistance issues yet
  - Disadvantages: incompatible with IPM programs; harsh on beneficials; toxic to fish; expensive

- Acetamiprid (Tristar)
  - Efficacy: good
  - Advantages: compatible with IPM programs; no resistance issues yet
  - Disadvantages: expensive

- Spirotetramat (Kontos)
  - Efficacy: good
  - Advantages: no resistance issues yet; compatible with IPM programs (minimal risk to natural predators)
  - Disadvantages: expensive

- Horticultural oils (Biocover, Glacial Spray, Purespray, Sunspray, Suffoil-X)
  - Efficacy: fair
  - Advantages: expensive; no resistance issues
  - Disadvantages: incompatible with IPM programs; cannot be applied when temperature is too high because of issues with phytotoxicity

Biological controls:

These are not a sole tactic, but an aid to pest control. These are not available for release.

- Parasites
  There are some naturally occurring parasites. If insecticides are not used, parasites may be present, especially if mealybug populations are high.

- Predatory midges
  There is a naturally occurring predatory midge. If insecticides are not used, predatory midges may be present, especially if mealybug populations are high.

Other pest management aids (cultural controls & others):
The following practices used to prevent the spread and establishment of mealybugs.

- Inspect roots
  All orchid plants are removed from the pot and the roots are inspected for the presence of mealybugs. This is a method for early detection.
  -Efficacy: good
  -Advantages: good IPM practice; prevents build-up of pest
  -Disadvantages: time-consuming

- Avoid root-bound plants
  Plants are re-potted as needed because root-bound plants encourage mealybugs.
  -Efficacy: good
  -Advantages: good cultural practice
  -Disadvantages: because markets and transportation costs dictate pot size, growers are limited to smaller pot sizes

- Sanitation
  Infested plants are removed from the farm and destroyed.
  - Efficacy: good
  -Advantages: compatible with IPM programs
  -Disadvantages: loss of plants (economic losses); labor costs

- Use clean pots and media for re-potting.
  Clean pots and media are used for re-potting.
  - Efficacy: Good
  -Advantages: good cultural practice; growers generally don't reuse pots or media; prevent introduction of pests
  -Disadvantages: perceived higher cost: pots and media must either be new or treated

- Removal of alternate hosts--especially weeds--and creation of buffer zones.
  Alternative hosts are removed from the premises or treated for mealybug infestations.
  -Efficacy: good. However, a grower only has control of his or her own property. If neighbors do not remove alternate hosts, success of this tactic will be limited.
  -Advantages: compatible with IPM programs
  -Disadvantages: loss of productive area; labor costs (one time)

- Ant control
  Ants "farm" mealybugs and other insect pests. Management of ants may reduce mealybug populations.
  -Efficacy: good
  -Advantages: prevents spread of several insect pests in addition to mealybugs
  -Disadvantages: Ants can be difficult to control; added control costs

- Isolation
  To prevent movement of mealybugs to uninfested plants, infested plants can be isolated in a quarantine area within the shadehouse
  - Efficacy: good.
  -Advantages: compatible with IPM programs
  -Disadvantages: growers need to have extra space to implement this practice; labor costs; the cost of materials to construct the containment area

Potential pest management tools and unregistered/new chemistries:

- none

Critical Needs for Management of Mealybugs

- Research
  - Research on efficacy of pesticides on individual mealybug species

- Regulatory
  - None

- Education
  - Continue to educate growers on identification of mealybug species and the most effective control options

Mites: False spider mites (red and black flat mite [*Brevipalpus phoenicis*]) and Pacific flat mite [*B. pacificus*]

Severity of crop damage
  Controlled: ≤5%
  Uncontrolled: 100%
Region(s) where pest is a problem: all islands
Affects dendrobiums or oncidums or both: both
Crop stage(s) affected: all stages
Crop stages at which controls are applied: all stages
Economic thresholds
  Local market: controls applied whenever mites are detected
  Export: zero tolerance for exports

False spider mites are a major pest of dendrobiums. Plant injury is characterized by stippling, a silver-like or bleached appearance resulting from mites sucking on plant sap and chlorophyll with their needle-like mouthparts. As the injured plant tissue oxidizes, the mite injury turns brown and black. False spider mites can be found on upper and lower leaf surfaces, stems, petioles, and flowers.

The development time from egg to adult is about 29 days. The eggs are oval, bright red, and usually found on both leaf surfaces. Each female lays about 50 eggs in her lifespan of 34 days. False spider mites have a wide host range and also feed on other orchids.

Early detection of the false spider mite is critical for effective control.

Chemical controls:

If used, 2 to 3 applications of a miticide are applied at 2-week intervals. Sprays should be directed to the underside of leaves and flowers. Growers should alternate applications of miticides effective against eggs, nymphs and adults.

- Chlorfenapyr (Pylon)
  -Efficacy: excellent (against nymphs and adults)
  -Advantages: compatible with IPM programs; also effective against thrips
  -Disadvantages: very expensive; only registered for use in "true" greenhouses

- Spinosad (Conserve, Entrust, Seduce)
  -Efficacy: poor
  -Advantages: less expensive than some other products; no known environmental issues
  -Disadvantages: incompatible with IPM programs; high levels of resistance

- Abamectin (Avid, Ardent, Lucid, Timectin, Abba)
  -Efficacy: good (against nymphs and adults)
  -Advantages: generic products are less expensive; also effective against thrips
  -Disadvantages: resistance-management issues; bad smell is an issue for workers; slow-acting; needs research on applicability for an IPM program

- Malathion
  -Efficacy: fair
  -Advantages: inexpensive
  -Disadvantages: incompatible with IPM programs because of resistance-management issues; bad smell and other worker issues; negative impacts to non-target organisms; water-contamination issues

- Dimethoate
  -Efficacy: fair
  -Advantages: broad spectrum; inexpensive
  -Disadvantages: resistance issues; bad smell is an issue for workers; possible phytotoxicity during hot summer periods; incompatible with IPM programs (broad spectrum)

- Spirotetramat (Kontos)
  Spirotetramat is labeled for use against spider mites.
  -Efficacy: unknown (new product)

-Advantages: compatible with IPM programs; no resistance issues yet
-Disadvantages: expensive

- Etoxazole (Tetrasan, Beethoven)
  -Efficacy: good (against eggs and nymphs, translaminar); effective against Pacific flat mite when followed with application of spiromesifin
  -Advantages: inexpensive; compatible with IPM programs; no resistance issues yet; may be tank mixed with pyridaben for contact control of adults; tank mix may be used in rotation with spiromesifen
  -Disadvantages: none identified; Beethoven for greenhouse use

- Fenpyroximate (Akari)
  Fenproximate can be effective against nymphs and adults.
  -Efficacy: unknown (not used much, needs research)
  -Advantages: for greenhouse and outdoor use
  -Disadvantages: expensive

- Bifenazate (Floramite)
  Bifenazate can be effective against adults.
  -Efficacy: unknown (not used much, needs research, but some growers report low efficacy)
  -Advantages: none identified
  -Disadvantages: none identified

- Hexythiazox (Hexygon)
  -Efficacy: good (against eggs)
  -Advantages: compatible with IPM programs; no resistance issues yet
  -Disadvantages: expensive; limited to one use per crop cycle or year; only effective against eggs

- Spiromesifen (Judo)
  -Efficacy: fair; effective against Pacific flat mite when used following application of etoxazole
  -Advantages: compatible with IPM programs; may be used in rotation with etoxazole-pyridaben tank mix
  -Disadvantages: expensive; resistance-management issues; phytotoxic to some plants

- Clofentezine (Ovation)
  -Efficacy: good (against eggs)
  -Advantages: compatible with IPM programs; no resistance issues yet
  -Disadvantages: expensive; limited to one use per crop cycle or year; only effective against eggs

- Pyridaben (Sanmite)
  -Efficacy: very good for contact control of adults

-Advantages: may be tank mixed with etoxazole for translaminar contact control of eggs and nymphs; etoxazole tank mix may be used in rotation with spiromesifen
-Disadvantages: none identified

- Fenbutatin-oxide (Promite, Meraz)
  -Efficacy: good
  -Advantages: inexpensive
  - Disadvantages: Restricted-Use Pesticide

- Acequinocyl (Shuttle)
  -Efficacy: excellent
  -Advantages: compatible with IPM programs; no resistance issues yet; effective against all mite stages
  -Disadvantages: moderately expensive

Biological controls:
- Predatory mites, which are generally killed by miticides.
- Other predators

Other pest management aids (cultural controls & others):
- Avoid broad spectrum insecticides
  Good IPM practices encourage beneficial organisms by avoiding use of broad spectrum insecticides. This technique may be an aid to managing mites.
  -Efficacy: probably good
  -Advantages: encourages beneficials
  -Disadvantages: Most growers use broad spectrum insecticides

- Overhead irrigation
  Water is a deterrent because mites favor hot and dry conditions.
  -Efficacy: fair
  -Advantages: keeps population lowered
  -Disadvantages: too much overhead irrigation favors diseases

Potential pest management tools and unregistered/new chemistries:
- none

Critical Needs for Management of Mites

- Research
  - Research on the effectiveness of naturally occurring predator mites
  - Research on possible mite-vectored viruses
  - Research on watering or irrigation as an effective tool for mite management
  - Evaluation of pesticides option and their efficacy on the different mite species

- Regulatory
  - None

- Education
  - Continued education on resistance management practices
  - Continue to provide research results to growers

Blossom midge (*Contarinia maculipennis*)

Severity of crop damage
Controlled: <5%
Uncontrolled: >80%
Region(s) where pest is a problem: Wai'anae (O'ahu) and other drier areas of all islands
Affects dendrobiums or oncidums or both: dendrobiums
Crop stage(s) affected: attacks flower buds
Crop stages at which controls are applied: mature plants, at flowering
Economic thresholds
Local market: destroys marketability (zero tolerance); plants are unsalable if flowers are damaged
Export: quarantine pest (zero tolerance)

Except for the adult, all stages of the blossom midge are secluded within the bud (as larvae) or in the soil (as pupae). The eggs are deposited in masses by the adult female into the open tips of flower buds. The larval stage of the blossom midge feeds inside unopened flower buds, causing deformity and aborted bud development. Severely infested dendrobium buds rot and/or drop off the plant. As many as 30 maggots may be found infesting a single dendrobium bud. Maggots crawl and feed in the bud, bathed in fluids from the damaged tissue. Maggots are able to leave the buds by "jumping" and burrowing into soil to pupate. Pupation is most successful in soil that is moist but not wet. Late stage pupae are active; 14–21 days after entering the soil, they burrow up to the soil surface in preparation for adult emergence. Adults normally emerge from pupae in the early evening hours. Adult blossom midges are very tiny and somewhat mosquito-like in appearance. The life cycle from egg to adult is approximately 21-28 days, with 14 days spent in the soil. The adult survives for only four days.

To ensure an optimal food source and moist environment, the adult midge avoids late-stage buds and prefers to lay eggs in young buds whose growth to maturity will approximately parallel that of the larvae. If growing conditions become unsuitable for larval development (for example, if the flower or bud on which maggots are feeding begins to dry), immature maggots may leave the flowers or buds to pupate in the soil. However, their pupation may take a few weeks longer, and these adult midges are typically smaller than adults from fully mature maggots.

The blossom midge has an unusually wide host range spanning at least six plant families including orchids (Orchidaceae), hibiscus (Malvaceae), tomato, eggplant, pepper, potato, Paraguay nightshade (*Solanum rantonnetii*) (Solanaceae), pak-choi (white mustard cabbage) (Brassicaceae), bitter melon (*Momordica charantia*) (Cucurbitaceae), and pikake (Oleaceae). Blossom midge can also be found on ornamentals like plumeria, pikake, tuberose as well as a number of weed species.

The blossom midge reproduces year-round in Hawaiʻi and can be found on all of the major Hawaiian Islands.

Chemical controls:

Contact foliar insecticides are only effective against the adult blossom midge because all other stages of the blossom midge are secluded either within buds or in the soil, only the adult blossom midge is vulnerable to contact foliar insecticides. Insecticides should also be applied as a soil drench to target the pupal stage of the blossom midge. Systemic insecticides are not effective because they are not translocated to orchid buds to affect the maggots.

- Abamectin (Avid, Ardent, Lucid, Timectin, Abba)
  -Efficacy: good
  -Advantages: generic products are less expensive; no known environmental issues; also effective against mites; translaminar and may penetrate buds to affect the maggots
  -Disadvantages: resistance-management issues; needs research on applicability for an IPM program; bad smell is an issue for workers; slow-acting

- Chlorpyrifos (Dursban, Vulcan, DuraGuard)
  -Efficacy: good against adults
  -Advantages: inexpensive; in addition to foliar spray, can be applied as a soil treatment to target pupae; is also effective against mealybugs
  -Disadvantages: incompatible with IPM programs (persistence issues); water quality issues, Restricted-Use Pesticide

- Spinosad (Conserve, Entrust, Seduce)
  -Efficacy: fair
  -Advantages: less expensive than some other products; no known environmental issues
  -Disadvantages: some resistance in certain locations/regions where spinosad products were used regularly and farms are very close to each other.

- Malathion
  -Efficacy: not reported
  -Advantages: inexpensive; in addition to foliar spray, can be applied as a soil treatment to target pupae
  -Disadvantages: incompatible with IPM programs; resistance-management issues; negative impacts to non-target organisms; bad smell and other worker issues; water contamination issues

- Cyfluthrin (Decathlon)
  -Efficacy: not reported
  -Advantages: inexpensive; also effective against some thrips; in addition to foliar spray, can be applied as a soil treatment to target pupae
  -Disadvantages: incompatible with IPM programs; resistance-management issues; toxic to fish

- Dimethoate
  -Efficacy: good against adults
  -Advantages: inexpensive
  -Disadvantages: systemic, but is probably not translocated to the flower buds to affect the maggots; applications repeated at 7-10 day intervals; incompatible with IPM programs (broad spectrum); resistance issues; bad smell is an issue for workers

- Acephate (Orthene)
  -Efficacy: Fair, overall; good against adults
  -Advantages: systemic; has some effectiveness against immature stages
  -Disadvantages: can burn sensitive buds

- Dinotefuran (Safari)
  -Efficacy: not reported
  -Advantages: compatible with IPM programs; no resistance issues yet
  -Disadvantages: very expensive

Biological controls:
No parasitoids have been specifically introduced by HDOA to control the blossom midge.

- General predators
  Adult blossom midges are vulnerable to general predators, such as web-spinning spiders.

Other pest management aids (cultural controls & others):

- Removal of infested buds
  Except for the adult stage, all stages of the blossom midge are secluded either within buds or in the soil. Removing and destroying infested buds is the most important management practice for the blossom midge. All infested buds must be removed and placed in trash bags or sealed containers to prevent the maggots from escaping.
  -Efficacy: not reported
  -Advantages: increases efficacy of insecticides when they are applied following bud removal and disposal
  -Disadvantages: time-consuming; labor-intensive

Potential pest management tools and unregistered/new chemistries:

- None

Critical Needs for Management of Blossom Midge

- Research
  – Determine efficacy of insecticides
  – Quantify effectiveness of various chemistries

- Regulatory
  – None identified

- Education
  - None identified

Other Invertebrate Pests

The following invertebrate pests can be important pests of potted orchids in Hawai‘i. Developing better control tactics for some of these pests are priorities for the potted orchid stakeholders. However, these pests were not discussed in detail at the workshop. Therefore, there no critical needs specified for these pests.

Shore flies and Fungus gnats

Severity of crop damage Controlled: 5-15% Uncontrolled: 85-100% Region(s) where pest is a problem: warm areas that support algal growth Affects dendrobiums or oncidums or both: both Crop stage(s) affected: seedlings Crop stages at which controls are applied: all Economic thresholds Local market: none identified Export: none identified

Shore flies and fungus gnats can be a problem for potted orchid growers. These pests feed on algae and are extremely effective at moving pathogens like *Fusarium* from pot to pot.

Chemical controls:

- None

Biological controls:

- None

Other pest management aids (cultural controls & others):

- Control amount of water available.
  This pest problem can be solved by reducing the amount of free water available.
  -Efficacy: excellent
  -Advantages: none identified
  -Disadvantages: none identified

Potential pest management tools and unregistered/new chemistries:

- None

Critical Needs for Management of Shore flies and Fungus gnats

- None identified

Ants: Little fire ant (*Wasmannia auropunctata*) and other ants [longlegged ant (*Anoplolepsis gracilipes*), bigheaded ant (*Pheidole megacephala*), tiny yellow house ant (*Tapinoma melanocephalum*) and whitefooted ant (*Technomyrmex albipes*)]

Severity of crop damage
Controlled: damage is not directly from ants
Uncontrolled: damage is not directly from ants
Region(s) where pest is a problem: all growing areas; Hawai'i Island and Kaua'i only for LFA
Affects dendrobiums or oncidiums or both: both
Crop stage(s) affected: all
Crop stages at which controls are applied: all
Economic thresholds
Local market: zero tolerance
Export: quarantine issue (zero tolerance)

Ants are quarantine pests. The presence of one worker ant results in shipment rejection. Ants also create or exacerbate various problems for orchid production. Ants support populations of other pests which directly affect the production or the quality of the plants. Aphids and scales secrete honeydew, which, in addition to providing a medium for sooty mold, serves as food for ants. Ants will drive off or kill aphid parasitoids, and this defense results in larger aphid populations. Controlling ants that tend aphids and scales will reduce the populations of these insects.

The little fire ant (LFA) was first reported in Hawai‘i in 1999, and it has since invaded a variety of agricultural sites, including nurseries, orchards, and pastures. LFA is currently known to be present on the eastern side of the Big Island and on two adjacent private properties on Kaua‘i. In December 2013, HDOA confirmed that LFA has spread to O‘ahu and Maui. LFA are pests to agricultural workers. They are small (1/16 inch), slow moving, orange-red ants that have a burning sting that may raise bumps that last for several weeks. Like other ants, LFA also nurture populations of Homoptera, e.g., scales, aphids, mealybugs, etc. LFA are known to have negative impacts on many animals, including vertebrates (pets and livestock) and invertebrates. In areas of high infestation, LFA sting the eyes of pet cats and other animals, resulting in blindness.

Chemical controls:

Bigheaded ant and LFA are effectively controlled with commercially available red imported fire ant bait insecticides (such as bifenthrin, hydramethylnon, s-methoprene, pyriproxyfen, metaflumizone and abamectin, see Appendix 2).

White-footed ants are very difficult to control. Foraging workers of other ant species return to the nest and regurgitate food they have eaten to feed the brood and non-foraging nestmates. However, white-footed ant workers do not regurgitate food or bait toxicants, nor do they share it with the other ants in the colony. (Instead, the workers digest the food and produce a sterile egg, which does not contain the pesticides, to feed the brood and nestmates.)

Pyrethroids such as bifenthrin, cyfluthrin, lambda cyhalothrin, deltamethrin, permethrin and fenpropathrin can be effective as a barrier treatment to prevent worker ants from foraging on plants nurturing honeydew-producing insects. (See Appendix 2.)

- Bifenthrin (Talstar, Wisdom, Onyxpro, Bisect, Menace, Up-Star, Attain, Bifen)
  Pyrethroids such as bifenthrin can be effective as a barrier treatment to prevent worker ants from foraging on plants nurturing honeydew-producing insects. Some products are labeled for imported fire ant quarantine treatment.
  -Efficacy: not reported
  -Advantages: not expensive; single or few (fewer applications of less effective chemicals) required (more applications of less effective alternatives hasten resistance development to those chemicals); can be used against bigheaded ant and LFA (labeled for imported fire ants)
  -Disadvantages: resistance-management issues; harsh on beneficials; chemical of last resort in an IPM programs; persists in water; some products are Restricted-Use Pesticides (RUP); some products are for greenhouse use only

- Fipronil (Taurus G)
  Taurus G is labeled for imported fire ant quarantine treatment.
  -Efficacy: good (highly effective)
  -Advantages: can be used against bigheaded ant and LFA (labeled for imported fire ants)
  -Disadvantages: slow-acting; Restricted-Use Pesticide (RUP)

- Orthoboric acid (Niban).
  Sugary liquid bait insecticides with boric acid have shown to be effectively kill white-footed ant workers. Then, deprived of their source of food, the brood and nestmates die of starvation.
  -Efficacy: good (for sugar-feeding ants)
  -Advantages: can kill network of nests; relatively safe to use
  -Disadvantages: requires repeated applications over a long period of time; specific for sugar-feeding ants.

Biological controls:
- None

Other pest management aids (cultural controls & others):
- None

Potential pest management tools and unregistered/new chemistries:
- None

Critical Needs for Management of Ants

- None identified

Scales: armored scales [boisduval scale (*Diaspis biosduvalii*), Florida red scale (*Chrysomphalus aonidum*), proteus scale (*Parlatoia proteus*)], and soft scales [brown soft scale (*Coccus hesperidum*), stellate scale (*Vinsonia stellifera*) and hemispherical scale (*Saissetia coffeae*)]

Severity of crop damage
Controlled: ≤10%
Uncontrolled: ≥80%
Region(s) where pest is a problem: all islands
Affects dendrobiums or oncidums or both: both
Crop stage(s) affected: young to mature plants
Crop stages at which controls are applied: young to mature plants
Economic thresholds
Local market: unmarketable if present on plants
Export: zero tolerance

Both armored scales and soft scales infest orchids. The armored scale makes a separate protective covering (armor) under which the insect lives, feeds, and lays eggs. The armored covering is nonliving and composed of secreted waxes that cement cast skins together to form the covering. Armored scales feed on plant juices and cause loss of vigor, deformation of infested plant parts, yellowish spots on leaves, loss of leaves, and even death of the plant. Most species of armored scale have similar life histories. The female deposits from 30 to 150 eggs under the armor. These hatch in 1–2 weeks. The hatched crawler is very mobile and moves about in search of an ideal place to feed. The crawler inserts its needle-like mouthpart into the plant and remains there as it develops into an adult. The adult stage is reached in 5–7 weeks.

The soft scale does not have a separate armor, and its body is exposed. Soft scales retain their legs and antennae throughout adult life. Young females are primarily sedentary but may move about for a brief time after feeding begins. Their life cycle is very similar to armored scales. However, soft scales excrete honeydew and are tended by ants which feed on the honeydew. This feeding can cause an increase in the populations of ants, which then farm the scales with more intensity. The resulting abundance of honeydew cannot all be consumed by the ants, and sooty mold develops on the excess honeydew. Sooty mold reduces photosynthesis.

Early detection of incipient infestations is a key to successful scale insect control because established scale insect infestations are very difficult to manage and plants are usually removed and disposed of at this point.

Chemical controls:

Scale insects are very difficult to control with insecticides, especially if the infestation is severe. Only the crawler stage of the armored scale is susceptible to contact insecticides, while the other stages are protected because of the armor covering. Soft scales are easier to control. Pruning and adequate plant spacing are important cultural practices that will allow maximum coverage when using contact insecticides. Systemic insecticides that are taken up by the roots and translocated to leaves may be effective against the nymph and adult stages of armored scales. However, systemic activity of insecticides varies among plants, and translocation of systemic insecticides in dendrobium orchids has not been demonstrated.

Horticultural oils have been shown to be effective against exposed eggs and crawlers of the armored scale and various stages of the soft scales

- Horticultural oils (Biocover, Glacial Spray, Purespray, Sunspray, Suffoil-X)
  -Efficacy: good (when spray is targeted properly); poor to fair (otherwise)
  -Advantages: inexpensive; no resistance issues
  -Disadvantages: incompatible with IPM programs; cannot be applied when temperature is too high because of issues with phytotoxicity; difficult to target spray effectively when foliage is dense

- Pyriproxyfen (Distance)
  -Efficacy: fair to good
  -Advantages: compatible with IPM programs
  -Disadvantages: none identified

- Buprofezin (Talus)
  -Efficacy: fair to good
  -Advantages: compatible with IPM programs; no resistance issues yet
  -Disadvantages: very expensive

- Dinotefuran (Safari)
  -Efficacy: fair to good
  -Advantages: systemic; compatible with IPM programs; no resistance issues yet
  -Disadvantages: very expensive

- Carbaryl (Sevin)
  -Efficacy: not reported
  -Advantages: none identified
  -Disadvantages: contact (only for crawler of armored scales)

- Imidacloprid + Cyfluthrin (Discus)
  -Efficacy: fair to good
  -Advantages: no resistance issues yet
  -Disadvantages: incompatible with IPM programs; harsh on beneficials; toxic to fish; expensive

- Fluvalinate (Mavrik)
  -Efficacy: not reported
  -Advantages: inexpensive
  -Disadvantages: incompatible with IPM programs (broad spectrum); resistance issues bad smell is an issue for workers

- Imidacloprid (Marathon, Imida E Pro, Mantra, Mallet, Majesty, Areca, Lada, Benefit, Imigold, Malice, Widow)
  -Efficacy: fair
  -Advantages: controls other sucking insects

-Disadvantages: very expensive; incompatible with IPM programs: harsh on beneficials; resistance-management issues

Biological controls:

Ladybird beetles and parasitic wasps have been introduced and have become established in Hawai‘i to control armored scales. Scale covers that look chewed and have no insect underneath are indications that predators have been feeding on the scales. In the landscape, these natural enemies can keep some scales insects, such as the hemispherical scale, under control. In nursery production, parasitic wasps are usually not established and chemical controls are required.

- Ladybird beetles

  Ladybird beetles are not available for release, but are naturally occurring. If insecticides are not used, ladybird beetles (and other natural enemies) will control scales.

- Parasitic wasps

  Wasps which parasitize scales are not available for release, but are naturally occurring. A tiny circular hole on the covering indicates that a parasitic wasp developed and emerged from the scale insect. If insecticides are not used, parasitic wasps (and other natural enemies) will control scales. However, in nursery production, parasitic wasps are usually not established and chemical controls are required.

- Fungi

  In Hawai‘i, fungi are not available as pesticides for use against scales, but they do occur naturally. If pesticides are not applied, entomopathic fungi (and other natural enemies) will control scales.

Other pest management aids (cultural controls & others):

- Destruction of infested plants

  The best control method is to destroy all severely infested plants and plant parts.
  -Efficacy: good
  -Advantages: helps efficacy of insecticides
  -Disadvantages: crop loss; labor intensive

- Scale-free propagation material

  Armored scales are spread chiefly through movement of nursery stock. Dendrobium orchids are entirely propagated using sterile tissue culture techniques, only this propagation material, which is free of scales should be planted. Oncidiums can be tissue-cultured, but are propagated by divisions, which are visually inspected for cleanliness.
  -Efficacy: good
  -Advantages: no infestation to start with
  -Disadvantages: None

- Pruning and plant spacing

  Pruning and adequate plant spacing are important cultural practices that will allow maximum coverage when using contact insecticides.
  -Efficacy: good

-Advantages: maximizes efficacy of pesticides; reduces infestation
-Disadvantages: labor intensive

- Elimination of ants
  Eliminating ants foraging for honeydew will lower scale populations.
  -Efficacy: good
  -Advantages: scales' protection is eliminated; scales cannot be spread without ants
  -Disadvantages: Eradication of ants is very difficult to achieve.

Potential pest management tools and unregistered/new chemistries:
- None

Critical Needs for Management of Scales

- None identified

Whiteflies: silverleaf whitefly (*Bemisia argentifolia*) and spiraling whitefly (*Aleurodicus disperses*)

Severity of crop damage
Controlled: <u><5%</u>
Uncontrolled: <u>>60%</u>
Region(s) where pest is a problem: <u>all islands</u>
Affects dendrobiums or oncidums or both: <u>both</u>
Crop stage(s) affected: <u>young and mature plants</u>
Crop stages at which controls are applied: <u>young and mature plants</u>
Economic thresholds
Local market: <u>unsalable if infested</u>
Export: <u>quarantine issue zero tolerance</u>

Silverleaf and spiraling whiteflies have been found infesting orchid flowers, causing aesthetic and quarantine problems. They cause damage directly by removing plant sap during feeding and indirectly when they excrete honeydew that becomes a medium for the growth of sooty mold fungus.

Whiteflies progress from egg to crawler (the first nymphal stage) through two nymphal stages to pupa and adult. Only the crawler and the winged adult stages are mobile. The entire life cycle from egg to adult may range from 15 to 70 days, depending on temperature and the plant host.

Chemical controls:
The efficacy of all the chemical controls is affected to a great degree by the population of insects and how much resistance has been developed to the particular insecticide.

- Imidacloprid (Marathon, Imida E Pro, Mantra, Mallet, Majesty, Areca, Lada, Benefit, Imigold, Malice, Widow)
  -Efficacy: not reported

-Advantages: controls other sucking insects
-Disadvantages: very expensive; harsh on beneficials; foliar application is incompatible with IPM programs; resistance-management issues

- Buprofezin (Talus)
  -Efficacy: not reported
  -Advantages: compatible with IPM programs; no resistance issues yet
  -Disadvantages: very expensive

- Imidacloprid + Cyfluthrin (Discus)
  - Efficacy: not reported
  -Advantages: no resistance issues yet
  -Disadvantages: incompatible with IPM programs; harsh on beneficials; toxic to fish; expensive

- Pyriproxyfen (Distance)
  -Efficacy: not reported
  -Advantages: compatible with IPM programs
  -Disadvantages: none identified

- Dinotefuran (Safari)
  -Efficacy: not reported
  -Advantages: systemic; compatible with IPM programs; no resistance issues yet
  -Disadvantages: very expensive

- Horticultural oils (Biocover, Glacial Spray, Purespray, Sunspray, Suffoil-X)
  -Efficacy: not reported
  -Advantages: inexpensive; no resistance issues
  -Disadvantages: incompatible with IPM programs; cannot be applied when temperature is too high because of issues with phytotoxicity

- Potassium salts of fatty acids (M-Pede, Dex-X, insecticidal soap)
  Description of how it is used
  -Efficacy: not reported
  -Advantages: can be used in resistance management rotation
  -Disadvantages: may be phytotoxic to dendrobiums

- Bifenthrin (Talstar, Wisdom, Onyxpro, Bisect, Menace, Up-Star, Attain)
  -Efficacy: not reported
  -Advantages: not expensive
  -Disadvantages: resistance-management issues; harsh on beneficials; incompatible with IPM programs; persists in water; Restricted-Use Pesticide

- Cyfluthrin (Decathlon)
  -Efficacy: not reported
  -Advantages: inexpensive

-Disadvantages: incompatible with IPM programs; resistance-management issues; toxic to fish

- Chlorpyrifos (Dursban, Vulcan, DuraGuard)
  -Efficacy: not reported
  -Advantages: inexpensive; is also effective against mealybugs
  -Disadvantages: incompatible with IPM programs (persistence issues); water quality issues, Restricted-Use Pesticide

- Dimethoate
  -Efficacy: not reported
  -Advantages: inexpensive
  -Disadvantages: incompatible with IPM programs (broad spectrum); resistance issues bad smell is an issue for workers

- Malathion
  -Efficacy: not reported
  -Advantages: inexpensive
  -Disadvantages: incompatible with IPM programs resistance-management issues; negative impacts to non-target organisms; water contamination issues; bad smell and other worker issues

- Acetamiprid (Tristar)
  -Efficacy: not reported
  -Advantages: compatible with IPM programs; no resistance issues yet
  -Disadvantages: expensive

Biological control:

- Parasitic wasps

  Wasps which parasitize whitefly pupae are not available for release, but are naturally occurring. If insecticides are not used, parasitic wasps may be an aid to control whiteflies.

Other pest management aids (cultural controls & others):

- Removal of weed hosts.

  Some weeds may serve as alternate hosts of whiteflies. The weeds should not be removed, however, if numerous pupae which have been parasitized are observed; fungal disease of whiteflies may be present.

Potential pest management tools and unregistered/new chemistries:

- None

Critical Needs for Management of Whiteflies

- None identified.

Aphids: cotton aphid (*Aphis gossypii*), fringed orchid aphid (*Cerataphis orchidearum*), green peach aphid (*Myzus persicae*), and orchid aphid (*Macrosiphum luteum*)

Severity of crop damage
Controlled: <5%
Uncontrolled: >40%
Region(s) where pest is a problem: all islands
Affects dendrobiums or oncidums or both: both
Crop stage(s) affected: flower buds and spikes
Crop stages at which controls are applied: at flowering
Economic thresholds
Local market: unsalable if infested
Export: zero tolerance

Aphids colonize dendrobium leaves and flowers. They have sucking mouthparts and feed on plant juices causing reduced plant vigor, stunting, leaf and flower deformities, and bud drop.

Aphids excrete a sugary substance known as honeydew, which is a perfect medium for the growth of sooty mold. In severe aphid infestations, flowers and leaves often become covered with black sooty mold. Honeydew also serves as food for ants and results in a symbiotic relationship that is beneficial to both the ants and the aphids. Ants will drive off or kill aphid parasitoids (parasites that kill their aphid host), and this defense results in larger aphid populations.

In Hawaiʻi, all aphids are females that give birth to live young, which allows their population to increase rapidly. No male aphids have been observed in Hawaiʻi due to our mild climate.

Chemical controls:

Because aphids are delicate, soft bodied, and slow moving, insecticidal soaps and ultrafine oils are effective controls. However, soaps and oils may injure flowers and leaves of orchids. If chemical insecticides are applied, at least two weekly applications are needed for effective control.

- Cyfluthrin (Decathlon)
  -Efficacy: good
  -Advantages: inexpensive
  -Disadvantages: incompatible with IPM programs (resistance-management issues); toxic to fish

- Chlorpyrifos (Dursban, Vulcan, DuraGuard)
  -Efficacy: good
  -Advantages: inexpensive; is also effective against thrips
  -Disadvantages: incompatible with IPM programs (persistence issues); water quality issues, Restricted-Use Pesticide

- Potassium salts of fatty acids (M-pede, Des-X, insecticidal soap)
  -Efficacy: good
  -Advantages: can be used in resistance management rotation
  -Disadvantages: may be phytotoxic to dendrobiums

- Imidacloprid (Marathon, Imida E Pro, Mantra, Mallet, Majesty, Areca, Lada, Benefit, Imigold, Malice, Widow)
  -Efficacy: not reported
  -Advantages: controls other sucking insects
  -Disadvantages: very expensive; harsh on beneficials; foliar application is incompatible with IPM programs (resistance-management issues)

- Acetamiprid (Tristar)
  -Efficacy: not reported
  -Advantages: compatible with IPM programs; no resistance issues yet
  -Disadvantages: expensive

- Acephate (Orthene)
  -Efficacy: good
  -Advantages: inexpensive
  -Disadvantages: none identified

- Bifenthrin (Talstar, Wisdom, Onyxpro, Bisect, Menace, Up-Star, Attain, Bifen, Up-Star)
  -Efficacy: good
  -Advantages: not expensive
  -Disadvantages: incompatible with IPM programs (resistance-management issues, harsh on beneficials); persists in water; Restricted-Use Pesticide

- Horticultural oils (Biocover, Glacial Spray, Purespray, Sunspray)
  -Efficacy: not reported
  -Advantages: inexpensive; no resistance issues; Can be used in resistance management rotation
  -Disadvantages: incompatible with IPM programs; cannot be applied when temperature is too high because of issues with phytotoxicity

Biological control:

- Ladybird beetles
  Ladybird beetles are not available for release, but are naturally occurring. If insecticides are not used, ladybird beetles may be an aid to control aphids.

- Lacewings
  Lacewings are not available for release, but are naturally occurring. If insecticides are not used, lacewings may be an aid to control aphids.

- Syrphid flies
  Syrphid flies are not available for release, but are naturally occurring. If insecticides are not used, syrphid flies may be an aid to control aphids.

- Parasitic wasps
  Wasps which parasitize aphids are not available for release, but are naturally occurring. If insecticides are not used, parasitic wasps may be an aid to control aphids.

Other pest management aids (cultural controls & others):

- Sanitation
  Severely-infested plants or plant parts are removed and disposed.
  -Efficacy: not reported
  -Advantages: none identified
  -Disadvantages: none identified

- Ant control
  Controlling ants that tend aphids will reduce aphid populations.
  -Efficacy: good
  -Advantages: none identified
  -Disadvantages: eradication is difficult to achieve

Potential pest management tools and unregistered/new chemistries:

- None

Critical Needs for Management of Aphids

- Research
  - Identification of aphid-transmitted viruses infecting orchids in Hawai‘i

- Regulatory
  - None identified

- Education
  - None identified

Ambrosia Beetle: Black twig borer (*Xylosandrus compactus*)

Severity of crop damage
  Controlled: <5%
  Uncontrolled: >20%
Region(s) where pest is a problem: all islands
Affects dendrobiums or oncidums or both: dendrobiums
Crop stage(s) affected: mature plants
Crop stages at which controls are applied: mature plants
Economic thresholds
  Local market: unsalable if infested
  Export: zero tolerance

The black twig borer bores into the canes of dendrobium and also attacks over 100 other species of plants in 44 families, including *Cattleya*, *Epidendrum*, *Vanda*, anthurium, avocado, citrus, cacao, coffee, hibiscus, lychee, macadamia, pikake, and floral ginger. Small pinholes in the cane indicate the presence of this pest. The area surrounding the pinhole is usually discolored. Additionally, the female beetle cultivates ambrosia fungus (*Fusarium solani*) on which she lays her eggs. The larvae feed entirely on the ambrosia fungus which is pathogenic to plant tissue and causes discoloration and death of the cane. Entire plant death has been reported in severe infestations. Since the longer a plant remains in a nursery, the greater the chances of infestation, it is advisable to cycle out plants for sale as soon as possible. Black twig borers can be minimized through monitoring and short production times.

Chemical controls:

Chemical control is targeted to the adults since eggs, larvae and pupae remain protected in the pseudobulb.

- Imidacloprid + Cyfluthrin (Discus)
  -Efficacy: not reported
  -Advantages: no resistance issues yet
  -Disadvantages: incompatible with IPM programs (harsh on beneficials); expensive; toxic to fish

- Cyfluthrin (Decathlon)
  -Efficacy: not reported
  -Advantages: inexpensive
  -Disadvantages: incompatible with IPM programs (resistance-management issues); toxic to fish

- Chlorpyrifos (Dursban, Vulcan, DuraGuard)
  -Efficacy: good
  -Advantages: inexpensive; is also effective against mealybugs
  -Disadvantages: incompatible with IPM programs (persistence issues); water quality issues, Restricted-Use Pesticide

- Bifenthrin (Talstar, Wisdom, Onyxpro, Bisect, Menace, Up-Star, Attain, Bifen, Up-Star)
  -Efficacy: not reported
  -Advantages: not expensive
  -Disadvantages: incompatible with IPM programs (resistance-management issues, harsh on beneficials); persists in water; Restricted-Use Pesticide

Biological control:
- None identified

Other pest management aids (cultural controls & others):
- Removal of infested plant materials
  Infested plants contain live beetles. All infested plants and plant parts are placed in a trash bag or a sealed container and disposed of.
  -Efficacy: good
  -Advantages: gets rid of bulk of the problem; effectively reduces the population
  -Disadvantages: labor intensive (expensive in terms of labor time and cost); difficult to identify newly infested plants; plant losses (economic loss)

- Maintain plant health
  This beetle is known to attack plants that are suffering from water, nutritional, or other stresses. Maintaining plants in good health minimizes attacks by the black twig borer.
  -Efficacy: good
  -Advantages: doesn't require pesticides, is an aid to prevent other problems from forming.
  -Disadvantages: none identified

Potential pest management tools and unregistered/new chemistries:

- None

Critical Needs for Management of Black Twig Borer

- Research
  - None identified

- Regulatory
  - None identified

- Education
  - None identified

Orchid weevils: orchid weevil (*Orchidophilus aterrimus*), lesser orchid weevil (*O. peregrinator*)

Severity of crop damage
Controlled: <5%
Uncontrolled: >10%
Region(s) where pest is a problem: all islands
Affects dendrobiums or oncidums or both: dendrobiums
Crop stage(s) affected: mature plants
Crop stages at which controls are applied: mature plants
Economic thresholds
Local market: unsalable if infested or damaged
Export: quarantine pest--zero tolerance

Orchid weevil larvae and adults have chewing mouthparts and feed on orchid flowers, stems, leaves, and exposed roots. The adult female chews a hole in the canes or leaf and deposits an egg. After hatching, the larva continues feeding within the cane for about 4 months. The grub then creates a frass and fiber chamber within the cane for pupation. About 2 weeks after pupation, the adult chews a hole about 1/16 inch in diameter and crawls out of the pupation site. Total development time from egg to adult is about 5 months. Adults live for about 9 months to a year.

Orchid weevil infestations s can be minimized through monitoring and short production times. Similar to the situation of black twig borer control, the longer a plant remains in a nursery, the more likely it will become infested with orchid weevils. Therefore, it is advisable to cycle out plants for sale as soon as possible.

Potted plants with feeding damage and other symptoms of orchid weevil infestation should not be marketed

Chemical controls:

Contact insecticides are only effective against the adult stage, and systemic insecticides are not effective against the grub stage. Therefore, insecticide applications must be repeated to effectively control orchid weevils in infested plants. Spray applications must be repeated every 2 to 3 weeks for four applications to effectively control orchid weevils in severely infested plants. Organophosphate and synthetic pyrethroid insecticides are effective against adult orchid weevils. Certain synthetic pyrethroids have a longer residual activity and greater repellency against the orchid weevil for more effective control than organophosphates.

A postharvest pyrethroid dip will help eliminate adults harbored in leaf axils and flowers but will not affect eggs, larvae, or pupae inside stems or leaves.

- Bifenthrin (Talstar, Wisdom, Onyxpro, Bisect, Menace, Up-Star, Attain, Bifen)
  -Efficacy: good
  -Advantages: not expensive
  -Disadvantages: incompatible with IPM programs (resistance-management issues, harsh on beneficials); persists in water; Restricted-Use Pesticide

- Cyfluthrin (Decathlon)
  -Efficacy: not reported
  -Advantages: inexpensive
  -Disadvantages: incompatible with IPM programs; resistance-management issues; toxic to fish

- Acephate (Orthene)
  -Efficacy: good
  -Advantages: none identified
  -Disadvantages: none identified

- Chlorpyrifos (Dursban, Vulcan, DuraGuard)
  -Efficacy: good
  -Advantages: inexpensive; is also effective against thrips
  -Disadvantages: incompatible with IPM programs (persistence issues); water quality issues, Restricted-Use Pesticide

- Imidacloprid + Cyfluthrin (Discus)
  -Efficacy: not reported
  -Advantages: no resistance issues yet
  -Disadvantages: incompatible with IPM programs; expensive; harsh on beneficials; toxic to fish

- Dimethoate
  -Efficacy: not reported

-Advantages: inexpensive
-Disadvantages: incompatible with IPM programs (broad spectrum); resistance issues bad smell is an issue for workers

- Malathion
  -Efficacy: not reported
  -Advantages: inexpensive
  -Disadvantages: incompatible with IPM programs resistance-management issues; negative impacts to non-target organisms; water contamination issues; bad smell and other worker issues

Biological controls:

- None identified

Other pest management aids (cultural controls & others):

- Sanitation
  Infested plants are removed from the farm and destroyed.
  -Efficacy: good
  -Advantages: compatible with IPM programs
  -Disadvantages: loss of plants (economic losses); labor costs

- Maintain plant health
  -Efficacy: fair
  -Advantages: none identified
  -Disadvantages: none identified

Potential pest management tools and unregistered/new chemistries:

- none

Critical Needs for Management of Orchid Weevils

- Research
  - Which insecticides are most effective

- Regulatory
  - None identified

- Education
  - None identified

Bugs: plant bug (*Taylorinlygus pallidulus*), seed bug (*Nysius* spp.), southern green stink bug (*Nezara viridula*)

Severity of crop damage
Controlled: unknown
Uncontrolled: unknown
Region(s) where pest is a problem: all islands
Affects dendrobiums or oncidums or both: dendrobiums
Crop stage(s) affected: flowering
Crop stages at which controls are applied: flowering
Economic thresholds
Local market: unsalable if damaged
Export: zero tolerance

Plant bugs, seed bugs, and stink bugs have been associated with bud drop on dendrobium. Although there are other causes for bud drop, including physiological, nutritional, and environmental causes, these insects possess piercing-sucking mouthparts to feed on developing flower buds and cause bud drop or abortion. At night, growers have observed plant bugs feeding on developing buds followed by bud drop a few days later.

Usually, these sucking bugs do not breed on orchids, but they breed on wild host plants located in areas adjacent to the orchid production area. Plant bugs, seed bugs, and stink bugs develop from eggs into nymphs and then adults. The life cycle (egg to adult) of these sucking bugs is completed in about 30–45 days.

Chemical controls:

Repeated insecticide applications to orchids will be necessary to control these bugs when they are breeding on adjacent host plants but feeding on the orchids.

- Malathion
  -Efficacy: not reported
  -Advantages: inexpensive
  -Disadvantages: incompatible with IPM programs resistance-management issues; negative impacts to non-target organisms; water contamination issues; bad smell and other worker issues

Biological control:

- Natural enemies
  The introduced parasites of southern green stink bug, *Trissolcus basalis*, an egg parasitoid, and *Trichopoda pilipes*, an adult parasitoid, are present in Hawai‘i. Their effectiveness is variable.

Other pest management aids (cultural controls & others):

- Removal of alternate hosts
  The most important management measure, if practical, is to remove alternate host plants or minimize their occurrence from the orchid production and adjacent areas. However,

alternate hosts should *not* be completely removed if numerous parasites of the stink bug eggs or adults are observed.
-Efficacy: not reported
-Advantages: none identified
-Disadvantages: none identified

Potential pest management tools and unregistered/new chemistries:

- none

Critical Needs for Management of Bugs

- Research
  - None identified

- Regulatory
  - None identified

- Education
  - None identified

Snails and Slugs: orchid snail (*Zonitoidese arboreus*), marsh slug (*Deroceras laeve*), brown slug (*Vaginulus plebeius*), two-striped slug (*Veronicella cubensis*), small garden snail (*Bradybaena similaris*), cone spiral shell (*Tornatellides* sp.), and *Liardetia doliolum*

Severity of crop damage
Controlled: <10%
Uncontrolled: >30% - 100%
Region(s) where pest is a problem: all islands
Affects dendrobiums or oncidums or both: both
Crop stage(s) affected: all stages
Crop stages at which controls are applied: all stages
Economic thresholds
Local market: very low; unsalable if damaged
Export: quarantine pest (zero tolerance)

Slugs and snails are among the major pests of dendrobium, causing feeding damage to leaves, roots, and flowers and quarantine rejections in export shipments. These pests also move pathogens between pots or within the field. Their feeding activity causes wounds, which aid pathogen entry.

During the day, snails and slugs hide in plants and plant debris or under rocks or pots. However, following rain, they are seen foraging in daylight. The most pestiferous slugs are the brown slug and the two-striped slug. High population levels of these slugs have resulted in severe damage to many ornamental, vegetable, and landscape plants in Hawaiʻi. In recent years, there has been an up-surge in problems caused by the orchid snail or bush snail.

Adult orchid snails damage plants by feeding on the thick, corky roots that grow from the base of the plant. Ordinarily these roots grow down into the media, holding the plant firmly within the pot. However, plants infested with snails become unstable. They cannot be sold until the pests have been controlled and the roots have re-grown. It only takes two or three adult snails in the medium of a 4-inch pot to cause serious root damage.

In a 1999 survey of commercial orchid growers in Hawai'i, 44% of the 64 respondents reported this snail species as a pest in their greenhouses, costing them an average of $503 per year in control costs and $5,708 in lost sales during the previous 12 months (unpublished survey data). Growers reported damage on nine different types of orchids, particularly in the genera *Oncidium*, *Dendrobium*, *Cattleya*, *Phalaenopsis*, and *Vanda*. Orchids in the *Oncidium* alliance were mentioned most frequently as being susceptible to attack (42% of the instances reported). The disparity between the amount of money these growers spent to control the pest and the value of lost sales indicates the insidious nature of the damage. In many cases, by the time the grower discovers the problem, serious damage has already occurred.

Chemical controls:

- Metaldehyde (Deadline, Metarex, Slug-fest)
  -Efficacy: good—when media is allowed to dry following application (This inhibits rehydration of the snail or slug body.)
  -Advantages: effective against most species of slugs and snails
  -Disadvantages: irrigation water destroys bait; some products for greenhouse use

- Methiocarb (Mesurol)
  -Efficacy: very good
  -Advantages: none identified
  -Disadvantages: Restricted Use Pesticide

Biological controls:

- Natural enemies
  Predatory snails, flatworms, toads, ducks, chickens, and other birds are natural enemies of snails and slugs.

Other pest management aids (cultural controls & others):

- Sanitation
  The control of snails and slugs must first include sanitation, the destruction of hiding places and removal of plant debris.
  -Efficacy: good if done consistently and frequently
  -Advantages: helps in keeping the population to a minimum
  -Disadvantages: very labor intensive

- Copper barriers
  An effective physical control is the use of barriers in the form of copper flashing or copper screen. Copper is highly repellent to snails and slugs, and continuous contact with copper will cause their death. Strips of copper flashing or mesh can be affixed to bench legs to inhibit snails and slugs from reaching bench tops from the ground.

-Efficacy: very good to excellent if the barrier is kept intact and the plants are totally free from infestation, initially, and no infested plants are introduced
-Advantages: effects 100% control
-Disadvantages: labor intensive to start out, maintenance of barrier is continuous effort

- Exclusion
  Snails usually come into the greenhouse with infested plant material and then spread to other plants. New plants should be quarantined and scrutinized for any signs of snails and slugs. Growers should keep snail-infested plants in separate greenhouses or on separate benches with copper covered legs, from plants known to be clean (such as those from flasks).
  -Efficacy: good
  -Advantages: effects 100% control
  -Disadvantages: requires constant monitoring

Potential pest management tools and unregistered/new chemistries:
- none

Critical Needs for Management of Snails and Slugs

- Research
  - None identified

- Regulatory
  - None identified

- Education
  - None identified

Vertebrate Pests

Coqui Frog (*Eleutherodactylus coqui*)

Severity of crop damage
Controlled: damage is not directly from coqui frogs
Uncontrolled: 100% rejection for export
Region(s) where pest is a problem: Big Island and Maui
Affects dendrobiums or oncidums or both: both
Crop stage(s) affected: all stages
Crop stages at which controls are applied: all stages
Economic thresholds
Local market: one frog will result in shipper rejection
Export: presence of one frog for certified nurseries

Since its introduction, the populations and ecological range of the coqui frog have expanded rapidly. In some areas, there may be more than 10,000 frogs per acre, consuming more than 50,000 insects per night. Therefore, coqui may endanger native Hawaiian insect populations, including pollinators, and compete with Hawaiʻi's native birds. The coqui is also a nuisance pest. The mating call of the male coqui starts at dusk and may continue throughout the night. Noise levels have been measured at 80-90 decibels at 1.5 feet.

Because it is a quarantine pest, coqui frog has a negative economic impact on Hawaiʻi's floriculture and nursery industries. Nursery plants are thought to be the vehicle for introduction of coqui frogs to the state, as well as their spread among the islands. HDOA requires that plant materials for export from infested areas be free of coqui frogs prior to transport. Growers must implement procedures to exclude coqui frogs from their sites and disinfest plants prior to shipping. Coqui is also a classified as a quarantine pest in California and Guam.

Native to the Caribbean, coqui frogs have no natural enemies in Hawaiʻi.

Chemical controls:

- Citric acid 16%
  Citric acid is phytotoxic and must be washed off plants within 1 hour of application to prevent burning. However, washing also reduces efficacy.
  -Efficacy: good
  -Advantages: compatible with IPM programs; exempt from pesticide registration
  -Disadvantages: very expensive; worker protection issues (corrosive, burns); phytotoxic

Biological controls:

- None in Hawaiʻi

Other pest management aids (cultural controls & others):

- Coqui frog barrier
  A 24 in. tall barrier of insect-proof screen (smaller mesh than window screen) prevents coqui intrusion.
  -Efficacy: excellent

-Advantages: compatible with IPM programs; no environmental or worker issues
-Disadvantages: initial cost of installation; care must be taken whenever the barrier is opened

- Heat treatments
  Frogs are very vulnerable to heat treatment. A few options are available to potted orchid growers:
  1) Hot water is applied as a **shower treatment** at 109°F for 3 minutes. For oncidiums, the water temperature may as high as 113°F for as long as 5 minutes; dendrobiums have shown adverse effects at the higher temperatures and longer exposure times.
  2) **Vapor treatment**. Exposure to a hot water vapor (115°F) for 0.5 – 1 hour is an effective treatment for coqui frogs.
  3) **Hot water drench**. Oncidium orchid plants are treated in a hot water (113° F) dip for 5 minutes.
  Treated plants are immediately transported to their destination or to an enclosed, non-infested holding area.

  -Efficacy: good
  -Advantages: effective against eggs and juvenile and adult frogs; compatible with IPM programs; no environmental or worker issues
  -Disadvantages: possible phytoxicity; high labor costs (vapor and drench treatments); cost to use treatment facility (vapor treatment)

- Control shrubbery
  Trees and shrubs in the nursery area are cut back to reduce coqui habitat. This is not a stand-alone control tactic, but can be an aid to other strategies.
  -Efficacy: fair
  -Advantages: compatible with IPM programs
  -Disadvantages: labor involved and space required

- PVC traps, retreat site
  This is not a stand-alone control tactic, but can be an aid to other strategies.
  -Efficacy: fair
  -Advantages: compatible with IPM programs; no environmental or worker issues; also kills bush snails
  -Disadvantages: none identified

Potential pest management tools and unregistered/new chemistries:
- none

Critical Needs for Management of Coqui Frog

- Research
  – New controls that will not hurt the plants or the environment
  – Trapping and containment procedures and devices
  – Find biocontrol agents

- Regulatory
  - None identified

- Education
  - Educate the general public about coqui frogs and how they can help to control them.

Birds: red vented bulbul (*Pycnonotus cafer*), red whiskered bulbul (*P. jacosus*), common sparrow (*Passer domesticus*), rice bird, (*Munia nisoria*), white-eye (a.k.a. mejiro) (*Zosterops palpebrosus japonica*), Kentucky cardinal (*Richmondena cardinalis*)

Severity of crop damage
    Controlled: ≤5%
    Uncontrolled: 75 – 80%
Region(s) where pest is a problem: statewide
Affects dendrobiums or oncidums or both: both
Crop stage(s) affected: bud stage to harvest
Crop stages at which controls are applied: all stages
Economic thresholds
    Local market: when birds are observed
    Export: when birds are observed

Birds are a severe problem in orchids in Hawai‘i, especially in September through December. During this period, crop losses can exceed 80% in certain growing areas. Bird damage is usually confined to spikes, buds, and open flowers. Flower buds are usually pecked off the spike, or spikes are sheared in half. In open flowers, birds remove the cap covering the pollinia (pollen masses) to get to the pollen. Once the pollen is removed, the flower begins to die.

Birds develop feeding habits and learned behaviors. Therefore, fields should be frequently monitored for birds so early action can be taken.

Chemical controls:

- The odor of certain insecticides and fungicides is also known to repel birds, but repellence is short-lived.
  -Efficacy: fair
  -Advantages: repels birds and can be used to control other pests
  -Disadvantages: cost of continuous use of pesticides; once the use is stopped, birds re-invade greenhouses.

Biological controls:

- Cats and dogs in the growing area
  -Efficacy: fair - good
  -Advantages: costs comparable to keeping pets; compatible with IPM programs
  -Disadvantages: concerns about safety of the animals who may contact and then be poisoned by snail and slug baits; animals may spread pathogens; animals may physically damage orchid plants

Other pest management aids (cultural controls & others):

- Seal shadehouse against invasion of birds
  To prevent birds from entering, cracks, gaps and other openings should be eliminated. Doors and openings should be sealed when not in use. This is the best long-term control practice.
  -Efficacy: excellent
  -Advantages: cost effective; compatible with IPM programs; if done correctly it is fairly permanent
  -Disadvantages: high cost of initial labor to seal the shadehouse; must be maintained and tears or openings closed immediately

- Various devices
  Several noise and visual scare devices are on the market including noise cannons, sticky traps for roosting birds, "look alive" predators, scare crows, flashing tape, and electronic bird repellers. Growers can also fabricate their own devices using such materials as pie pans or discarded CDs. Many of these methods work for a while, but birds eventually learn that these devices are not harmful. Electronic bird repellers, which broadcast bird distress calls, are species-specific. For optimum control, a combination of devices should be used, and the devices should be removed as soon as the birds are not a problem.
  - Efficacy: poor - fair
  -Advantages: compatible with IPM programs
  -Disadvantages: "fair" levels of control are not good enough; these devices only work for a short time, at best

- Predator sounds
  -Efficacy: fair
  -Advantages: compatible with IPM programs
  -Disadvantages: "fair" levels of control are not good enough

Potential pest management tools and unregistered/new chemistries:

- None

Critical Needs for Management of Birds

- Research
  - Deterrent methods
  - Improved predator calls to repel birds

- Regulatory
  - None identified

- Education
  - Provide information about constructing and maintaining a bird-proof area. Growers must learn to seal their shadehouses. Some think it is too much work, but the labor is a one-time input.

Mice: house mouse (*Mus musculus*)

Severity of crop damage
Controlled: 5%
Uncontrolled: 100%
Region(s) where pest is a problem: dry areas, all islands
Affects dendrobiums or oncidums or both: dendrobiums
Crop stage(s) affected: all, particularly at flowering
Crop stages at which controls are applied: flowering
Economic thresholds
Local market: unsalable if flowers are damaged
Export: N/A

Mice are not among the most critically important pests of potted orchids. However, they can become a problem in dendrobium production at any time of the year due to their fast reproductive capability and their ability to adapt to various foods and environmental conditions. Mice outbreaks and damage to crops usually occur during a drought period when wild food and water sources dwindle. During such times, dendrobium growers have experienced widespread damage to flower spikes. Mice usually feed on the newly-emerged immature spikes. Damage by mice can easily be mistaken for bird injury. However, unlike bird injury, mice usually leave no remnants of the spike, and the severed end appears serrated and not sheared off. The best way to distinguish mouse damage from bird damage is to monitor the field at night for mouse activity. Mice have been known to feed on the pollen sack and cause premature wilting of flowers.

Chemical controls:

- Rodenticides (diphacinone, chlorophacinone)
  -Efficacy: good
  -Advantages: easy to apply in bait stations
  -Disadvantages: requires a great amount of chemical to stop the large numbers of invading mice; need to take precautions to prevent injury to household pets and young children

Biological controls:

- Cats in the growing area
  -Efficacy: good
  -Advantages: costs comparable to keeping pets; compatible with IPM programs
  -Disadvantages: concerns about safety of the animals who may contact and then be poisoned by snail and slug baits; animals may spread pathogens; animals may physically damage orchid plants

Other pest management aids (cultural controls & others):

- Water-peanut butter traps
  A very effective mouse trap for huge infestations can be a 5-gallon bucket with about 3 inches of water. Inside the bucket, a line of peanut butter is spread completely around approximately 2-3 inches down from the bucket's rim. The mice jump up to the rim and

hang over to get the peanut butter. When they fall inside, the water prevents them from jumping out of the bucket.

Potential pest management tools and unregistered/new chemistries:

- None

Critical Needs for Management of Mice

- Research
  - None identified

- Regulatory
  - None identified

- Education
  - None identified

Diseases

Environmental conditions in the tropics are frequently conducive to disease development; plant pathogens proliferate in Hawai‘i’s warm, moist environment. Importation of ornamental plants and cut flowers from elsewhere in the world introduces new pathogens to the state. Monoculture, the practice of planting large fields of the same clone or similar clones, also favors rapid disease spread. If appropriate and effective pest and disease control practices are not available and practiced, Hawai‘i’ will be unable to economically produce dendrobiums for the world market.

While several diseases of potted orchids are described in the literature, other than *Fusarium*, there have not been many confirmed identifications of other fungi as pathogens. Two bacterial pathogens, *Erwinia* and *Burkholderia*, have been isolated from diseased and dying dendrobium plants and confirmed as pathogens (see below). The prevalence of other diseases, especially those caused by unidentified viruses is not known.

Because *Fusarium* is the only pathogen reliably confirmed for many diseases of potted orchids in Hawai‘i, the details of the disease symptoms described below are for *Fusarium* diseases. Diseases attributed to other pathogens are described following the discussion of *Fusarium* disease symptoms.

The control tactics identified are for *Fusarium* diseases. However, there are general management practices that apply to all plant pathogens. These include using clean planting stock, maintaining good sanitation, testing suspect plants, maintaining good irrigation practices, and destroying infected plants. Some control measures which are applicable for pathogens other than *Fusarium* diseases are noted.

Following the disease descriptions, the critical needs for fungal diseases, in general, of potted orchids are identified.

Fusarium rot (*Fusarium proliferatum* and at least two other *Fusarium* species)

Severity of crop damage
- Controlled: 5 to 20 % of the crop is affected
- Uncontrolled: 100% of the crop is affected.

Region(s) where pest is a problem: Statewide (Also common in other orchid growing areas--California, Florida, Taiwan, Japan and other South East Asian countries. These diseases are spread because many plants which are produced in Taiwan and South East Asia have a low level of *Fusarium* contamination.)

Affects dendrobiums or oncidiums or both: both dendrobiums and oncidiums are affected (along with more than 30 other genera and intergeneric hybrids)

Crop stage(s) affected: all crop stages, with seedlings the most susceptible

Crop stages at which controls are applied: all stages. Controls are applied when *Fusarium* is detected. However, this is actually too late.

Economic threshold:
- Local market: zero tolerance
- Export: quarantine pest (zero tolerance)

Fusarium is most damaging to seedlings and young shoots. Young plants in community pots are rapidly killed by this pathogen. Surviving plants continue to be negatively affected by the infection as they mature and new growth is destroyed as new shoots are attacked.

Fusarium causes flower spots, leaf spots, leaf blights or large rots, sheath rots, and rots of the shoot tip (apical meristem). Flower spots are oval and dark brown, while leaf spots are brown to blackish-brown. Leaves are infected when young, and the severity of the disease depends on the age and moisture levels of the shoots. Spots on mature leaves are commonly small, dark, and sunken. An arrangement of rows of three to four spots across the leaf blade, usually close to the cane, is a common characteristic of spots cause by *Fusarium*. This distribution reflects the infection time, which often occurs when high moisture levels allow fungal establishment in the young folds of new leaves on emerging shoots.

Immature sheaths are also very susceptible, and blackened sheath rots are common when plants are grown in moist environments. Young shoots can be completely rotted if infection occurs as shoots emerge. If not completely destroyed, young leaves and the tip of the cane are blackened, while older leaves are green. These infected shoots produce short canes and no flowers when mature.

Other fungal diseases which may affect Hawai‘i's potted orchid production

- **Botrytis Blossom Blight/Gray Mold (*Botrytis cinerea*)**

  Botrytis cinerea causes spots and soft rots or blights of flowers. The spots are frequently circular and brown or pink. These rapidly expand into translucent soft rots that initially have oval to nearly circular shapes. The entire petal or flower is frequently rotted. During cool, moist periods, specialized fungal threads called conidiophores are produced on the surface of diseased flowers. Large quantities of spores are formed on these conidiophores. Spores are spread by air movement, splashing, or through contact. When moisture is present, *Botrytis* spores germinate on healthy flowers by producing a single thread called a germ tube. This germ tube penetrates the host and initiates spot development. Under favorable disease conditions, numerous spores will land on the host, germinate, and penetrate in close proximity to each other. This favors establishment of the pathogen and eventual spot formation. Although less common, single spores can also initiate spot development.

  Botrytis also infects floral buds, but not leaves and stems. Most commercial dendrobium and vanda cultivars are susceptible to *Botrytis.* Unlike diseases caused by many tropical pathogens, temperatures must drop below 70°F before botrytis blossom blight becomes much of a problem and disease progress is reduced when the temperature rises above 81°F. Thus, development of this disease is favored during cool, moist winter periods. The primary fungal species involved is *B. cinera*, although several other *Botrytis* species are also present.

- ***Colletotrichum* Diseases: Flower Spots and Blights, Leaf Spots, Shoot Blight, Spike and Bud Rots, and Damping-off (*Colletotrichum* sp.)**

  This *Colletotrichum* species is highly pathogenic to dendrobium cultivars. Oncidium orchids are also hosts of this fungus. (Other hosts of *Colletotrichum* include cattleya, cymbidium, phalaenopsis, grammatophyllum, encylcia, epicochleatum, miltassia, vanda, miltonia orchids, other ornamentals such as anthurium and schefflera, fruit and vegetable crops including papaya, tomatoes, peppers, basil, and coffee.)

Small seedlings and young growth on mature plants are very susceptible to this pathogen. The fungus will infect leaves, sheaths, or canes (stalks or pseudostems) of small, young seedlings and eventually kill them. On new shoots, *Colletotrichum* causes black rots that destroy immature leaves and apical tips of new canes. The fungus also causes sheath rots that lead to leaf yellowing and loss. Spots on expanding leaves are circular to oval, dark brown, and, in time, may be surrounded by a wide chlorotic area.

Dark, oval rots develop on stems of floral sprays. These rots expand and girdle the spikes, causing buds to wither and fall off. Advanced rots caused by *Colletotrichum* may have salmon-colored spore masses on the surface of rotted tissue. These spore masses sometimes develop concentric patterns. Spores of *Colletotrichum* are spread by splashing water or by contact, but not readily by air movement. Thus, handling diseased plants before working on clean plants can potentially move the pathogen.

As with botrytis blossom rots, cool weather favors disease caused by *Colletotrichum*. Rots and blights are common during the winter, and prolonged periods of moisture during this cool period can foster high disease levels such that entire fields are defoliated. *Colletotrichum* is also quite destructive during warmer periods, 79-82°F, when *Botrytis* is generally not a problem.

Blossom diseases caused by *Colletrichum* are similar to those caused by *Botrytis* and are easily confused with them. The important clue that the disease is caused by *Colletotrichum* is the presence of leaf and spike spots.

Many other diseases caused by *Colletotrichum*, such as anthurium anthracnose, are controlled by thiophanate-methyl fungicides, but the *Colletotrichum* which occurs on orchids cannot be controlled with these fungicides. *Colletrotrichum* species that are pathogenic to orchids have narrow spores and may be *C. acutatum.*

- ***Phytophthora* diseases: damping-off (rot of seedlings); leaf spots and blights; and root, pseudostem (cane), and stem rots (*Phytophthora palmivora*, *P. nicotianiae*, *P. erythymous*, and other *Phytophthora* species)**

In the tropics, diseases caused by *Phytophthora* are common. Once these pathogens are introduced into a tropical environment, the warm temperature (75-86°F) and high humidity favor their growth, spread, and infectivity. Several species of *Phytophthora* have been isolated from diseased orchids in Hawai‘i. *Phytophthora palmivora* and *P. nicotianae* have been the most common. The major diseases on dendrobium caused by *Phytophthora* are leaf spots and blights, root, stem, pseudostem (cane) rots, damping-off of seedlings, and occasional flower blights.

Young orchid seedlings of many genera are highly susceptible to damping-off caused by *Phytophthora*. Seedlings infected with *Phytophthora* typically have water-soaked leaf lesions, pseudobulb or stem rots, and root loss. Root rots of seedlings also cause chronically weakened plants that grow slowly and fail to thrive as they mature. Dendrodium plants also exhibit leaf yellowing and premature leaf loss. Root rots cause plant decline, and plants are killed if the pathogen moves into the stems and pseudostems. In moist, warm weather, infected plants less than a year old can be killed in a few weeks by *Phytophthora*. Root rots are severe in potted plants and in the field during rainy seasons or if drainage is poor.

Leaf spots are initially olive-green to greenish yellow and darken to brown or black rots as the leaf dries. Defoliation is common. In older plants, leaf infections progress into canes, leaves become yellow, and the disease gradually reduces plant size and vigor.

Cane rots are dark and wet in young canes and lighter brown, dry, and fibrous in mature canes.

Phytophthora is most destructive on young seedlings in community pots and on small plants individually potted. The common practice of closely packing plants increases humidity and optimizes use of space, but the resulting close proximity of plants favors pathogen spread and rapid disease development. Sporangia are usually spread by splashing water, plant-to-plant contact, and movement of spores by insects, slugs, snails, and plant handlers.

Phytophthora also causes serious diseases of dendrobium blossoms, buds, and spikes. Lesions on flowers begin as small, water-soaked spots that rapidly expand into large, wet, translucent rots, which may resemble the gray mold disease caused by *Botrytis* spp. Infected blossoms may also become brown or brownish black due to colonization of dead tissue by secondary fungi producing dark mycelia or spores.

Fungicide chemicals should be used in conjunction with sanitation and moisture control practices to attain maximum benefits for reducing *Phytophthora* blights. Disinfectant chemicals can be used on tools, pots and equipment.

- ***Phyllostica* leaf spot and other diseases *(Phyllostica capitalensis)***

Several diseases of dendrobium are caused by *Phyllosticta*, which produces small, circular, yellow spots on leaves. Histological studies show that the amount of fungal growth within the yellow spots is very small. Some spots may also become blackened, and both types will harbor the fungus for many months to years. However, with time, some of the *Phyllosticta* in the black and yellow spots fail to survive and perish. As the leaf becomes older, yellow spots become tan spots, and fungal growth within the tan spots greatly increases. This is followed by rapid fungal growth and invasion of the entire leaf. The fungus accumulates nutrients and forms small, dark fruiting bodies (pycnidia) on the surface of the leaf. These fruiting bodies produce large numbers of asexual spores that are microscopic in size, hyaline (clear), and lemon-shaped with a short appendage (tail-like attachment). Under wet conditions, these spores splash onto young leaves, germinate, penetrate the epidermis, and spread the disease.

Phyllosticta also produces another type of black fruiting body called the perithecium. These contain sexual spores (ascospores) that are forcibly discharged into the air and spread by air currents. Like the asexual spores, ascospores also land on young leaves, germinate with moisture, penetrate the leaf, and spread the disease. Dead leaves commonly have both pycnidia and perithecia.

Leaf spots in commercial dendrobium fields are common and probably reduce yield to some degree. When disease levels are high, flowers are also attacked. Infected flowers show no symptoms, although colored cultivars may have faint purple to blue spots visible during certain parts of the day (mornings). Blue spots become brown only after the flowers are harvested. These symptoms do not occur on infected white blossoms. Infected flowers rot rapidly during shipment.

Potted plants with *Phyllosticta* leaf spots ship poorly and also decline in most garden-shop environments. Yellow spots indicate leaf infections in which fungal growth is being kept in check by the plant. Photosynthetic products manufactured by the plant keep the fungus from growing into surrounding leaf cells. In reduced light or darkness, the plant is unable to produce these compounds in sufficient quantities, and the fungus rapidly grows into adjacent leaf cells. Leaf rots expand rapidly, causing leaf loss (drop) that frequently results in plants with flowers but few to no leaves. Without leaves, longevity of the floral sprays is also reduced, and the value of the potted orchid is greatly diminished.

Inoculations of healthy plants have demonstrated that young shoots are very susceptible and that symptoms take 2–5 months to develop.

Fungicides are applied to prevent spore germination. No chemical treatment has been found that eliminates *Phyllosticta* once it has penetrated the leaf and the yellow spot has developed. More research is needed to screen new fungicides.

- **Blossom Flecks and Spots (*Alternaria alternata*, *Exserohilum rostratum*, *Bipolaris setariae*, *B. sorokiniana* and other *Bipolaris* species)**

Blossom flecks and spots are caused by several species of fungi, of which *Alternaria alternata* is the most commonly identified. Spores of these fungi are produced on grasses, weeds, and other plants growing in and around orchid fields.

Fungi such as *Alternaria* are also good saprophytes, growing on almost any dead plant tissue and rapidly colonizing dead flowers, leaves, sheaths, and spikes, producing many spores in a few days.

Bipolaris and *Exserohilum* species commonly attack plants in the grass family and cause leaf spots and rots of leaves. Spores produced on these grasses are readily moved by wind currents into dendrobium fields. These air-borne spores land on buds and flowers, germinate when moisture is present, and initiate infection. Growth of these fungi in dendrobium flower tissue is limited, and after a few weeks the fungus dies. The aborted infections are of no biological consequence to the plant, but they make the flowers unmarketable.

- ***Pythium* root diseases (*Pythium* spp.)**

Several *Pythium* species cause root rots of potted and field-grown dendrobiums. Infected plants have brown, rotted roots, or fewer roots in general. Roots may also be hollow, with only the epidermis surrounding the vascular elements. Invasion of stem tissues is rare. Pythium root rot causes lack of plant vigor, slow decline, and reduced productivity. *Pythium* incidence can be minimized by avoiding potting media that retain moisture excessively. Wound injuries and burns from fertilizer salts may predispose roots to *Pythium* infection. Use of fungicides may aid disease prevention and control.

- **Seedling rot (*Calonectria ilicicola*; previously *Calonectria crotalariae*)**

Calonectria ilicicola has been associated with dead seedlings in community pots. This fungus can be readily recognized by the production of numerous small, orange-red fruiting bodies on the surface of dead seedlings near the base of the plants. However, definitive microscopic identification is needed, because a few saprophytic fungi also produce red fruiting bodies. *Calonectria* produces spores within these red fruiting bodies that are forcibly discharged into the air and are thus easily spread within greenhouses. These spores are produced on diseased seedlings.

- **Leaf diseases (*Pseudocercospora* spp.)**

This group of fungi primarily causes leaf spots and irregular blemishes. Depending on the *Pseudocercospora* species and dendrobium cultivar, leaf spots can be circular to nearly-circular, reflecting the growth pattern of the fungal colony. These circular blemishes are yellow, with greater amounts of brown to black flecks forming as the spots enlarge. Premature defoliation occurs, and the yellow, detached leaves have brown spots. Other species of *Pseudocercospora* cause smaller, irregular blemishes. These are 0.12-0.20 inch in diameter and generally occur in large numbers. A general mosaic pattern occurs when large sections of the leaf are diseased. Blemishes on potted plants, if numerous, detract from their appearance and marketability. Defoliation is common in environments with less than optimal amounts of light (homes, offices, garden shops, etc.).

The fungus produces hyphae (fungal threads) within the leaf that feed on the plant. Conidiophores (specialized spore-producing hyphae) are produced on the surface of the leaf within the blemished area. These conidiophores produce conidia (spores) that are easily blown or splashed onto healthy leaves or other parts of the same leaf. The conidia germinate when moisture is present on the leaf surface and the pathogen penetrates the host epidermis. Growth and lesion development of this fungus is very slow. Members of *Pseudocercospora* require several weeks after penetration before the first symptom of infection is evident.

To reduce disease levels, all dead leaves are regularly removed to lower inoculum (spore) levels. If the disease is severe, a fungicide is applied after all infected leaves are removed.

- **Rhizoctonia root rot (*Rhizoctonia solani*)**

  Rhizoctonia solani is a common pathogen of roots, collars, and tubers and also causes blights of leaves and stems. Although *Rhizoctonia solani* is frequently reported to be associated with diseased orchid roots, detailed pathogenicity studies are needed to separate the roles of binucleate *Rhizoctonia solani*-like fungi, multinucleate *Rhizoctonia solani*, and other multinucleate *Rhizoctonia* fungi that may be mutualistic, saprophytic, or pathogenic. The cells of *Rhizoctonia solani* have four or more nuclei (commonly six) per cell, while the binucleate *Rhizoctonia solani*-like fungi mostly have two nuclei per cell (sometimes three). The pathogenicity and exact role of these closely related organisms is not known.

Chemical controls:

Efficacy ratings are for *Fusarium*, unless otherwise noted.

- Mancozeb (Dithane, Fore, Pentathlon, Manzate, Protect)

  Mancozeb is applied preventively. The Dithane labels specify use for dendbrobiums.

  -Efficacy: fair, especially if the *Fusarium* has already penetrated the host.

  -Advantages: inexpensive; no resistance-management issues; compatible with IPM programs

  -Disadvantages: some Dithane labels are for greenhouse use.

- Thiophanate-methyl (3336, 6672, T-Methyl, TM, Transom, T-Storm, Allban, Incognito, Primera One, FungoFlo)

  Most populations of *Fusarium* have developed resistance to this fungicide because of years of exposure as growers applied it to control *Botrytis* and other pathogens. While this chemical is used to control other fungi—often in rotation with mefenoxam—it is no longer widely used for control of *Fusarium*.

  -Efficacy: poor (excellent if the *Fusarium* is not resistant)

  -Advantages: systemic

-Disadvantages: resistance has developed; incompatible with IPM programs

- Fludioxonil (Medallion, Mozart)
  -Efficacy: good
  -Advantages: moderately priced; no resistance observed, yet
  -Disadvantages: Mozart for use in greenhouses only

- Pyraclostrobin (Pageant, Insignia)
  -Efficacy: good
  -Advantages: reasonably priced; no resistance observed, yet
  -Disadvantages: limited to two applications (then rotated with a different fungicide); possible problems with phytotoxicity

- *Bacillus subtilis* (Cease, Companion, Rhapsody, Double Nickel)
  - Efficacy: fair
  -Advantages: moderately priced; no resistance observed, yet, compatible with IPM programs; certified for organic production
  -Disadvantages: none identified

- Etridiazole (Terrazole, Truban)
  -Efficacy: good for *Phythophthora* and *Pythium*, root and collar diseases (used as a drench)
  -Advantages: no reported development of resistance
  -Disadvantages: not effective on other fungi such as *Rhizoctonia*; some products for greenhouse use only

- Fludioxonil + mefenoxam (Hurricane)
  -Efficacy: good for *Phytophthora*, *Pythium*, and *Rhizoctonia* root and collar rots
  -Advantages: easy drench
  -Disadvantages: not effective for *Fusarium*, *Cylindrocladium*, *Thielaviopsis* and *Sclerotium* spp.; resistance developed to mefenoxam; to be discontinued after 2014

- Quaternary ammonium chlorides (Consan, Physan, Kleengrow)
  -Efficacy: poor to fair
  -Advantages: none identified
  -Disadvantages: none identified; Kleengrow for greenhouse use

- Captan (Captec)
  -Efficacy: poor to fair
  -Advantages: none identified
  -Disadvantages: ”old” chemistry

- Chlorothalonil + thiophanate-methyl (Spectro, TM/C)
  Most populations of *Fusarium* have developed resistance to thiophanate-methyl because of years of exposure as growers applied it to control *Botrytis* and other pathogens.
  -Efficacy: fair to good depending on pathogens

-Advantages: many diseases controlled
-Disadvantages: resistance among some populations of fungi such as *Botrytis*, *Colletotrichum*, and *Fusarium*

- Copper hydroxide (Nu-Cop, Champ, Champion, CuPRO, Spin-Out)
  -Efficacy: A few fungi (downy mildews, *Alternaria*, *Cercospora*) may be controlled.
  -Advantages: easy application; fairly effective against bacterial diseases,
  -Disadvantages: blue color

- Copper hydroxide + mancozeb (Junction)
  -Efficacy: poor
  -Advantages: mancozeb controls many fungi with no reports of resistance development
  -Disadvantages: none identified

- Dazomet (Basamid)
  Dazomet is a preplant fumigant for potting soil.
  -Efficacy: fair to good
  -Advantages: preplant control of weeds, nematodes, and soil borne diseases
  -Disadvantages: only applicable to preplant

- Dimethomorph (Stature)
  -Efficacy: good (with excellent plant coverage)
  -Advantages: none identified
  -Disadvantages: high rate of resistance development of the pathogen; must be tank mixed with other fungicides to reduce risk of resistance development; resistant pathogens common

- Flutolanil (Prostar, Contrast)
  -Efficacy: fair to good for diseases caused by Basidiomycetes
  -Advantages: useful for common turf diseases, thread blight of ornamentals, and for rusts
  -Disadvantages: limited range of efficacy to pathogens

- Fosetyl-Al (Aliette, Flanker)
  Ratings apply to Aliette.
  -Efficacy: fair to good against *Phytophthora*, *Pythium*, and downy mildews (Aliette)
  -Advantages: none identified
  -Disadvantages: should not be mixed with foliar fertilizers or copper compounds

- Hydrogen peroxide (Zerotol)
  -Efficacy: low to high depending on the situation
  -Advantages: none identified
  -Disadvantages: none identified

- Iprodione (Ipro, 26019, 26 GT)
  -Efficacy: with good coverage, can be useful against diseases caused by *Alternaria*, *Rhizoctonia*, *Fusarium*, and other pathogens
  -Advantages: none identified
  -Disadvantages: can be used on a few crops (impatiens, pothos, and spathiphyllum) cannot be drenched; not effective on *Pythium* and *Phytophthora*

- Iprodione + thiophanate-methyl (26/36, TM+IP)
  Most populations of *Fusarium* have developed resistance to thiophanate-methyl because of years of exposure as growers applied it to control *Botrytis* and other pathogens.
  -Efficacy: can be effective for fungi that are susceptible
  -Advantages: none identified
  -Disadvantages: resistance has developed; incompatible with IPM programs; will not control fungi that are resistant to thiophanate-methyl

- Mefenoxam [Metalaxyl-M] (Subdue, Metastar, Ariel)
  Mefenoxam is used by some growers in rotation with thiophanate-methyl products for diseases other than *Fusarium*.
  -Efficacy: good for Oomycetes such as *Pythium*, *Phythophthora*, and downy mildews
  -Advantages: systemic
  -Disadvantages: prolonged use may foster resistant pathogens

- Pentachloronitrobenzene (PCNB) (Terraclor)
  -Efficacy: good for *Botrytis*, *Phyllosticta*, *Rhizoctonia*, *Sclerotium;*fair for other fungi
  -Advantages: none identified
  -Disadvantages: for new ornamentals, apply to only a few plants to check for phytotoxicity; discontinued 12/31/2014

- Phosphorous acid (Allude, Vital, Fosphite, Phorcephite, Rampart, Phostrol, AgrFos)
  -Efficacy: fair to good for *Phytophthora*, *Pythium* and downy mildew (Vital); *Phytophthora*, *Pythium*, *Fusarium*, *Rhizoctonia*, downy mildew, powdery mildew (Fosphite)
  -Advantages: systemic; no reports of resistance development; bacterial control is also listed on the Fosphite label (but control is questionable)
  -Disadvantages: none identified

- Potassium bicarbonate (Kaligreen)
  -Efficacy: fair to good for powdery mildew
  -Advantages: 4-hour REI
  -Disadvantages: none identified

- Pyraclostrobin (Insignia, Pageant)
  -Efficacy: fair to good on diseases caused by *Colletotrichum*, *Rhizoctonia*, *Bipolaris*, *Excerohilum*, *Pythium*, *Fusarium*, *Phytophthora*, *Phyllosticta*, and others

-Advantages: none identified
-Disadvantages: none identified

- *Reynoutria sachalinensis* (Regalia)
  -Efficacy: poor to fair
  -Advantages: none identified
  -Disadvantages: none identified

- Thiophanate-methyl + etridiazole (Banrot)
  Most populations of *Fusarium* have developed resistance to thiophanate-methyl because of years of exposure as growers applied it to control *Botrytis* and other pathogens. While this chemical is used to control other fungi—often in rotation with mefenoxam--it is no longer used for control of *Fusarium*.
  -Efficacy: fair to good if pathogen is not resistant to thiophanate-methyl
  -Advantages: systemic
  -Disadvantages: incompatible with IPM programs; resistance development to thiophanate-methyl

- Triadimefon (Bayleton, Strike)
  -Efficacy: fair to good for *Colletotrichum* (dendrobium only)
  -Advantages: none identified
  -Disadvantages: none identified

Biological controls:
There is a need for testing of potential biological controls and their efficacy.

Other pest management aids (cultural controls and others):
Once a plant is infected, it is very difficult, if not impossible, to eliminate *Fusarium*. Thus for seedlings and potted plants, the greatest emphasis must be placed on disease prevention. Every effort must be made to prevent infection of young plants.

- Plantlet selection
  If plantlets or seedlings are purchased in community pots or larger pot sizes, growers must first scrutinize young plants for disease symptoms before purchasing them. A single dead plant within a community pot is an important warning.

  Growers must also inform themselves about the suppliers of their propagation material. Knowledge of the sanitary practices of the suppliers will determine whether they are capable of delivering disease-free plantlets. In less developed countries with low labor costs, clean water is not readily available, thus although compots may be cheaper, diseases will be a constant problem.

  -Efficacy: Proper plantlet selection results in excellent control of *Fusarium*.
  -Advantages: compatible with IPM programs
  -Disadvantages and special considerations:
    - Newly purchased seedlings should be placed in a covered greenhouse and monitored closely for any sign of disease development.

- Difficult to know practices of out-of-state suppliers

- Isolation of seedlings & plantlets
  Seedlings should be grown in a separate, clean propagation house or area of the greenhouse used only for new seedlings. Plants should be obtained in flasks, grown clean, and kept healthy. Seedlings (any plants not in flasks) purchased from different growers should not be mixed, but kept separate on different benches and separated by solid plastic barriers if possible.

  -Efficacy: Isolation provides excellent control of *Fusarium*.
  -Advantages: compatible with IPM programs
  - Disadvantages and special considerations:
    - Isolation requires the dedication of valuable greenhouse space.
    - Care must be taken not to contaminate the isolation area as well as the rest of the nursery.

- Moisture control
  Moisture control is crucial to disease prevention and control, in general. The greenhouse should have a solid roof. Overall plant growth and vigor will be improved under solid-covered greenhouses. In dry environments with low rainfall, it is possible to grow mature, healthy dendrobium in shade houses.

  -Efficacy: Fair. The efficacy of moisture control for the control of *Fusarium* is only fair but should not be ignored. High moisture supports high numbers of spore production and disease levels will greatly increase without moisture control.
  -Advantages: Compatible with IPM programs
  -Disadvantages and special considerations:
    - Expensive (The initial cost of installation of the expensive solid-covered structure can be an impediment). Thus, only a small area for new plants and seedling should be covered if cost is a limitation.

- Clean cultural practices
  Growers must first purchase clean planting materials (in flask) and then maintain clean plants. This results in excellent disease control. The reputation of growers who have clean planting material will be excellent and there will be demand for their plants because clean planting material is not easy to find.

  -Efficacy: Excellent
  -Advantages: Compatible with IPM programs
  -Disadvantages and special considerations:
    - Growers must be absolutely attentive and diligent.
    - Growers must be willing to invest the time and care needed to produce disease-free plants.
    - Growers must distinguish between clean plants established from the flask and smaller plants purchased from another grower who is believed to have disease-free plants. If compots are purchased, growers must carefully observe all plants and keep plants in quarantine for several months.

- Sanitation
  Diseased and dead plant materials serve as organic matter that harbors pathogens. All dead plants, diseased plant parts and fallen leaves should promptly be removed from the nursery. *Fusarium* is a prolific sporulator. Large numbers of spores are continually produced on dead and infected tissues. Even small black spots are sources of many thousands of spores. *Fusarium* spores are splashed from one plant to another, carried on hands or anything that comes into contact with diseased plants, transported in running water or contaminated soil or potting mixes, and moved by frogs, mice, snails, slugs, and insects. *Fusarium* spores can be blown to healthy plants within the greenhouse and can survive for months on walls and other contaminated surfaces. In areas with chickens, these animals will also carry pathogens into the greenhouses and up onto the benches.

  -Efficacy: Excellent
  -Advantages: Compatible with IPM programs
  -Disadvantages: Labor costs; time needed to diligently keep the crop clean.

- Steam pasteurization of potting media (and clean pots)
  A steam pasteurization unit can be designed to provide heat to kill pathogens. Most pathogenic fungi are killed at 143˚F for 30 minutes. The core temperature of the media must reach the appropriate temperature and be held at that temperature for at least 30 minutes to be effective.

  -Efficacy: Excellent
  -Advantages: Works very well when done correctly. Results are fast growing healthy plants.
  -Disadvantages: Added cost of steam unit; effort and cost to set up the pasteurization system.

Potential pest management tools and unregistered/new chemistries:

- Subirrigation
  - Subirrigation provides moisture to roots while keeping the rest of the plants dry. However, subirrigation systems are very expensive to set up.
  - The water level for subirrigation will have to be at least ½ of the pot volume. Roots need to be submerged to take up water. Given that the potting medium is porous and orchid roots are not fibrous, water contact is needed.
  - Like aqua-culture, the system will be highly susceptible to contamination by severe pathogens such as *Phytophthora*, *Pythium* and other pathogens. In the short term, water can be used more efficiently, but potential for disaster is very high. The orchid is a very long-term crop and once the root system is contaminated, the plant will be in decline, a source of inoculum, and further contamination of many parts of the nursery.

Critical Needs for Management of Fungal Diseases

- Research
  – Research to determine IPM compatibility of current chemical control options.
  – Continue to develop new controls for *Fusarium* rot.

  - Continue to identify new pathogens and screen fungicides to control them. (*Fusarium* was very common in Big Island commercial nurseries but *Phytophthora* may be more common on O‘ahu.)
  - Testing of potential biological controls and their efficacy.
  - Cross infectivity of fungal pathogens. (For example, can the fungi from *Dendrobium* infect *Phalaenopsis*?) (Low priority)

- Regulatory
  - None identified

- Education
  - Continue to update growers on new species of pathogens.
  - Educate growers about disease identification.
  - Continue to educate growers on the importance of plant selection/site for disease management (including overseas vendors).
  - Educate off-shore suppliers of plant material on BMPs
  - Proper and lawful use of chemicals: Growers must be educated that the pesticide product label is the legal document that dictates the use of each product and that they must follow the label for all pesticides used. Growers need to be trained to understand and follow the label directions for proper application methods, protective clothing and foot wear, time for re-entry into sprayed greenhouses, disposal of excess chemicals, etc. Some highly effective chemicals, are Restricted Use Pesticides. Growers who wish to use RUPs require a Pesticide Applicator Certification from HDOA. Such growers also need training (available from CTAHR’s Pesticide Risk Reduction Education Program) to earn and maintain the appropriate certification.
  - Educate growers about HDOA’s Export Certification requirements (procedures to comply with the requirements and to apply for the permit).
  - Educate suppliers of planting material about the importance of sterile practices and training in proper techniques. (See “Special Critical Needs,” p. 85, below.)

Bacterial diseases (*Erwinia chrysanthemi*, *Burkholderia gladioli* pv *gladioli*)

Severity of crop damage
Controlled: n/a
Uncontrolled: widespread infection; unsalable potted plants; limiting to floral harvest to field destruction
Region(s) where pest is a problem: Statewide, National, and International
Affects dendrobiums or oncidiums or both: both
Crop stage(s) affected: all crop stages
Crop stages at which controls are applied: Prevention is the key; bacteria must be excluded; all infected plants should be discarded
Economic thresholds
Local market: Almost zero but low levels are tolerated with reduced quality
Export: Zero, but, for practical purposes, low levels are tolerated

The two major bacterial pathogens that have been identified on *Dendrobium*, *Oncidium*, *Cattleya* and *Miltonia* spp. and hybrids in Hawai'i are *Erwinia chrysanthemi* and *Burkholderia gladioli* pv. *gladioli* (formerly *Pseudomonas gladioli* and *P. marginata*).

The symptoms caused by these bacteria are similar. Any part of a plant, including leaves, leaf tips, pseudobulbs and flower spikes, can be affected, but leaf symptoms are likely to be noticed first. Leaf spots begin as small, water-soaked, dark green areas that rapidly enlarge into soft rots which are associated with cellular destruction. (The water-soaking common for bacterial infections may not be present.) The surrounding tissue may be yellow, while the center of the spot becomes tan to brown. The entire leaf is invaded by bacterial cells, and soft, flaccid, yellow leaves are a common result. The bacteria move into the cane from diseased leaves, and the entire cane rots. Infected canes become soft and brittle, commonly breaking in half in the field and in pots. The plants have poor vigor. Young tissues (e.g., new shoots) are very susceptible and may be destroyed within two weeks; many young plants die in a few months.

Bacteria survive well in the diseased plant, in plant debris, and other organic matter. Within the plant, pathogenic bacteria are protected from starvation, drying and chemicals. Diseased plant tissue contains billions of bacterial cells. Large populations of bacteria contained in plant sap may also survive for a few weeks outside the plant. However, in areas such as soil, which are outside of the protection and nutrient sources provided by host plant tissue, pathogenic bacteria die within a few months.

Unlike fungi, whose body structure is in the form of long tubular threads, pathogenic bacteria are much simpler, microscopically small, single, motile cells. They multiply by dividing in half, growing, and then dividing in half again. Under optimal conditions (good nutrition, warm temperature, high humidity) each cell can divide every 20–30 minutes. Thus, bacterial multiplication can be extremely rapid, a necessary condition for successful colonization of host tissue.

Bacteria commonly enter plants through wounds, but wounds are not necessary for infection. Bacteria can also enter through natural openings like stomates. The surface of any natural opening, wound or break in the epidermis of a diseased plant will serve as a breeding ground where huge quantities of bacteria can multiply and accumulate. These bacterial cells are then spread to other plant parts or to healthy plants by splashing water or direct contact. Water that drains from diseased sections of the field will also carry bacteria to other parts of the farm. Additionally, bacterial cells can contaminate pots, trays, potting media, plant tags, clothing, gloves, clippers, and anything else that comes into contact with a diseased plant.

Slugs and snails also move pathogens within a field or from the ground onto bench tops. Insects such as weevils not only carry the bacteria on their bodies but also cause wounds through which the pathogen enters the plant. Mites feeding on *Phalaenopsis* buds may vector *B. gladioli* into the flower tissues causing buds to abort. Weeds within or near farms can also serve as alternative hosts.

Prolonged periods of high moisture and low light levels favor development of bacterial diseases. High moisture favors bacterial emergence, movement, infection, and multiplication. In Hawaiʻi, certain wet areas have environmental conditions that make disease control difficult.

Bacterial disease can result in widespread crop losses if not prevented from entering a nursery. Once a nursery is contaminated, it is virtually impossible to eradicate bacterial pathogens economically. *B. gladioli* can be isolated from surface-sterilized orchid tissues which show water-soaked lesions. This indicates that the bacteria colonize the inside of their host plants. *B. gladioli* can also be recovered from healthy-looking plants with no signs of infection, indicating that the pathogen can survive on the leaf surface as an epiphyte.

Disease prevention is crucial. Bacterial pathogens are practically impossible to eradicate from infected plants. There is no cure for a bacterial disease. Any plant with symptoms of bacterial disease should be discarded and the area should be treated with disinfectant. In the field, areas with bacterial pathogens should not be replanted with orchids. Several techniques are available for detecting and confirming the pathogenicity of *B. gladioli* and *E. chrysanthemi* on orchids, including semi-selective media, PCR and commercially available tests such as the API 20NE and Biolog.

Chemical controls:
Chemical control is not possible since bactericides are limited in availability and also in effectiveness. Bacteria live and multiply within the plant. They are systemic and are protected inside diseased plants. Thus, most chemicals never come in contact with the bacteria. Genetic elements which confer copper and antibiotic resistance, have been found in *B. gladioli* in Hawai'i. Therefore, prevention, and consistently using practices such as sanitation, and roguing are better management strategies than using chemical control once bacterial problems have presented. Some disease reduction has been reported with the use of antibiotics or other chemicals, but this effect is temporary or partial and no available chemical can stop an epidemic in wet weather.

- Quaternary ammonium chlorides (Consan, Physan, Kleengrow)
  -Efficacy: poor; kills bacteria on the surface of plants
  -Advantages: decreases inoculums level
  -Disadvantages: Growers may be wasting time and funds.

- Hydrogen peroxide (Zerotol)
  -Efficacy: poor; kills bacteria on the surface of plants and objects
  -Advantages: decreases inoculums level
  -Disadvantages: may waste growers' resources

- Hydrogen peroxide + peroxyacetic acid + octanoic acid (X3, Xeroton)
  -Efficacy: poor; kills bacteria on plant surface

-Advantages: reduces bacterial levels
-Disadvantages: may waste growers' resources

- Sodium chlorite (Selectrocide)
  -Efficacy: unknown, can reduce bacterial levels
  -Advantages: can reduce bacterial levels
  -Disadvantages: efficacy unknown

- Yeast extract hydrolysate from *Saccharomyces cerevisiae*
  -Efficacy: unknown
  -Advantages: none identified
  -Disadvantages: none identified

Biological control:
- None

Other pest management aids (cultural controls & others):
- Proper nursery site selection
  Disease management is always more difficult and more expensive in wet areas. Also growers should consider the amount of the wind in the area. Windy environments increase costs because the screens in such environments will need more maintenance.

- Solid-covered greenhouses
  Growers producing dendrobiums in wet areas should seriously consider solid-covered greenhouses.

- Cultivar selection
  Other cultivars such as *Phalaenopsis* and *Oncidium* hybrids are also very susceptible.

- Good air movement
  In the nursery, the position of benches (spacing between rows, direction of rows, etc.) should be designed for good air movement to keep foliage as dry as possible.

- Avoid windbreaks
  Unless windbreaks are necessary, keep trees and other plant growth around the shade-house to a minimum. This will provide good air circulation and adequate light and discourage conditions conducive to insect and weak pathogen breeding.

- Clean potting media
  New plants are planted in pasteurized or sterilized potting media.

- Start with good planting stock
  All plants used to start a nursery should be carefully checked for bacteria. Growing plants from flasks is recommended because bacterial contamination is difficult to detect in infected community pots, especially when plants are produced in dry environments.

- Isolation of new plants
  New plants are maintained in an area separate from production areas and monitored for the presence of pathogens. Immediately upon discovery, diseased plants are discarded.

- Sanitation
  All dead and diseased plants are placed in waste containers and removed from the field. All leaves, stems, roots, and flowers from diseased plants must also be gathered and removed from the site. It is impossible to cure a dendrobium plant that has a bacterial infection, so all infected plants must be discarded. The disease may seem to disappear in dry weather but will return with wet weather. All infected plants are sources of inoculum for the next disease outbreak.

  Common nursery items will move pathogens from diseased plants to healthy plants. It is extremely important to allow no contamination of any crop by the use of contaminated clippers, pots, tags, trays, benches, media, aprons, gloves, etc. In most nurseries, failure to control pathogen movement on plants and by those items listed above, is more common than by footwear tracking pathogens into clean areas. Thus, to keep contamination to minimum levels, workers must avoid working in clean areas after working in diseased areas. Separate sets of tools, gloves, etc., should be provided. These items are relatively inexpensive compared to the continuous contamination of new plants.

- Control of vector pests
  Pests, such as insects and slugs, can carry pathogenic bacteria. Consequently, these insects and slugs must be controlled or eliminated. Insects that do not damage plants, such as millipedes and ants are effective in moving pathogens. The activities of birds, large lizards, and toads also spread the bacteria and their entry must be prevented.

- Employee training
  Employee training is crucial to disease movement. Employees must understand how minute the bacterial pathogens are and how easily they are moved.

Potential pest management tools and unregistered/new chemistries:

- None

Critical Needs for Management of Bacterial Diseases

- Research
  - Identification of potentially effective chemicals such as Agribrom and efficacy rates, applications, and alternatives.

- Regulatory
  - Increase knowledge to develop better importation requirements and screening for bacterial contamination at entry.

- Education
  - Educate growers on symptoms and how to effectively prevent introduction of bacterial pathogens into their nurseries.

Viral diseases: Cymbidium mosaic virus (CyMV) and Odontoglossum ringspot virus (ORSV)

Severity of crop damage
Controlled: no controls are available for viruses (infections are permanent)
Uncontrolled: 100% if symptoms are evident;
production is decreased when asymptomatic infection is present;
infected but asymptomatic plants are also hidden sources of inoculum
Region(s) where pest is a problem: statewide (and nationally and internationally)
Affects dendrobiums or oncidums or both: both and *Cattleya* and many intergeneric hybrids
Crop stage(s) affected: all stages
Crop stages at which controls are applied: there are no controls for viruses available; infections are permanent
Economic thresholds
Local market: plants are removed as soon as any symptoms are observed
Export: plants are removed as soon as any symptoms are observed; viruses are quarantine pests

The two most commonly identified viruses which affect dendrobiums are *Cymbidium mosaic virus* (CyMV) and *Odontoglossum ringspot virus* (ORSV). These viruses multiply only within the plant and are systemic within the plant. In other words, once the plant is infected, the virus is present throughout the plant. Thus, for plants that are vegetatively reproduced (e.g., by cuttings, division, or tissue culture), the virus is a permanent part of the plant and propagules from it.

The presence of large amounts of viral particles can trigger cell death and the formation of white or dark necrotic tissue, observable as the symptomatic streaks or blemishes on flowers and leaves. On white dendrobium cultivars, symptoms of viral infection include brown streaks on the lips of the flowers, brown streaks on petals, and black sunken areas on leaves. Leaf symptoms are common on the under-surface, but both surfaces can have black areas or lesions. Growth reduction, decreased flower yield, and poor vigor also result from viral infection.

Infected plants may not show disease symptoms for a variety of reasons. Some cultivars such as Louis Bleriot harbor viruses, but do not show symptoms. These plants serve as symptomless reservoirs of viruses (i.e., they are hidden sources of inoculum). (A virus-free cultivar, Louis Bleriot, UH1392, was developed and seeds were released by the UH dendrobium breeding program.)

Newly infected plants will not display symptoms. After infection, the virus must multiply within the plant and reach a minimum population level before symptoms are expressed. The rate of symptom development will depend on the cultivar, environment, strain of the virus, location of the infection site, and initial amount of inoculum that infected the plant. The environment affects expression of virus infection symptoms. In Hawai‘i, the warm tropical temperature decreases symptom expression in dendrobiums. Thus, white dendrobium cultivars expressing severe symptoms during the cooler months produce flowers with few or no symptoms during the summer. The amount of light and nutrition may also play a role in symptom expression.

CyMV and ORSV are very stable viruses that are easily transmitted among orchid plants. Orchid plants are commonly infected when the virus is transferred from diseased plants to healthy plants, often in contaminated sap. Any action that transfers sap from a diseased plant to a wounded healthy plant will transmit the disease. These actions include insect activities and worker activities such as harvesting flowers, trimming leaves or canes, and other mechanical operations. There is some evidence that snails and slugs may also transmit viruses on orchids.

Viruses are quarantine pests.

Breeder/supplier issues. It is essential to find and purchase plants from a reputable dealer that does not have virus-infected plants. At times, this is difficult especially if the cheaper plant sources may be those that have contaminated plants.

Chemical controls:
The virus within diseased plants cannot be eliminated with chemicals, and infection is permanent.

- none

Biological control:
There are no biological controls for the viruses. The only biological controls possible would be any organisms which might control vectors. However, this will not provide complete control.

Other pest management aids (cultural controls & others):

- Clean starting material
  Prior to purchasing, propagation materials should be tested and determined to be virus-free. Growers would also be wise to do another test after sterile calluses are formed, before mass propagation. Testing adds to the cost of the propagation material. However, the investment will result in lower losses for the growers.
  - Efficacy: excellent
  -Advantages: compatible with IPM programs
  -Disadvantages: costs of testing

- Isolation
  Isolation serves to minimize the spread of viruses. Plants which are purchased in flasks should be established in isolation to produce disease-free seedlings. A few plants should be tested to confirm virus-free status. Community pots purchased from wholesalers or other growers and mature plants are potential sources of pathogens. Growers must keep these plants away from the plants obtained from flasks that have been tested to be virus free.
  -Efficacy: good to excellent
  -Advantages: virus-free plants stay that way; IPM compatible; growers gets a reputation for virus-free plants.
  -Disadvantages: labor and other costs to create an isolated area; can be costly, but is worth the cost and effort.

- Sanitation
  Good sanitation minimizes the spread of viruses. The propagation area or nursery must be kept free of any weeds that may serve as reservoirs for viruses or insect vectors. Stable viruses such as CyMV and ORSV can remain dormant in dead organic matter. Dead leaves or seedlings that have not survived transplanting from flasks should be carefully removed. Any completely dried stems, pseudobulbs and spikes can be cut and disposed

of. However, any green or living tissue will contain the virus in the sap. Therefore, if living tissue is cut, the knife or clipper must be disinfected between plants. In commercial nurseries, the rate of virus spread greatly increases after growers begin to harvest flowers Flowers should be harvested by snapping the stems. If the field is entirely virus free, clippers can be used. For the entire nursery, any dendrobium or other orchid plants with viral symptoms are removed and discarded.

-Efficacy: good to excellent
-Advantages: IPM compatible; keeps the environment viral free.
-Disadvantages: extra labor costs; must take the time to inspect and discard all suspect plants.

- Clean clay pots and potting media
  Steam-sterilization at 180°F for a minimum of 30 minutes (60 minutes is recommended) of pots and potting media is a good method to control the introduction of viruses. Although, sterilization is inconvenient and involves the initial investment in the sterilizing equipment, this is important to prevent many other diseases as well as weeds, and is a very good investment. Plastic pots need to be washed and soaked in a sterilizing chemical solution.
  -Efficacy: good
  -Advantages: compatible with IPM programs
  -Disadvantages: initial cost of equipment

- Raised benches
  In order for a nursery to be certified to export orchids, that nursery must grow their plants on benches that are at least 18 inches off the ground. The efficacy of this requirement for control of virus transmission is minimal if there are no other sources of viral infection in the greenhouse. However, adherence to this requirement is essential to prevent nematode infestation because nematodes are a quarantined pest.
  -Efficacy: unknown
  -Advantages: compatible with IPM programs; allows nursery to obtain certification for export; helps control viral and other diseases by reducing vectors.
  -Disadvantages: costs of benches and construction are added costs

- Disinfection of surfaces
  The surfaces of tools, benches and other items that contact the plants are disinfected by chemicals or heat.
  -Efficacy: good to excellent
  -Advantages: compatible with IPM programs
  -Disadvantages: cost of disinfectant chemicals or equipment; extra time/labor are required to properly dip tools

- Viral disease management
  Orchid viruses may be transmitted by a variety of vectors, including humans. Handling large plants can easily contaminate clothing with viral, bacterial, or fungal pathogens. Workers should bathe and change their clothing if they have handled large mature plants prior to working in the isolation area for clean plants. Alternatively, working in the clean

area should be done only on certain days, or by certain employees, or only in the mornings.
-Efficacy: excellent
-Advantages: cost effective; compatible with IPM programs
-Disadvantages: workers must be properly trained

Potential pest management tools and unregistered/new chemistries:
- None

Critical Needs for Management of Viral Diseases

- Research
  - Field test kit for the presence of viruses
  - Identification of currently unknown viruses
  - Identification of vectors of viruses
  - Chemicals for tool sanitation
  - Virus-resistant varieties
  - Combination cutting tool and virus test kit

- Regulatory
  - Certification program for propagators who produce virus-free plants

- Education
  - Education about how to handle contaminated materials and plants
  - Importance of obtaining clean plants from suppliers, including overseas suppliers.
  - For suppliers, both local and overseas, the importance of providing clean planting material
  - Certification program for overseas suppliers
  - Training about BMPs on multiplication techniques

Special Critical Needs:
Reliable sources of planting materials and disease management education for foreign suppliers of planting materials

There is good evidence that many serious pathogens have traveled on ornamental plants. After arriving in the U.S., these new pathogens attack our fruit and vegetable crops, forests and native plants. Foreign nations often do not have strong regulations or enforcement of laws governing the use of chemicals, and, furthermore, their growers may fail to rotate pesticides. Many resistant strains of pathogens and other pests have been the results of these conditions.

Planting material for Hawaiʻi's orchid growers often comes from sources outside the state, including foreign sources. Growers presently do not monitor conditions under which these materials are produced, and are vulnerable to stocking their nurseries with infected planting materials. Importing pathogens increases the cost of pathogen control on contaminated plants and may place other crops or plants in Hawaiʻi at risk.

- Reliable, local sources of disease-free planting material
  Hawai‘i's potted orchid producers would benefit if there were reliable, in-state suppliers of seeds, seedlings and starter plants.

- Education
  Sufficient supplies of locally produced planting material are not currently available. Growers continue to import planting materials from foreign sources, and, for economic reasons, are likely to continue to do so even if local supplies increase.
  Therefore, Hawai‘i's orchid producing community needs to educate their foreign suppliers about the dangers posed by international shipping of plant materials, the unintended consequences of spreading pathogens and about techniques to prevent or minimize transmitting pathogens.
  For example, CTAHR plant pathologists could conduct plant protection workshops in Bangkok (where most of Hawai‘i's growers obtain their starter plants) and provide IPM instruction and demonstrations to the producers with whom Hawai‘i growers contract. This training should include education about the proper techniques to produce seedlings in flasks. Such seedlings are thought by most people to be disease-free. They may not be. Seedlings *in the flasks* may have been infected with viruses if the technician who extracted the seed from the pod was not careful to avoid contact between the scalpel and the pod. The pod, which is the orchid fruit, is maternal tissue. If the mother plant is virus-infected, the placental tissue inside the pod will be infected as well. Technicians need to be educated that their goal is to protect the seed from contamination and should be trained in the proper technique to extract the seed from an infected pod without contacting the placental tissue in the pod.

Emerging Viral Disease Issues:

- **Research on Mite-Vectored Viruses**
  Orchid fleck virus (OFV) is a non-systemic, bacilliform-shaped virus that causes necrotic or chlorotic rings in many species and genera of the orchid family. OFV was first discovered in Japan, but has since been reported in North and South America, Europe, Australia, and continental Asia. There are two distinct forms of OFV which cause similar symptoms; one primarily infects the nucleus of plant cells whereas the other is found in the cytoplasm. Both forms are transmitted by tenuipalpid mites of the genus *Brevipalpus*, also known as false spider mites, flat mites, or red and black flat mites. OFV is a hindrance to orchid production in these areas, particularly when the mite vector is poorly managed. *Brevipalpus* mites are widespread in Hawai‘i and symptoms similar to those caused by OFV have been observed in Hawai‘i's orchids. Further research is required to determine if OFV is present in Hawai‘i and to develop management strategies should it arrive.

Symptoms caused by Orchid fleck virus in various orchid species and hybrids in Brazil. (Photo by Michael Melzer.)

- **Watermelon mosaic virus in Hawai‘i**

  Watermelon mosaic virus (WMV; previously known as WMVII) is an aphid-transmissible virus belonging to the genus *Potyvirus* of the family *Potyviridae*. WMV is an economically important pathogen of cucurbits worldwide and is also a pathogen of orchids. In *Vanilla* sp. grown in the South Pacific, WMV (often referred to as vanilla necrosis virus) causes leaf chlorosis, distortion, and necrosis and is responsible for considerable production losses of this valuable spice. In Vanuatu, infection rates as high as 64% have been reported. WMV has also been reported in the wild ornamental orchid *Habenaria radiata* (Thunb.) Spreng. in Japan. *H. radiata* plants infected with WMV are stunted and show foliar mosaic and distortion. In Hawai‘i, in 2010, honohono orchids (*Dendrobium anosmum* Lind.) were found to be infected with WMV. The symptoms exhibited by these plants were chlorotic flecks in the leaves and malformed flowers with color-break. Preliminary work indicated that these symptoms were mild in honohono plants infected only with WMV; however, plants infected with WMV and *Cymbidium mosaic virus* (CyMV) showed severe stunting or death of the plant. Further research is needed to determine if the strain of WMV present in Hawai‘i is a threat to local vanilla production, ornamental orchid species, and to confirm the apparent synergistic effect when plants are co-infected with WMV and CyMV.

Mild chlorosis in a honohono orchid leaf infected with WMV (left); a honohono orchid infected with WMV (center) or with WMV and CyMV (right). (Photo by Michael Melzer.)

Nematodes (*Aphelenchoides besseyi* and *A. fragariae*)

Severity of crop damage
- Controlled: 5 to 10%
- Uncontrolled: 90 to 95% Severe losses.

Region(s) where pest is a problem: wet environments or rainy seasons in dry environments
Affects dendrobiums or oncidums or both: dendrobiums--leaf loss and failure of buds to open
Crop stage(s) affected: all
Crop stages at which controls are applied: all
Economic thresholds
- Local market: 10% or less (should be 0)
- Export: no tolerance

The most common plant parasitic nematodes attacking orchids are *Aphelenchoides besseyi* and other *Aphelenchoides* species. These foliar nematodes are active crawlers and swimmers and can move in a thin film of water on the external surface of the plant. After sufficient rain, irrigation, or dew formation, they emerge from diseased tissue or roots and swim in films of water on the external surfaces of the plant, moving rapidly to the upper parts of the plants.

Foliar nematodes enter plants through wounds or natural openings such as stomatal pores on leaves. The method of entry varies among host plants. Inside, they feed on the cells by using a spear-like structure in their mouth called a stylet. They often move internally between cells. Multiplication occurs within the plant tissue by egg laying.

On dendrobiums, these nematodes cause leaf blotches with irregular discolored areas. The epidermis of the infected leaf is often intact and unbroken. On green leaves, the blotches are slightly yellow-brown and become darker brown as the leaf turns yellow and dies. Development of these blotches is relatively slow, and green leaves can remain blotchy for several weeks. On Nobile dendrobiums, the leaves have somewhat rectangular lesions or spots, which are frequently surrounded by yellow tissue. These expand to rot the length of the leaf and are easy to find.

On oncidiums, infected buds are slightly yellow and the sheath covering the buds becomes yellow. Eventually, the buds dry and become deformed as they fail to develop. Infected flower spikes are short and barren. Dark, elongated streaks develop on leaf sheaths covering the bulb. Very thin, black scar tissue forms on leaf sheaths and spikes. These scars represent areas of host tissue that have been damaged by nematode movement and feeding. The dead cells become blackened. On *Vanda* (Papilionanthe) Miss Joaquim, buds become yellow then brown, flowers can have deformed areas which are curled and brown. This symptom is known as “yellow bud.”

In most potted orchids, foliar nematodes reside in the roots of the plant. They feed on root tissues and multiply within infected roots. Plants thus infected may have reduced vigor and be stunted. These symptoms can be confused with poor nutrition or fungal diseases of the root system. These nematodes may also feed on fungi in the rhizosphere.

The numbers of foliar nematodes in infected plant tissue can be high. They may survive in dried buds and spikes for many months. In moist weather, nematodes are commonly present on the plant surface, especially near rotted areas. Water droplets on infected vanda plants may each contain 100–200 nematodes. Nematodes are easily splashed from one plant to another. They also migrate from one plant to another if the environment is moist and plants are kept close together. Foliar nematodes can be carried in drainage water also. Most long-distance movement of foliar nematodes occurs when infected host plants, contaminated soil, or infested potting media are transported to new locations.

Foliar nematodes can remain in potted plants or in field soil for long periods, feeding on roots and fungi in the root zone. They have a wide host range and can spread to many different kinds of plants, including weeds. Dry environments prevent nematode migration and rapid population increases.

While foliar nematodes attack orchids and cause damage, the presence of other nematodes such as *Radopholus*, the burrowing nematode, in the media or root system will prevent the orchids from passing inspection for national or international export. *Radopholus* is a quarantine pest.

Chemical controls:

- Abamectin (Avid, Ardent, Abba, Lucid, Timectin)
  - -Efficacy: good against foliar nematodes, *Aphelenchoides sp.*
  - -Advantages: low concentrations are effective against foliar nematodes, *Aphelenchoides sp.*
  - -Disadvantages: expensive; added cost for treatment

Biological control:

- None

Other pest management aids (cultural controls & others):

Preventing crop contamination is the key to nematode disease control. Moving infected plants under solid cover and controlling irrigation can greatly decrease the level of infestation. During the non-blooming periods, keeping the crop dry discourages nematode survival and multiplication.

- Clean starting material
  When crops are started from clean seeds or tissue-cultured plantlets, they are generally free of pathogenic nematodes. However, they become contaminated by the use of old media from diseased plants, contaminated pots, tags or poor management of diseased and clean plants. Contamination also occurs when clean plants are irrigated with water that drains or splashes from diseased plants.
  -Efficacy: excellent
  -Advantages: avoids the necessity of chemicals; tissue-cultured plants are inexpensive and available from various regions, both domestically and foreign; control measures are unnecessary; starting with healthy plants; and profits are higher
  -Disadvantages: efforts involved with using clean material and plants in an uncontaminated area; cost of starting with clean plants

- Sanitation
  Crop contamination must be prevented. Nursery and production areas must be kept clean. Non-orchid plants may be diseased or infested with foliar nematodes. Growers should keep only clean orchids in the nursery. Any plant with symptoms of nematode infection, such as leaf spots should be removed. Tires of vehicles and footwear of employees may carry nematodes during moist periods, particularly if plant debris is scattered over the roadway or in aisles.
  -Efficacy good to excellent
  -Advantages: reduces the need for chemicals; makes preventing introduction of nematodes easy to accomplish
  -Disadvantages: labor involved: costs for cleanliness and diligence, time to keep the nursery clean

- Isolation
  Other orchid plants introduced to an orchid production area may be diseased or infested. Newly acquired orchid plants should be kept in an isolated area and monitored frequently for disease symptoms for at least six months.
  -Efficacy: good to excellent; very good to excellent if done properly
  -Advantages: prevents contamination of nematode free plants; provides a management option to prevent nematode introduction, especially by suspect plants; keeps the nursery clean and disease free
  -Disadvantages: need for a quarantine area (additional greenhouse space that is located far away from clean production areas); time needed for inspections

- Clean potting media
  Cinders that have been gathered near infected plants may be infested with nematodes. Cinders should be obtained from a cinder source with minimal vegetation.

  If the quality of the cinders is uncertain, it can be fumigated or pasteurized. Also, exposure to high temperatures (above 40°C, 104°F) for 30 minutes kills plant parasitic nematodes; higher temperatures require less time. When using heat to eliminate nematodes, the center of the cinder pile must reach the desired temperature for the required amount of time.

The same sanitation considerations given for cinder apply to all other ingredients of the potting mixture.

Potting media should not be reused or mixed with new materials because it harbors many pathogens and pests that will cause plant diseases. If economic conditions require reuse of media, the media must be pasteurized before reuse.

-Efficacy:	good - excellent
-Advantages:	one step if starting with clean material; if sterilization is done (>185˚F for 30 minutes), then other disease pathogens and weed seeds are killed, too; clean, disease free plants
-Disadvantages:	labor and energy costs, added cost for sterilization equipment, cost of set up and time to pasteurize media

- Raised benches

  For growers producing potted plants for export, the crops must be grown on raised benches. If a new planting area was previously covered with vegetation, the ground is cleared and covered with weed mat and a thick layer of gravel. In existing nurseries, benches with infested plants should be cleared of plants, cleaned, disinfected with an appropriate solution, and allowed to dry. All old roots must be removed. The ground below these benches should be covered with a thick layer of fresh gravel or cinder. Old gravel and soil should be removed from under the benches if the addition of new gravel raises the ground level and the benches become lower than quarantine regulations allow.

-Efficacy:	good to excellent
-Advantages:	required for Burrowing Nematode Certification by HDOA; keeps new plants disease free
-Disadvantages:	costs of materials (benches, weed mat) and inspection fees; time to set up

- Surface disinfection

  Pots, tags, stakes, trays, and tools should be cleaned with soap and water and surface-disinfested with an appropriate disinfecting solution. Disinfecting solutions should be prepared immediately before use and should not be stored. Air bubbles on the surface of pots interfere with nematode kill; a few drops of detergent added to the solution reduce air bubbles. All materials must be dried completely.

-Efficacy:	good to excellent
-Advantages:	meets requirement for HDOA's Burrowing Nematode Certification (must follow HDOA's procedures for Certification); keeps new plants disease free
-Disadvantages:	time required to implement and complete the tasks well

- Barriers

  Snails, slugs, toads, frogs, mice, and other small animals, including pets, can move nematodes into clean fields or onto clean benches. Prevent entry of pests such as toads and eliminate slug, snail, and insect infestations. A dry barrier of gravel without weeds or plants should surround the greenhouse to discourage entry of these pests. The barrier should be at least 5 feet wide because weeds near the field will harbor many pests and make control difficult.

-Efficacy: good

-Advantages: greenhouses are conducive to providing physical barriers; aids in keeping the nursery clean

-Disadvantages: added cost to maintain barrier integrity; time to accomplish

Potential pest management tools and unregistered/new chemistries:

- none

Critical Needs for Management of Nematodes

- Research
  - Chemicals that are effective, safe, and affordable

- Regulatory
  - None identified

- Education
  - Teach growers how to recognize the signs of infestation and control. Provide education on the biology and management of nematodes to growers

Weeds

Weeds: broadleaf weeds and ferns

Severity of crop damage	
Controlled:	0, if controls are applied early
Uncontrolled:	100%
Region(s) where pest is a problem:	statewide
Affects dendrobiums or oncidums or both:	both
Crop stage(s) affected:	all stages
Crop stages at which controls are applied:	all stages
Economic thresholds	
Local market:	when any weed is observed
Export:	when any weed is observed

Weeds are a problem in orchid cultivation for several reasons. Weeds in potted plants are aesthetically unpleasing. Weeds can serve as hosts for insect pests and diseases, and, at high density levels, increase humidity levels. Increased humidity levels enhance environmental conditions for disease development. Weeds compete with orchids for water and nutrients and may also compete with young orchid plants for light. The roots of weeds encroach on the air spaces in the growing medium, which reduces drainage and aeration and may hasten the decomposition of organic media. Weeds are also quarantine pests and may cause rejection of shipments.

Removal of weeds by hand can damage orchid roots and break tender root tips. The damage can be especially serious when the weeds removed are large or mature. Early removal of weeds is critical to avoid competition and prevent damage to orchid roots. Removing weeds before they set seed can minimize if not prevent re-infestation. The importance of weeding when the weeds are immature cannot be overemphasized. For example, a delay in weeding by one month can increase a weed population a thousand fold.

Many weed species have seeds or spores (ferns and mosses) that can be airborne or transported in irrigation water or on tools or clothing. Precautions should be taken to minimize the entry of weed seeds and spores into the growing facility. The area surrounding the facility should be kept weed-free to the extent practical. Water catchment containers should be covered to keep weed seeds and spores out, or a sand filter should be used to screen out weed seeds and spores. Tires should be hosed off before carts and equipment are brought into the growing area. Animals should be kept out of the growing area. (Furry animals transport seeds, and seedlings can sprout from bird droppings.) If a person has been in a weedy area, shoes and clothing should be inspected or changed before entering the growing area. Ferns of any kind should not be grown in or near the production area because they are abundant producers of airborne spores. Organic potting media such as bark, coir, tree fern fiber, peat, and sphagnum moss may contain weed seeds and spores and may need to be treated.

Broadleaf weeds, in general, and ferns are the most important weed pests of potted orchids in Hawai‘i. Artillery plant and bitter cress are among the broadleaves identified as pests that frequently affect orchid production. While they do not present as serious a problem as the broadleaves and ferns, grassy weeds can also present problems for orchid growers.

Chemical controls:

Media for potted orchids in Hawai‘i (screened basaltic gravel, peat and perlite mixes, shredded coconut husks, cubed coconut husks, styrofoam, volcanic cinders or other light materials) are selected because they provide adequate drainage and aeration for short-term production purposes such as potted plants. When an herbicide is applied to plants in such media, the chemical almost immediately drains out of the pot, leaving little product to remain to control weeds. This is particularly problematic because the herbicides labeled for container-grown orchids are preemergence products. There are no postemergence herbicides labeled for use on potted orchids.

- Trifluralin + isoxaben (Snapshot)
  -Efficacy: good
  -Advantages: compatible with IPM programs
  -Disadvantages: preemergence only; not for newly-transplanted nursery stock or pots less than 4”wide; user determines suitability of product on their plants

- Trifluralin + isoxaben + oxyfluorfen (Showcase)
  -Efficacy: good
  -Advantages: compatible with IPM programs
  -Disadvantages: preemergence only; not for newly-transplanted ornamentals or pots less than 4”wide; user determines suitability of product on their plants; injury (leaf burn) possible when applied to wet leaf surfaces.

- Pendimethalin + dimethenamid-P (FreeHand)
  -Efficacy: unknown (new product)
  -Advantages: unknown
  -Disadvantages: unknown

Biological control:

- none

Other pest management aids (cultural controls & others):

- Hand weeding
  -Efficacy: good
  -Advantages: compatible with IPM programs
  -Disadvantages: labor costs; difficult to completely remove all weeds; can damage orchid roots

- Sanitize potting media
  A steam pasteurization unit can be designed and manufactured to provide enough heat to kill weed seeds. Potting media require pasteurization at 180°F for a minimum of 30 minutes. (60 minutes is recommended.) The core temperature of the media must reach the appropriate temperature and be held at that temperature for at least 30 minutes to be effective. As an added benefit, this process will also kill most disease pathogens.
  -Efficacy: fair

-Advantages: cost effective; compatible with IPM programs; also kills most disease pathogens
-Disadvantages: Clean media must be stored and kept clean while in storage.

- Clean water
  Growers may not have access to municipal or other potable water supplies. If not, growers should filter their water to remove weed seeds.
  -Efficacy: good
  -Advantages: cost effective; compatible with IPM programs
  -Disadvantages: filtration process may be difficult

- Weed mats
  Weed mats on the floor of the shade house, or nursery are used to facilitate the removal of soil and other debris.
  -Efficacy: good
  -Advantages: cost effective (in the long run); compatible with IPM programs
  -Disadvantages: high initial cost; disposal issues; life span of plastic mats (600-2300 hours, depending on UV exposure)

- Early removal of weeds
  It is critical to remove weeds while they are still immature (before they set seeds or become reproductive).
  -Efficacy: excellent
  -Advantages: prevents the propagation of more weed seeds; prevents widespread establishment of weed populations
  -Disadvantages: labor and constant attention required; added labor costs; lack of postemergence herbicides labeled for use

- Mulches for top of pots.
  Circles of a material designed to block weed growth are placed in the top of pots. A hole is cut in the circle to allow the plant to grow through.
  -Efficacy: not reported
  -Advantages: long lasting; can be embedded with herbicides
  -Disadvantages: Initial cost and labor involved with placement

Potential pest management tools and unregistered/new chemistries:

- none

Critical Needs for Management of Weeds

- Research
  - Application methods that will integrate herbicide with potting media and maintain availability of the herbicide
  - Procedure to incorporate herbicide with coir or granular material (similar to a fortified mulch) to be applied as a top dressing.

- Regulatory
  - Label diuron for potted orchids, pre- and postemergence.

- Education
  - Continue to educate growers about weed identification and management

Acronyms and Abbreviations

APHIS	Animal and Plant Health Inspection Service (of USDA)
CSREES	Cooperative State Research, Education and Extension Service (see NIFA)
HDOA	Hawai‘i Department of Agriculture
LFA	Little Fire Ant
NASS	National Agricultural Statistics Service
NIFA	National Institute of Food and Agriculture (formerly CSREES)
PMSP	Pest Management Strategic Plan
PQ	Plant Quarantine Branch (of HDOA)
TPSS	Tropical Plant and Soil Sciences
UHM	University of Hawai‘i at Mānoa
USDA	United States Department of Agriculture
WIPMC	Western Integrated Pest Management Center
WPS	Worker Protection Standards

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Appendix 1. Registered Pesticides for Potted Orchids in Hawai‘i

Active Ingredient	Trade name	Company
INSECTICIDES & MITICIDES		
Abamectin	Abamectin	Makhteshim-Agan of North America, Inc.
		Nufarm Americas Inc.
	Avid	Syngenta Crop Protection, Inc.
	Ardent	
	Award II Fire Ant Bait	
	Abba CS	Control Solutions, Inc.
	Lucid	Rotam North America, Inc.
	Timectin 0.15 EC T&O	Tide International, USA, Inc.
Acephate	Acephate 97UP	United Phosphorus, Inc.
	Acephate 90 WDG	Loveland Products, Inc.
	Precise Acephate	Agrium Advanced Technologies (US)
	OrtheneTurf, Tree & Ornamental WSP	Amvac Chemical Corp.
	OrtheneTurf, Tree & Ornamental 97 Spray	
	1300 Orthene	Whitmire Micro-Gen Res. Labs., Inc.
Acephate + Fenpropathrin	Tame/Orthene TR Total Release	Whitmire Micro-Gen Res. Labs., Inc.
Acequinocyl	Shuttle 15	Arysta Lifescience North America, LLC
		OHP, Inc.
Acetamiprid	Tristar	Cleary Chemicals, LLC
		Nippon Soda Company
Azadirachtin	Amazin Plus 1.2% ME	AMVAC Chemical Corp.
	Debug Turbo	Agro Logistic Systems, Inc.
	Azaguard	Biosafe Systems
	Molt-X	Bioworks, Inc.
	Azatin XL	OHP, Inc.
	AzaMax	Parry America Inc.
	Azatrol EC	PBI/Gordon Corp.
	Ornazin	Sepro Corporation

Active Ingredient	Trade name	Company
Bacillus thuringiensis	Agree	Certis USA, LLC
	Crymax Bioinsecticide	
	Deliver	
	Javelin	
	DiPel Pro DF	Valent Biosciences Corp.
	Gnatrol (Disc.)	
	Gnatrol WDG	
	Xentari	
Beauveria bassiana	Botanigard	Laverlam International Corporation
	Mycotrol	
Bifenazate	Floramite SC	OHP, Inc.
Bifenazate + Abamectin	Sirocco	OHP, Inc.
Bifenthrin Q IFA quarantine (potting media) P potting media (other pests) F foliar application	Wisdom Flowable * (Q P F)	AMVAC Chemical Corp.
	Wisdom Nursery Granular (Q P)	
	Qualil-Pro Bifenthrin Nursery 7.9 * (Q P F)	Farmsaver.com LLC
	Quali-Pro Bifenthrin Golf & Nursery 7.9F * (Q P F)	
	Onyxpro * (Q P F)	FMC Corporation Agricultural Products Group
	Talstar Nursery Granular (Q P)	
	Talstar N Granular (Q P)	
	Talstar Select * (Q P F)	
	Bisect G * (Q P)	Loveland Products, Inc.
	Bisect L (Q)	
	Quali-Pro Bifenthrin Golf and Nursery 7.9f * (Q P F)	Makhteshim-Agan of North America, Inc.
	Menace GC 7.9% Flowable * (Q P)	Nufarm Americas Inc.
	Bifen *	Tacoma Ag,LLC
	Up-Star SC Lawn & Nursery * (Q P F)	United Phosphorus, Inc.
	Up-Star Nursery Granular Insecticide (Q P)	
	Attain TR(commercial greenhouses)	Whitmire Micro-Gen Res. Labs., Inc.
Orthoboric Acid	Niban Granular Bait	Nissus Corporation

Active Ingredient	Trade name	Company
Buprofezin	Talus 70DF	Sepro Corporation.
Carbaryl	Sevin 80S	Bayer Environmental Science
	Sevin 80 WSP	
	Sevin RP2	
	Sevin RP4	
	Sevin 4F	
	Sevin SL	
	Carbaryl 4L	Loveland Products, Inc.
		Drexel Chemical Company
	Sevin SL	Prokoz Inc
Clofentezine	Ovation SC	Everris NA, Inc.
		Scotts-Sierra Crop Protection Co.
Chlorfenapyr	Pylon	BASF Corporation
		OHP, Inc.
		Whitmire Micro-Gen Res. Labs., Inc.
Chlorpyrifos Q USDA quarantine D Drench application	Dursban 50W in water soluble packets *	Dow AgroSciences, LLC
	Chlorpyrifos 4E *	Farmsaver.com LLC
	Chlorpyrifos 4E Ag * (Q D)	Makhteshim-Agan of North America, Inc.
	Vulcan * (Q D)	
	Chlorpyrifos SPC 4 (Q)	Nufarm Americas Inc.
	DuraGuard	Whitmire Micro-Gen Res. Labs., Inc.
Chlorpyrifos + Cyfluthrin	Duraplex *	Whitmire Micro-Gen Res. Labs., Inc.
Clofentezine	Ovation	Scotts-Sierra Crop Protection Co.
		Everris NA, Inc.
Cyfluthrin	Decathlon 20 WP	OHP, Inc.
Lambda cyhalothrin	Scimitar GC *	Syngenta Crop Protection, Inc.
	Lambda-CY EC *	United Phosphorus, Inc.
Cyromazine	Citation	Syngenta Crop Protection, Inc.
Deltamethrin	Deltagard GC 5 SC *	Bayer Environmental Science

Active Ingredient	Trade name	Company
Dimethoate	Dimethoate 4E	Cheminova, Inc.
	Dimethoate 4EC Systemic	Drexel Chemical Company
	Dimethoate 400	Loveland Products, Inc.
Dinotefuran	Safari 2 G	Valent U.S.A. Corporation
	Safari 20 SG	
Etoxazole	Tetrasan 5 WDG	Valent Biosciences Corp.
	Beethoven TR	Whitmire Micro-Gen Res. Labs., Inc.
Fenbutatin-oxide	Promite 50WP Miticide *	Sepro Corporation
	Meraz *	United Phosphorus, Inc.
Fenoxycarb	Award Fire Ant Bait (Disc.)	Syngenta Crop Protection, Inc.
	Award II Fire Ant Bait	
Fenpropathrin	Tame 2.4 EC *	Valent U.S.A. Corporation
Fenpyroximate	Akari 5SC Miticide/Insecticide	Sepro Corporation
Fipronil	Taurus G *	Control Solutions, Inc.
Flonicamid	Aria	FMC Corp - Agricultural Products Group
Fluvalinate	Mavrik Aquaflow	Wellmark International
Hexythiazox	Hexygon DF Ovicide/Miticide	Gowan Company
Hydramethylnon	Amdro Pro	Ambrands
		BASF Corporation
	Maxforce	Bayer Environmental Science
Hydramethylnon + S-methoprene	Extinguish Plus	Wellmark International
Imidacloprid	Quali-Pro Imidacloprid 1G Nursery & Greenhouse	Farmsaver.com LLC
	Quali-Pro Imidacloprid 2F Nursery & Greenhouse	
	Malice 2F	Loveland Products, Inc.
	Widow	
	Primeraone Imidacloprid 2F (Disc.)	Makhteshim-Agan of North America, Inc.
	Quali-Pro Imidacloprid 1G Nursery & Greenhouse	
	Quali-Pro Imidacloprid 2F	

Active Ingredient	Trade name	Company
Imidacloprid (*continued*)	Mallet 2F Greenhouse and Nursery (Disc.)	Nufarm Americas Inc.
	Mallet 0.5G	
	Mantra 1G Greenhouse and Nursery	
	Mantra 60 WSP	
	Mallet 2 F T&O	
	Mallet 75 WSP	
	Marathon 1% Granular Greenhouse & Nursery	OHP, Inc.
	Marathon 60 WP Greenhouse and Nursery	
	Marathon II Greenhouse and Nursery Insecticide	
	Lada 2F	Rotam North America, Inc.
	Benefit 60 WP	Everris NA, Inc.
	Imigold 70DF	United Phosphorus, Inc.
Imidacloprid + Cyfluthrin	Discus Nursery Insecticide (Disc.)	OHP, Inc.
	Discus N/G	
Imidan	Imidan	Gowan Company
Kaolin clay	Surround WP Crop Protectant	Tessenderlo Kerley, Inc.
Malathion	Malathion 5EC	Arysta Lifescience North America, LLC
	Malathion 8 Aquamul	Loveland Products Inc.
	Prentox 5 Lb. Malathion Spray	Prentiss Inc.
Metaflumizone	Siesta	BASF Corporation
Methiocarb	Mesurol *	Gowan Company
S-Methoprene	Extinguish Professional Fire Ant Bait	Wellmark International
Methoxyfenozide	Intrepid 2F Agricultural	Dow AgroSciences, LLC
Milbemectin	Ultiflora Miticide*	Gowan Company
Neem extracts/ Cold pressed neem oil + Azadirachtin	Debug Turbo	Agro Logistic Systems, Inc.
Neem extract/neem oil	NimBioSys Neem Oil	The Ahimsa Alternative, Inc.
	Triact	OHP, Inc.
Novaluron	Pedestal	Chemtura Corporation

Active Ingredient	Trade name	Company
Horticultural oils (petroleum & mineral)	Suffoil-X	Bioworks, Inc.
	Biocover UL	Loveland Products, Inc.
	Biocover SS	
	Glacial Spray Fluid	
	Purespray Green	Petro-Canada
	Sunspray Ultra-Fine Spray Oil	Hollyfrontier Refining & Marketing
	Ultra-Pure Oil (9454.224)	Whitmire Micro-Gen Res. Lab, Inc.
Permethrin	Ambush *	AMVAC Chemical Corp.
	Permethrin 3.2 AG* (Disc.)	Arysta Lifescience North America, LLC
	Pounce *	FMC Corporation
	Permethrin *	Loveland Products, Inc.
	Perm-Up *	United Phosphorus, Inc.
Potassium salts of fatty acids (insecticidal soap)	Des-X Insecticidal Soap Concentrate	Certis USA, LLC
	M-Pede	Gowan Company
Potassium silicate	Sil-matrix	PQ Corporation
Pyrethrins	Pyganic Crop Protection EC 1.4 II	McLaughlin Gormley King Company
	Pyganic Crop Protection EC 5.0 II	
Pyridaben	Sanmite	Gowan Company
Pyridalyl	Overture 35 WP	Valent Biosciences Corp.
Pyriproxyfen	Distance Fire Ant Bait	Valent Biosciences Corp.
	Distance Insect Growth Regulator	
Silicon dioxide (diatomaceous earth) + Piperonyl butoxide + Pyrethrins	Perma-guard	Perma-guard, Inc.
Spinosad	Seduce	Certis USA, L.L.C.
	Entrust	Dow AgroSciences, LLC
	Conserve SC	
	Ferti-Lome Come and Get it! Fire Ant Killer	Voluntary Purchasing Group
Spiromesifen	Judo	OHP, Inc.
Spirotetramat	Kontos	OHP, Inc.
Thyme oil + 2-Phenylethyl propionate+ Pyrethrins	EcoPCO WP-X (Disc.)	Prentiss Incorporated

Active Ingredient	Trade name	Company
MOLLUSCICIDES		
Boric acid	NiBan Granular	Nisus Corporation
Copper hydroxide (paint)	Spin Out	Sepro Corporation
Imidan	Imidan 70-W	Gowan Company
Iron phosphate	Sluggo	Certis USA, L. L. C.
	Sluggo	Loveland Products, Inc.
	Leaf Life Sluggo	
Iron phosphate + Spinosad	Bug-n-sluggo	Certis USA, L. L. C.
Methiocarb	Mesurol 75-W *	Gowan Company
Metaldehyde	Deadline Bullets	Amvac Chemical Corp.
	Deadline M-PS Mini Pellets	
	Metaldehyde Granules 3.5	
	Metaldehyde Granules 7.5	
	Metarex	Liphatech, Inc.
	Slug-fest (Disc.)	Or-Cal, Inc.
	Slug & Snail Bait (Disc.)	
Sodium Ferric EDTA	IronFist	Engage Agro USA, LLC
	Ferroxx	W. Neudorff GmbH KG

Active Ingredient	Trade name	Company
RODENTICIDES & OTHER VERTEBRATE CONTROLS		
Brodifacoum	Final All-Weather Blox	Bell Laboratories, Inc.
	Final Ready-to-Use Place Pac	
	Final Soft Bait	
	Formus All-Weather Blox	
	Ropax Bait Pack	Fort Dodge Animal Health, Inc.
	Havoc Pellets	Hacco, Inc.
	Havoc XT Blok	
	Jaguar	Motomco
	Jaguar All-Weather Bait Chunx	
	Jaguar Place Pac	
	Jaguar Soft Bait	
	Talon G	Syngenta Crop Protection, LLC
	Weatherblok XT	

Active Ingredient	Trade name	Company
Bromadiolone	Contrac All-Weather Blox	Bell Laboratories, Inc.
	Contrac All-Weather Cake	
	Contrac Bulk Pellets	
	Contrac with Lumitrack	
	Contrac Rat & Mouse Bait	
	Contrac Rat & Mouse Bait Ready to Use Place Pacs	
	Contrac Rodenticide Place Pacs	
	Contrac Rodenticide Ready-to-use Place Pacs	
	Contrac Super-size Blox	
	Rodenthor Block Bait	Ensystex II, Inc.
	Boot Hill Mini Blocks	Liphatech, Inc.
	Boot Hill Paraffin Blocks	
	Boot Hill Paraffinized Pellets	
	Boot Hill Pellets Place Packs	
	Maki Mini Blocks	
	Maki Paraffin Blocks	
	Maki Paraffinized Pellets	
	Maki Pellets Place Packs	
	Resolv Soft Bait	
	Revolver Soft Bait	
	Hawk	Motomco
	Hawk All-Weather Bait Chunx	
	Hawk Rodenticide Ready-to-use Place Pacs	
	Brigand SB Soft Bait	Pelgar International Ltd.
	Brigand WB Agricultural Use	
	Brigand WB Wax Block	
	Rodentex Rat & Mouse Bait Place Packs	Wellmark International
	Rodentex Rat & Mouse Bait Chunks	
Bromethalin	Fastrac All-Weather Blox	Bell Laboratoares, Inc.
	Fastrac Pellets	
	Fastrac Place Pacs	
	Top Gun All Weather Bait Block	J. T. Eaton & Co., Inc.
	Top Gun Pellet Place Pack	

Active Ingredient	Trade name	Company
Bromethalin (*continued*)	Just One Bite Ex Bait Blocks	Farnam Companies, Inc.
	Just One Bite Pellet Place Packs	
	CyKill Blocks	Hacco, Inc.
	CyKill Place Packs	
	Gunslinger Mini Blocks	Liphatech, Inc.
	Gunslinger Placepacks (Disc.)	
	Rampage All-Weather Bait Chunx	Motomco
	Rampage Meal Bait	
	Rampage Place Pacs	
	Rampage Pelleted Bait	
	Rampage Pellets	
	Tomcat Bait Chunx	
	Tomcat Pelleted Bait	
	Tomcat Place Pacs	
	Real-Kill Mouse Killer Place Packs	Realex
	Real-Kill Rat Killer Place Packs	
	Real-Kill Rat & Mouse Killer All Weather Bars	
	Victor V Fast-Kill Pellets II	Woodstream Corporation
	Victor V Fast-Kill Blocks II	
Chlorophacinone	AC Formula 90	J.T. Eaton & Co., Inc.
	Rozol Mini Blocks	Liphatech, Inc.
	Rozol Pellets	
Cholecalciferol	Terad3 Pellets	Bell Laboratories, Inc.
	Terad3 Ag Blox	
	Terad3 Ag Pellets	
	Terad3 Blox	
	Agrid3 Bait Chunx	Motomco
	Agrid3 Pelleted Bait	
Citric acid	Citric acid anhydrous	Various companies
Difenacoum	Sorexa Blocks	Whitmire Micro-Gen Res. Labs., Inc.
	Multi-Kill Blocks II	Woodstream Corporation
Difethialone	FastDraw Soft Bait	Liphatech, Inc.
	FirstStrike Soft Bait	
	Generation Mini Blocks	
	Generation Pellets	

Active Ingredient	Trade name	Company
Difethialone (*continued*)	Generation Pellets Place Packs	Liphatech, Inc. (*continued*)
	Generation BlueMax Meal Bait	
	Generation BlueMax Mini Blocks	
	Hombre Mini Blocks	
	Hombre Pellets	
	Hombre Pellets Place Packs	
Diphacinone	Ditrac	Bell Laboratories, Inc.
	Ditrac Tracking Powder *	
	Ditrac All-Weather Blox	
	Ditrac All-Weather Cake	
	Bait Block (peanut butter and apple flavors)	J. T. Eaton & Co., Inc.
	Rodentex Multi-Feed Bars	Farnam Companies, Inc.
	Ramik Green	Hacco, Inc.
	Ramik Green (Disc.)	
	Ramik Green Mini Bait Packs	
	Ramik Bars All-Weather Rat & Mouse Killer	
	Ramik Mini Bars	
	Harris All-Weather Rat & Mouse Killer	P. F. Harris Manufacturing Company, LLC
	Tomcat All-Weather Bait Chunx	Motomco
	Tomcat All-Weather Rodent Block	
	Tomcat Rat and Mouse Bait	
	Tomcat Rat and Mouse Bait Place Pac	
Methyl anthranilate	Bird Shield Repellent Concentrate	Bird Shield Repellent Corporation
Zinc Phosphide	ZP Rodent Bait AG *	Bell Laboratories, Inc.
	ZP Rodent Oat Bait AG *	
	ZP Ag Pellets *	
	Eraze Rodent Pellets	Motomco
	ZP AG Oats *	
	Zinc Phosphide Oat Bait *	Hacco, Inc.
	Zinc Phosphide Pellets *	

Active Ingredient	Trade name	Company
FUNCTIONS		
Quaternary ammonium chlorides	Physan 20	Maril Products, Inc.
	Kleengrow	Pace 49 Inc.
	Consan 20	Voluntary Purchasing Groups, Inc.
Azoxystrobin	Heritage	Syngenta Crop Protection, LLC.
Bacillus amyloliquefaciens strain D747	Double Nickel 55	Certis USA, L.L.C.
	Double Nickel LC	
Bacillus subtilis GB03	Companion	Growth Products, Ltd.
QST 713 strain of *Bacillus subtilis*	Rhapsody	AgraQuest, Inc.
	Cease	Bioworks, Inc.
Captan	Captan 50	Arysta Lifescience North America, LLC.
	Captec 4L	
	Captan 50W	Drexel Chemical Company
Chlorothalonil	Chlorothalonil 82.5% WDG	Arysta Lifescience North America, LLC
	Ensign 82.5%	Loveland Products, Inc.
	Initiate 720 Flowable	
	Daconil Ultrex	Syngenta Crop Protection, Inc.
	Docket DF	
Chlorothalonil + Propiconazole	Protocol	Loveland Products, Inc.
Chlorothalonil + Thiophanate-methyl	Spectro 90 WDG	Cleary Chemicals, LLC
	TM/C WDG (Disc.)	Makhteshim-Agan of North America, Inc.
Chlorothalonil + Iprodione + Thiophanate-methyl + Tebuconazole	Enclave Flowable	Control Solutions, Inc.
Copper hydroxide	Nu-Cop 3L (Disc.)	Albaugh, Inc.
	Nu-Cop HB	
	Nu-Cop 50 DF (Disc.)	
	Nu-Cop 50WP (Disc.)	
	Champ Formula 2	Nufarm Americas, Inc., Agt Div.
	Champion WG	
	CuPRO T/N/O 2005	Sepro Corporation
	Spin Out Root Growth Regulator	
Copper hydroxide + Mancozeb	Junction	Sepro Corporation
	Junction WSP	
Basic copper sulfate	Cuproxat Flowable	Nufarm Limited
	Cuprofix Ultra 40 Disperss	United Phosphorus, Inc.

Active Ingredient	Trade name	Company
Copper sulfate pentahydrate	Phyton 27	Phyton Corporation
	Phyton 35	
Cyazafamid	Segway	FMC Corporation
Dazomet	Basamid G *	Certis USA, L.L.C
Didecyl dimethyl ammonium chloride	Kleengrow	Pace 49 Inc.
Dimethomorph	Stature SC	BASF Corporation
Etridiazole	Terrazole 35% Wettable Powder	Chemtura Corporation
	Truban 30 WP	Everris NA, Inc.
	Truban 25 EC	
	Terrazole L	OHP, Inc.
	Truban 25 EC	Scotts-Sierra Crop Protection Co.
Fludioxonil	Medallion	Syngenta Crop Protection, Inc.
	Medallion WDG	
	Mozart (greenhouse)	Whitmire Micro-Gen Research Labs, Inc.
Fludioxonil + Mefenoxam	Hurricane (Disc. In 2014)	Syngenta Crop Protection, Inc.
Fluoxastrobin	Disarm 480 SC	Arysta LifeScience North America, LLC
	Disarm G	
	Disarm O	OHP, Inc.
Flutolanil	ProStar 70 WG	Bayer Environmental Science
	ProStar 70 WDG	
	Contrast 70 WSP (Disc.)	Scotts-Sierra Crop Protection Co.
Fosetyl-Al	Aliette WDG	Bayer Environmental Science
	Fosetyl-Al 80 WDG	Makhteshim Agan of North America, Inc.
	Flanker	Tessenderlo Kerley, Inc.
Furfural	Multiguard Protect	Agriguard Company
Gliocladium virens	SoilGard	Certis USA, L.L.C.
Hydrogen peroxide	Zerotol	BioSafe Systems LLC
Hydrogen peroxide + Peroxyacetic acid	Oxidate 2.0	BioSafe Systems LLC
	ZeroTol 2.0	
Hydrogen peroxide + Peroxyacetic acid + Octanoic acid	X3	Phyton Corporation
	Xeroton	
Imazalil	Fungaflor (Disc.)	Whitmore Micro-Gen Research Labs, Inc.

Active Ingredient	Trade name	Company
Iprodione	26019	Bayer Environmental Science
	Ipro 2SE	Makhteshim-Agan of North America, Inc.
	Iprodione 2SE (Disc.)	
	Iprodione SPC	Nufarm Americas, Inc., Agt Div.
	26 GT-O (Disc.)	OHP, Inc.
	26019	
Iprodione + Thiophanate-methyl	TM+IP SPC	Nufarm Americas,Inc.
	26/36	
Mancozeb	Protect	Cleary Chemicals, LLC
	Dithane 75DF Rainshield	Dow Agrosciences, LLC
	Dithane WF Rainshield Turf and Ornamental	
	Fore 80WP Rainshield	
	Junction	Sepro Corporation
	Junction WSP	
	Pentathlon DF	
	Pentathlon LF	
	Manzate Flowable T&O	United Phosphosphorus, Inc.
	Manzate Max T&O	
	Manzate Pro-Stick T&O	
Mandipropamide	Micora	Syngenta Crop Protection, LLC
Mefenoxam (Metalaxyl)	Mefenoxam 2 AQ	Makhteshim-Agan of North America, Inc.
	Ariel	Syngenta Crop Protection, LLC
	Subdue GR	
	Subdue Maxx	
	Subdue WSP	
	Metastar 2E	LG International (America), Inc.
Oils (petroleum & mineral)	Tritek	Brandt Consolidated
	Suffoil-X	Bioworks, Inc.
	Sunspray Ultra-Fine Spray Oil	Hollyfrontier Refining & Marketing
PCNB (Pentachloronitro benzene)	Turf & Ornamental Fungicide containtaining 10% Terraclor (Disc. 12/31/2014)	Voluntary Purchasing Groups, Inc.

Active Ingredient	Trade name	Company
Phosphorous acid (Mono- and di- potassium salts of phosphorous acid)	Alude	Cleary Chemicals, LLC
	Fosphite	JH Biotech, Inc.
	Agri-Fos	Liquid Fertilizer Pty. Ltd.
	Phorcephite	Loveland Products, Inc.
	Rampart	
	Phostrol	Nufarm Americas Inc.
Polyoxin D	Affirm WDG	Cleary Chemicals LLC
	Veranda	OHP, Inc.
Potassium bicarbonate	Kaligreen	Otsuka Agritechno Co., Ltd.
Mono potassium phosphate + Sulfur	Sanction	Loveland Products, Inc.
Potassium silicate	Sil-matrix	PQ Corp.
Propiconazole	Propiconazole 41.8% EC	Amtide, LLC
	Fitness	Loveland Products, Inc.
	Procon-Z	
	Primeraone Propiconazole 14.3	Makhteshim-Agan of North America, Inc.
	Propiconazole SPC 14.3 MEC	Nufarm Americas Inc.
	Strider	
	ProPensity 1.3 ME	Sipcam Agro USA, Inc.
	Banner Maxx	Syngenta Crop Protection, LLC
	Banner Maxx II	
Pyraclostrobin	Insignia	BASF Corporation
	Pageant	
Quillaja Saponin	Nema-Q	Brandt Consolidated
Reynoutria sachalinensis	Regalia PTO	Marrone Bio Innovations
Sodium chlorite	Selectrocide 2L500	Selective Micro Technologies, LLC
	Selectrocide 12G	
Sodium hypochlorite	Clorox Commercial Solutions Clorox Germicidal Bleach1	The Clorox Professional Products Co.
Streptomyces lydicus	Actinovate SP	Natural Industries Inc.
Streptomycin sulfate	Agri-Mycin 17	Nufarm Americas, Inc.
Tebuconazole	Torque	Cleary Chemicals, LLC
	Monsoon	Loveland Products, Inc.
	Tebuconazole 3.6 F	Makhteshim-Agan of North America, Inc.
	Offset 3.6F	Rotam North America, Inc.

Active Ingredient	Trade name	Company
Thiophanate-methyl	3336 DG Lite	Cleary Chemicals, LLC
	3336 EG	
	3336 F	
	3336 G	
	3336 GC	
	3336 WP	
	Incognito 85 WDG	Makhteshim-Agan of North America, Inc.
	TM 4.5	
	TM 85 WDG	
	OHP 6672 4.5 F	OHP, Inc.
	OHP 6672 50 WP	
	T-Methyl SPC 4.5 F	Nufarm Americas Inc.
	T-Methyl SPC 50 WSB	
	T-Storm Flowable	
	Transom 4.5 F	Prokoz Inc.
	Transom 50 WSB	
	Allban 50 WSB	Scotts-Sierra Crop Protection Co.
	Allban Flo	
	FungoFlo	United Phosphorus, Inc.
	Primera One 4.5	
Thiophanate-methyl + Etridiazole	Banrot	Scotts-Sierra Crop Protection Co.
Triadimefon	Bayleton Flo	Bayer Environmental Science
	Strike 50 WDG	OHP, Inc.
Trichoderma harzianum	RootShield	Bioworks, Inc.
	RootShield WP	
Trichoderma harzianum + *Trichoderma virens*	RootShield Plus Granules	Bioworks, Inc.
	RootShield Plus WP	
Trifloxystrobin	Compass 0 50 WDG	OHP, Inc.
Trifloxystrobin + Triadimefon	Strike Plus 50 WDG	OHP, Inc.
Triflumizole	Terraguard SC	Chemtura Corporation
Triticonazole	Trinity (supplemental label)	BASF Corporation
	Trinity TR	Whitmore Micro-Gen Research Lab, Inc.
Yeast extract hydrolysate from *Saccharomyces cerevisiae*	KeyPlex 350 OR	Keyplex

Active Ingredient	Trade name	Company
HERBICIDES (Pre-emergence)		
Benefin + Oryzalin	Surflan XL 2G	United Phosphorus, Inc.
Dimethenamid-P	Tower	BASF Corporation
Dithiopyr	Dimension 0.25G	The Andersons Lawn Fertiliizer Div., Inc.
	Dithiopyr 2L	Control Solutions, Inc.
	Dimension 2EW	Dow Agrosciences, LLC
	Dimension Ultra 40WP	
	Dimension 270G Specialty	J. R. Simplot Co.
Isoxaben	Gallery 75 Dry Flowable	Dow Agrosciences, LLC
Oryzalin	Oryzalin Coated Granules	Loveland Products, Inc.
	Surflan A.S.	United Phosphorus, Inc.
	Surflan WDG	
Oxadiazon	Fertilizer with 1% Oxadiazon (waiting for label)	Loveland Products, Inc.
Oxadiazon+ Pendimethalin	Jewel	Everris NA, Inc.
	Jewel (Disc.)	Scotts-Sierra Crop Protection Co.
Oxyfluorfen + Oryzalin	Rout	Everris NA, Inc.
		Scotts-Sierra Crop Protection Co.
Pendimethalin	Coral 2.68G	The Scotts Company
	Pendulum 2G	BASF Corporation
	Pendulum 3.3 EC	
	Pendulum Aquacap	
Pendimethalin + Dimethenamid-P	FreeHand 1.75G	Dow Agrosciences, LLC
Prodiamine	ProcClipse 4F	Nufarm Americas Inc
	ProClipse 65 WDG	
	Barricade 4FL	Syngenta Crop Protection, Inc.
	Barricade 65 WG	
	Endurance	
	Resolute 4FL	
	Resolute 65WG	
Prodiamine + Isoxaben	Gemini 3.7 SC	Everris NA, Inc.
Trifluralin	Trifluralin 10G	Loveland Products, Inc.
Trifluralin + Isoxaben	Snapshot DG (Disc.)	The Andersons Lawn Fertiliizer Div., Inc.
	Snapshot 2.5 TG	Dow Agrosciences, LLC
	Snapshot DG	
	T/I 2.5 G	Makhteshim-Agan of North America, Inc.

Active Ingredient	Trade name	Company
Trifluralin + Isoxaben + Isoxben	Showcase	Dow Agrosciences, LLC
Active Ingredient	**Trade name**	**Company**
ALGAECIDES		
Hydrogen peroxide + Peroxyacetic acid	ZeroTol 2.0	BioSafe Systems LLC
Sodium chlorite	Selectrocide 2L500	Selective Micro Technologies, LLC
	Selectrocide 12G	
Sodium percarbonate	GreenClean Pro	BioSafe Systems LLC
Active Ingredient	**Trade name**	**Company**
FUMIGANTS		
Dazomet (soil media)	Basamid G *	Amvac Chemical Corp.
	Basamid G *	Certis USA, L.L.C.
PLANT GROWTH REGULATORS		
Abscisic acid	Contego Pro SL	Valent Biosciences Corporation
Ancymidol	Abide	Fine Americas, Inc.
	A-rest	Sepro Corporation
6-Benzylademine	Riteway	Nufarm, Inc.
	Configure (supplemental label)	Fine Americas, Inc.
Chlormequat chloride	Citadel	Fine Americas, Inc.
	Chlormequat SPC (greenhouse use)	Nufarm Americas Inc.
	Cycocel	OHP, Inc.
Copper hydroxide	Spin Out	Sepro Corporation
Cyclanilide	Tiberon SC (Disc.)	Bayer Environmental Science
Cyclopropene, 1-methyl-	Ethylbloc	Floralife, Inc.
	Ethylbloc Sachet	
Cytokinin	Foliar Triggrr	Westbridge Ag Products
	Soil Triggrr	
Cytokinin + indolebutyric acid	Radiate	Loveland Products, Inc.
Daminozide	B-Nine WSG	Chemtura Corporation
	Dazide 85 WSG	Fine Americas, Inc.
	B-Nine WSG	OHP, Inc
Dikegulac sodium	Augeo	OHP, Inc.

Active Ingredient	Trade name	Company
Ethephon	Florel	Lawn & Garden Products, Inc.
Flurprimidol	Topflor	Sepro Corporation
Gibberellic acid	N-Large	Stoller Enterprises, Inc.
Gibberellic acid + N6-Benzyladenine	Fascination	Valent Biosciences Corporation
Gibberellic acid + Kinetin	Green-sol 48	Green Sol, Inc.
Paclobutrazol	Piccolo	Fine Americas, Inc.
	Piccolo 10 XC	
	Paczol	OHP, Inc
	Bonzi	Syngenta Crop Protection, Inc.
	Paclo Pro	
	Bush Load Paclo 0.4%	Water Environmental Technologies, Inc.
	Paclo	Zhejiang Tide Cropscience Co., Ltd.
Uniconazole	Concise	Fine Americas, Inc.
	Sumagic	Valent U.S.A. Corporation

* Restricted Use Pesticide (RUP)

Appendix 2. Efficacy of Pest Management Tools for Control of Insects and Other Invertebrate Pests on Potted Orchids in Hawai‘i

Management Tool	Pest													Comments
	Critical Insect & Mite Pests				*Lower-impact insect pests*							*Other Invertebrate Pests*		
	Mites	Mealybugs	Thrips	Blossom Midge	Aphids	Black twig borer	Bugs	Fungus gnats/ Shore flies	Orchid Weevils	Scales	Whiteflies	Ants	Snails & Slugs	
Registered Pesticides														
Abamectin	G [N]	–	P-G*	G	–	–	–	–	–	–	–	–	–	[N] against nymphs & adults * against greenhouse thrips, melon & western flower thrips
Acephate	–	–	F*	F[1] – G[2]	G	–	–	–	G	–	–	–	–	* against melon & western flower thrips [1] overall [2] against adults
Acephate + Fenpropathrin	–	–	–	–	–	–	–	–	–	–	–	–	–	For commercial greenhouses
Acetamiprid	–	G	–	–	?	–	–	-	–	-	?	-	–	
Acequinocyl	E	–	–	–	–	–	–	–	–	–-	–	–	–	
Azadirachtin	–	–	–	–	–	–	–	–-	–	–	–	–	–	
Bacillus thuringiensis	–	–	–	–	–	–	–	–	–	–	–	–	–	
Beauveria bassiana	–	–	?	–	–	–	–	–	–	–	–	–	–	

Management Tool	Pest													Comments
	Critical Insect & Mite Pests				Lower-impact insect pests							Other Invertebrate Pests		
	Mites	Mealybugs	Thrips	Blossom Midge	Aphids	Black twig borer	Bugs	Fungus gnats/ Shore flies	Orchid Weevils	Scales	Whiteflies	Ants	Snails & Slugs	
Registered Pesticides (*continued*)														
Bifenazate	?	-	-	-	-	-	-	-	-	-	-	-	-	Some reports of low efficacy
Bifenazate + abamectin	-	-	-	-	-	-	-	-	-	-	-	-	-	
Bifenthrin	-	G	G*	-	G	?	-	-	G	-	?	? F	-	* against dendrobium & vanda thrips and greenhouse thrips F Imported fire ant quarantine treatment; potting media; some products RUP; Some products for greenhouse use
Orthoboric acid	-	-	-	-	-	-	-	-	-	-	-	G*	-	* for sugar-feeding ants; " except fire ants"
Buprofezin	-	G	-	-	-	-	-	-	-	F - G	?	-	-	
Carbaryl	-	-	-	-	-	-	-	-	-	?	-	?	-	
Chlorfenapyr	E	-	E	-	-	-	-	-	-	-	-	-	-	Greenhouse only
Chlorpyrifos	-	G	G	G*	G	G	-	-	G	-	?	-	-	* against adults
Chlorpyrifos + cyfluthrin	-	-	-	-	-	-	-	-	-	-	-	-	-	Greenhouse only
Clofentezine	G*	-	-	-	-	-	-	-	-	-	-	-	-	* Effective against eggs only

Management Tool	Pest: Critical Insect & Mite Pests: Mites	Mealybugs	Thrips	Blossom Midge	Lower-impact insect pests: Aphids	Black twig borer	Bugs	Fungus gnats/ Shore flies	Orchid Weevils	Scales	Whiteflies	Other Invertebrate Pests: Ants	Snails & Slugs	Comments
Registered Pesticides (*continued*)														
Copper hydroxide paint	-	-	-	-	-	-	-	-	-	-	-	-	-	
Cyfluthrin	-	G	P-G*	?	G	?	-	-	?	-	?	?[B]	-	* against dendrobium & vanda thrips, greenhouse thrips [B] barrier treatment
Lambda cyhalothrin	-	-	-	-	-	-	-	-	-	-	-	?[B]	-	[B] barrier treatment
Cyromazine	-	-	-	-	-	-	-	-	-	-	-	-	-	
Dazomet	-	-	-	-	-	-	-	-	-	-	-	-	-	
Deltamethrin	-	-	-	-	-	-	-	-	-	-	-	?[B]	-	[B] barrier treatment
Dimethoate	F	F	F	G[A]	-	-	-	-	?	-	?	-	-	[A] against adults
Dinotefuran	-	G	?	?	-	-	-	-	-	F - G	?	-	-	
Etoxazole	G*	-	-	-	-	-	-	-	-	-	-	-	-	Beethoven is for greenhouse use * against eggs & nymphs
Fenbutatin-oxide	G	-	-	-	-	-	-	-	-	-	-	-	-	
Fenoxycarb	-	-	-	-	-	-	-	-	-	-	-	-	-	Preclude is for greenhouse use

Management Tool	Pest													Comments
	Critical Insect & Mite Pests				*Lower-impact insect pests*							*Other Invertebrate Pests*		
	Mites	Mealybugs	Thrips	Blossom Midge	Aphids	Black twig borer	Bugs	Fungus gnats/ Shore flies	Orchid Weevils	Scales	Whiteflies	Ants	Snails & Slugs	
Registered Pesticides (*continued*)														
Fenpropathrin	-	-	-	-	-	-	-	-	-	-	-	?[B]	-	[B] barrier treatment
Fenpyroximate	?	-	-	-	-	-	-	-	-	-	-	-	-	
Fipronil	-	-	-	-	-	-	-	-	-	-	-	G	-	
Flonicamid	-	-	-	-	-	-	-	-	-	-	-	-	-	
Fluvalinate	-	-	-	-	-	-	-	-	-	?	-	-	-	
Dinotefuran	-	-	-	-	-	-	-	-	-	F - G	?	-	-	
Hexythiazox	G*	-	-	-	-	-	-	-	-	-	-	-	-	* Effective against eggs only
Hydramethylnon	-	-	-	-	-	-	-	-	-	-	-	-	-	
Hydramethylnon + methoprene	-	-	-	-	-	-	-	-	-	-	-	-	-	
Imidacloprid	-	F[1]-G[2]	G	-	?	-	-	-	-	F	?	-	-	[1]foliar application [2]drench application
Imidacloprid + cyfluthrin	-	G	-	-	-	?	-	-	?	F - G	?	-	-	
Imidan	-	-	-	-	-	-	-	-	-	-	-	-	-	

Management Tool	Pest													Comments
	Critical Insect & Mite Pests				*Lower-impact insect pests*							*Other Invertebrate Pests*		
	Mites	Mealybugs	Thrips	Blossom Midge	Aphids	Black twig borer	Bugs	Fungus gnats/ Shore flies	Orchid Weevils	Scales	Whiteflies	Ants	Snails & Slugs	
Registered Pesticides (*continued*)														
Iron phosphate	-	-	-	-	-	-	-	-	-	-	-	-	-	
Iron phosphate + spinosad	-	-	-	-	-	-	-	-	-	-	-	-	-	
Kaolin clay	-	-	-	-	-	-	-	-	-	-	-	-	-	Suppression only
S-Kinoprene	-	-	-	-	-	-	-	-	-	-	-	-	-	
Malathion	F	P-G	P-F*	?	-	-	?	-	?	-	?	-	-	* against dendrobium & vanda thrips, geeen house thrips
Metaldehyde	-	-	-	-	-	-	-	-	-	-	-	-	G	Some products for greenhouse use
Metaflumizone	-	-	-	-	-	-	-	-	-	-	-	-	-	
Methiocarb	-	-	G*	-	-	-	-	-	-	-	-	-	G	* against melon & western flower thrips
S-methoprene	-	-	-	-	-	-	-	-	-	-	-	-	-	
Methoxyfenozide	-	-	-	-	-	-	-	-	-	-	-	-	-	
Milbemectin	-	-	-	-	-	-	-	-	-	-	-	-	-	
Neem extract/Neem oil	-	-	-	-	-	-	-	-	-	-	-	-	-	

Management Tool	Pest													Comments
	Critical Insect & Mite Pests				Lower-impact insect pests							Other Invertebrate Pests		
	Mites	Mealybugs	Thrips	Blossom Midge	Aphids	Black twig borer	Bugs	Fungus gnats/ Shore flies	Orchid Weevils	Scales	Whiteflies	Ants	Snails & Slugs	
Registered Pesticides (*continued*)														
Neem extract/Neem oil + azadirachtin	-	-	-	-	-	-	-	-	-	-	-	-	-	Greenhouse ornamentals
Novaluron	-	-	G-E	-	-	-	-	-	-	-	-	-	-	
Horticultural oils (petroleum & mineral)	-	F	-	-	?	-	-	-	-	P – G*	?	-	-	* when spray is targeted properly
Permethrin	-	-	-	-	-	-	-	-	-	-	-	?[B]	-	[B] barrier treatment
Potassium salts of fatty acids (insecticidal soap)	-	-	-	-	G	-	-	-	-	-	?	-	-	
Potassium silicate	-	-	-	-	-	-	-	-	-	-	-	-	-	
Pyrethrins	-	-	-	-	-	-	-	-	-	-	-	-	-	
Pyridaben	G *	-	-	-	-	-	-	-	-	-	-	-	-	* Against nymphs & adults
Pyridalyl	-	-	?	-	-	-	-	-	-	-	-	-	-	For use in greenhouses only
Pyriproxyfen	-	-	-	-	-	-	-	-	-	F - G	?	-	-	
Silicon dioxide	-	-	-	-	-	-	-	-	-	-	-	-	-	

Management Tool	Pest													Comments
	Critical Insect & Mite Pests				Lower-impact insect pests							Other Invertebrate Pests		
	Mites	Mealybugs	Thrips	Blossom Midge	Aphids	Black twig borer	Bugs	Fungus gnats/ Shore flies	Orchid Weevils	Scales	Whiteflies	Ants	Snails & Slugs	
Registered Pesticides (*continued*)														
Spinosad	P	-	P*-G	F	-	-	-	-	-	-	-	-	-	
Spirotetramat	?	G	-	-	-	-	-	-	-	-	-	-	-	
Thyme oil + 2-Phenylethyl propionate+ pyrethrins	-	-	-	-	-	-	-	-	-	-	-	-	-	
Unregistered Materials														
Endosulfan (Thionex * SLN HI-070006)	-	-	E	-	-	-	-	-	-	-	-	-	-	*expired 07/31/2012
Potential Pest Management Tools														
Entomopathogenic fungi such as *Paecilomyces fumosoroseus*	-	-	?	-	-	-	-	-	-	-	-	-	-	

Management Tool	Pest													Comments
	Critical Insect & Mite Pests				Lower-impact insect pests							Other Invertebrate Pests		
	Mites	Mealybugs	Thrips	Blossom Midge	Aphids	Black twig borer	Bugs	Fungus gnats/ Shore flies	Orchid Weevils	Scales	Whiteflies	Ants	Snails & Slugs	
Biological Controls (naturally occurring)														Aids to pest control; not used as a sole pest control tactic
Pirate bugs	-	-	? *	-	-	-	-	-	-	-	-	-	-	* Thrips are controlled when there is a ratio of 20 thrips to 1 minute pirate bug (*Orius* spp.)
Predatory mites	?	-	? *	-	-	-	-	-	-	-	-	-	-	
Parasites (general, unspecified)	-	?	-	-	-	-	?	-	-	-	-	-	-	
Predatory midges	-	?	-	-	-	-	-	-	-	-	-	-	-	
Predators (general, unspecified)	?	-	-	?	-	-	-	-	-	-	-	-	-	
Ladybird beetles	-	-	-	-	?	-	-	-	-	?	-	-	-	
Lacewings	-	-	-	-	?	-	-	-	-	-	-	-	-	
Parasitic wasps	-	-	-	-	?	-	-	-	-	?	?	-	-	
Syrphid flies	-	-	-	-	?	-	-	-	-	-	-	-	-	
Fungi	-	-	-	-	-	-	-	-	-	?	-	-	-	

Management Tool	***Pest***													Comments
	Critical Insect & Mite Pests				***Lower-impact insect pests***							***Other Invertebrate Pests***		
	Mites	**Mealybugs**	**Thrips**	**Blossom Midge**	**Aphids**	**Black twig borer**	**Bugs**	**Fungus gnats/ Shore flies**	**Orchid Weevils**	**Scales**	**Whiteflies**	**Ants**	**Snails & Slugs**	
Biological Controls (naturally occurring) (*continued*)														
Predatory snails	-	-	-	-	-	-	-	-	-	-	-	-	?	
Predatory flatworms	-	-	-	-	-	-	-	-	-	-	-	-	?	
Toads	-	-	-	-	-	-	-	-	-	-	-	-	?	
Chickens, ducks & other birds	-	-	-	-	-	-	-	-	-	-	-	-	?	
Cultural/Nonchemical Controls														
Despiking (removal of infested spikes)	-	-	F	-	-	-	-	-	-	-	-	-	-	
Inspect roots (early detection)	-	G	-	-	-	-	-	-	-	-	-	-	-	
Avoid root-bound plants	-	G	-	-	-	-	-	-	-	-	-	-	-	
Sanitation (remove & destroy infested plants)	?	G	-	-	?	G	-	-	G	G	-	-	-	
Removal of alternate hosts with creation of buffer zones	-	G	-	-	-	-	?	-	-	-	?	-	-	
Ant control	-	G	-	-	G	-	-	-	-	G	-	-	-	

Management Tool	Pest													Comments
	Critical Insect & Mite Pests				*Lower-impact insect pests*							*Other Invertebrate Pests*		
	Mites	Mealybugs	Thrips	Blossom Midge	Aphids	Black twig borer	Bugs	Fungus gnats/ Shore flies	Orchid Weevils	Scales	Whiteflies	Ants	Snails & Slugs	
Cultural/Nonchemical Controls (*continued*)														
Isolation (quarantine of infested plants)	-	G	-	-	-	-	-	-	-	-	-	-	-	
Avoid broad-spectrum insecticides	G?	-	-	-	-	-	-	-	-	-	-	-	-	
Overhead irrigation	F	-	-	-	-	-	-	-	-	-	-	-	-	
Removal of infested buds	-	-	-	?	-	-	-	-	-	-	-	-	-	
Pest-free propagation material/planting material	-	-	-	-	-	-	-	-	-	G	-	-	-	
Pruning and plant spacing	-	-	-	-	-	-	-	-	-	G	-	-	-	
Maintain plant health	-	-	-	-	-	G	-	-	F	-	-	-	-	
Destruction of hiding places	-	-	-	-	-	-	-	-	-	-	-	-	G	If done consistently & frequently
Removal of plant debris	-	-	-	-	-	-	-	-	-	-	-	-	G	If done consistently & frequently
Copper barriers	-	-	-	-	-	-	-	-	-	-	-	-	G - E	If maintained and pest-free plants are used and introduced
Exclusion/quarantine of new or pest-infested plants	-	-	-	-	-	-	-	-	-	-	-	-	G	

Management Tool	Pest													Comments
	Critical Insect & Mite Pests				*Lower-impact insect pests*							*Other Invertebrate Pests*		
	Mites	Mealybugs	Thrips	Blossom Midge	Aphids	Black twig borer	Bugs	Fungus gnats/ Shore flies	Orchid Weevils	Scales	Whiteflies	Ants	Snails & Slugs	
Cultural/Nonchemical Controls (*continued*)														
Clean pots & media for re-potting	-	G	-	-	-	-	-	-	-	-	-	-	-	
Reduce amount of free water available	-	-	-	-	-	-	-	E	-	-	-	-	-	

Efficacy rating scale: E = excellent (90–100% control); G = good (80–90% control); F = fair (70–80% control);
P = poor (<70% control); ? = no data, more research needed;
- = not applicable or not used; + = no data, but successful on other related organisms;
X = used but not a stand-alone management tool; * = not enough experience to rate.

Appendix 3: Efficacy of Pest Management Tools for Control of Vertebrate Pests on Potted Orchids in Hawai'i

Management Tool	*Pest*			Comments
	Coqui frogs	Birds	Mice	
Registered Pesticides				
Brodifacoum	-	-	-	
Bromadiolone	-	-	-	
Bromethalin	-	-	-	
Chlorophacinone	-	-	G	
Cholecalciferol	-	-	-	
Difenacoum	-	-	-	
Difethialone	-	-	-	
Diphacinone	-	-	G	
Methyl anthranilate	?	-	-	
Zinc Phosphide	-	-	-	
Other insecticides & fungicides	-	F	-	
Unregistered Materials				
Citric Acid	G	-	-	
Biological Controls				
Cats	-	-	G	
Cats & dogs	-	F-G	-	

Management Tool	Pest			Comments
	Coqui frogs	Birds	Mice	
Cultural/Nonchemical Controls				
Coqui frog barrier	E	-	-	
Hot water shower treatment	G	-	-	
Vapor treatment	G	-	-	
Hot water drench	?	-	-	
Control shrubbery	F	-	-	
PVC traps, retreat site	F	-	-	
Seal shadehouse	-	E	-	
Various devices	-	P-F	-	
Predator sounds	-	F	-	
Water-peanut butter traps	-	-	G	

Efficacy rating scale: E = excellent (90–100% control); G = good (80–90% control);
F = fair (70–80% control); P = poor (<70% control);
? = no data, more research needed; - = not applicable or not used;
+ = no data, but successful on other related organisms;
X = used but not a stand-alone management tool;
* = not enough experience to rate.

Appendix 4: Efficacy of Pest Management Tools for Control of Plant Disease Pathogens and Nematode Pests on Potted Orchids in Hawai‘i

Efficacy ratings are available for *Erwinia* on orchids (research conducted by Dr. David Norman, University of Florida, pgs. 5-6): http://riseofbiopesticides.com/files/BioWorks/Use%20Of%20Biopesticides%20To%20Manage%20Xanthomonas%20and%20Erwinia%20in%20Flowering%20Potted%20Crops.pdf

Management Tool:		Pest						Comments
		Fusarium rots	Other fungal diseases	Oomycetes	Bacterial diseases	Viral diseases	Foliar nematodes	
Registered Pesticides								
Quaternary ammonium chlorides	with disease absent (prevention)	G	G	-	G	G	G	
	with disease present	P	P	-	P	P	F	
Abamectin		-	-	-	-	-	G	
Azoxystrobin		F	F	-	P	P	P	
Bacillus subtilis		F	P-F	-	P	-	-	
Captan		P-F	P-F	-	-	-	-	
Chlorothalonil		F - G	F - G	-	-	-	-	
Chlorothalonil + propiconazole		-	-	-	-	-	-	

Management Tool:	Pest						Comments
	Fusarium rots	Other fungal diseases	Oomycetes	Bacterial diseases	Viral diseases	Foliar nematodes	
Registered Pesticides (*continued*)							
Chlorothalonil + thiophanate-methyl	P - F	F* - G	-	-	-	-	* resistance among some populations of fungi such as *Botrytis* and *Colletotrichum*
Chlorothalonil + iprodione + thiophanate-methyl + tebuconazole	-	-	-	-	-	-	
Copper hydroxide	P	P - F*	-	P - F	-	-	* A few fungi (downy mildews, *Alternaria*, *Cercospora*) may be controlled.
Copper hydroxide + mancozeb	P	P - F	-	-	-	-	
Basic copper sulfate	-	-	-	-	-	-	
Copper sulfate pentahydrate	-	-	-	-	-	-	
Cyazafamid	-	-	-	-	-	-	
Dazomet	F - G	F - G	F - G	?	?	?	Fumigant for potting soil
Didecyl dimethyl ammonium chloride	?	?	?	?	?	?	For greenhouse use
Dimethomorph	P - G*	P - G*	-	-	-	-	* if coverage is excellent
Etridiazole	-	P	G[p]	-	-	-	[p] *Phytophthora* and *Pythium* root and collar rots

Management Tool:	Pest: Fusarium rots	Pest: Other fungal diseases	Pest: Oomycetes	Pest: Bacterial diseases	Pest: Viral diseases	Pest: Foliar nematodes	Comments
Registered Pesticides (*continued*)							
Fludioxonil	G	F-G	-	-	-	-	Mozart for greenhouse use only.
Fludioxonil + mefenoxam	P - G	P[O] - G[R]	F - G[p]	-	-	-	[O] *Cylindrocladium*, *Thielaviopsis* and *Sclerotium* spp. [R] *Rhizoctonia* root and collar rots [p] *Phytophthora* and *Pythium* root and collar rots
Fluoxastrobin	-	-	-	-	-	-	
Flutolanil	-	F[B]-G[B]	-	-	-	-	[B] For basidiomycetes (*Rhizoctonia*, rusts)
Fosetyl-Al ("?" need to check w/Janice what this means)	-	-	F[p] -G[p]	-	-	-	[p] *Phytophthora* and *Pythium* and downy mildews
Furfural	-	-	-	-	-	-	
Gliocladium virens	-	-	-	-	-	-	
Hydrogen peroxide	P	P	-	P - F	-	-	
Hydrogen peroxide + Peroxyacetic acid	-	-	-	-	-	-	
Hydrogen peroxide + Peroxyacetic acid + Octanoic acid	P-?	P-?	-	P - ?	-	-	
Imazalil	?	P - G	-	-	-	-	

Management Tool:	Pest						Comments
	Fusarium rots	Other fungal diseases	Oomycetes	Bacterial diseases	Viral diseases	Foliar nematodes	
Registered Pesticides (*continued*)							
Iprodione	**F**	**P[A] - G[A]**	**P[p]**	**-**	**-**	**-**	[A] *Alternaria*, *Rhizoctonia* and others [p] *Phytophthora* and *Pythium*
Iprodione + thiophanate-methyl	**F**	**P - G**	**-**	**-**	**-**	**-**	
Mancozeb	**F**	**F**	**-**	**-**	**-**	**-**	*Dendrobium* and other orchids specified on some labels.
Mandipropamide	**-**	**-**	**-**	**-**	**-**	**-**	
Mefenoxam (Metalaxyl-M)	**P**	**P**	**G[p]**	**-**	**-**	**-**	[p] *Phytophthora* and *Pythium* and downy mildews
Metalaxyl	**P**	**-**	**P - G[p]**	**-**	**-**	**-**	
Oils (petroleum & mineral)	**P**	**P**	**-**	**-**	**-**	**-**	Controls insects for preventing sooty molds
PCNB (Pentachloronitro benzene)	**-**	**P- G***	**-**	**-**	**-**	**-**	* *Botrytis*, *Phyllosticta*, *Rhizoctonia*, *Sclerotium* Discontinued 12/31/14
Phosphorous acid (Mono- and di-potassium salts of phosphorous acid)	**P - G**	**P - F[R] - G[R]**	**F[p] - G[p]**	**-**	**-**	**-**	[p] *Phytophthora* and *Pythium* and downy mildews [R] *Rhyzoctonia* and powdery mildews
Potassium bicarbonate	**P - G**	**P - F[p] - G[p]**	**-**	**?**	**-**	**-**	[P] Powdery mildews
Mono potassium phosphate + sulfur	**P - G**	**P - G**	**-**	**?**	**-**	**-**	

Management Tool:	Pest: Fusarium rots	Other fungal diseases	Oomycetes	Bacterial diseases	Viral diseases	Foliar nematodes	Comments
Registered Pesticides (*continued*)							
Potassium silicate	-	-	-	-	-	-	
Propiconazole	-	-	-	-	-	-	
Pyraclostrobin	G	F[C] - G[C]	F[p] - G[p]	-	-	-	[C] *Colletotrichum*, *Rhizoctonia*, *Bipolaris*, *Excerohilum*, *Phyllosticta*, and others [P] *Pythium*, and *Phytophthora*
Quillaja Saponin	?	?	-	-	-	-	
Reynoutria sachalinensis	P - F	P	-	-	-	-	
Sodium chlorite	-	-	-	?*	-	-	Good surface disinfectant * can reduce bacterial levels
Sodium hypochlorite	?	?	?	?	-	-	
Streptomyces lydicus	?	?	-	-	-	-	
Streptomycin sulfate	-	-	-	-	-	-	
Tebuconazole	-	-	-	-	-	-	
Thiophanate-methyl	P	P - G	-	-	-	-	

Management Tool:		Pest: Fusarium rots	Other fungal diseases	Oomycetes	Bacterial diseases	Viral diseases	Foliar nematodes	Comments
Registered Pesticides (*continued*)								
Thiophanate-methyl + etridiazole		-	F – G*	G	-	-	-	* for pathogens not resistant to thiophanate-methyl
Triadimefon		P - F	P - G[c]	-	-	-	-	[c] *Colletotrichum*
Trichoderma harzianum		?	? – F*	-	-	-	-	* may have some efficacy for some fungi
Triticonazole		-	-	-	-	-	-	Trinity TR for greenhouse use.
Yeast extract hydrolysate from *Saccharomyces cerevisiae*		?	? – F*	-	-	-	-	* may have some efficacy for some fungi
Unregistered Materials								
Maneb			F – G					Dendrobiums only. Registration cancelled
Copper salts of fatty and rosin acids		P	?	-	?	-	-	Product registrations (Tenn-Cop 5E and Camelot) cancelled
Potential Pest Management Tools								
Subirrigation	absolutely no contamination	E	G		G	-	E	
	with contamination	P	P		P	P	P	

Management Tool:		Pest: Fusarium rots	Other fungal diseases	Oomycetes	Bacterial diseases	Viral diseases	Foliar nematodes	Comments
Biological Controls								
There is a need for testing of potential biological controls and their efficacy.								
Cultural/Nonchemical Controls								
Plantlet selection		E	E	-	E	E	E	Efficacy ratings as preventive method
Isolation of seedlings & plantlets		E	E	-	E	G - E	G - E	Efficacy ratings as preventive method
Moisture control	If infection prevented	F	E	-	E	E	E	
	If disease is present	P - F	P - F	-	P - F	P - F	P - F	
Clean cultural practices		F - E	P - F	-	P - F	-	-	Assumes disease is present
Sanitation	To prevent disease spread	E	E	-	E	E	G - E	
	For infected fields	P - F	P - F	-	P - F	P - F	P - F	
Steam pasteurization of potting media		E	E	-	E	G – E	G - E	Plants must also be clean (preventive).
New or clean potting media		E	E	-	E	G - E	G - E	Plants must also be clean (preventive).

Management Tool:		Pest: Fusarium rots	Other fungal diseases	Oomycetes	Bacterial diseases	Viral diseases	Foliar nematodes	Comments
Cultural/Nonchemical Controls (*continued*)								
Proper nursery site selection	no disease (preventive)	E	E	-	E	E	E	
	with disease	F	F	-	P	P	F	
Solid-covered greenhouses		E	E	-	E*	E*	E*	* no disease present
Cultivar selection		?	?	?	?	?	?	
Good air movement	no disease (preventive)	E	E	-	E	E	E	
	with disease	F	F	-	P	P	F	
Avoid windbreaks	no disease (preventive)	E	E	-	E	E	E	
	with disease	P	P	-	F	-	P	
Start with good or clean planting stock		E	E	-	E	E	E	
Control of vector pests		G	G	-	G	E	F	
Raised benches	no disease	E	E	-	E	?	G - E	
	with disease	P	P	-	P	P	P	

Management Tool:		**Pest** Fusarium rots	Other fungal diseases	Oomycetes	Bacterial diseases	Viral diseases	Foliar nematodes	**Comments**
Cultural/Nonchemical Controls (*continued*)								
Disinfection of surfaces, tools, etc.	no disease	G - E	G - E	-	G - E	G - E	G - E	
	with disease	G	G	-	P	P	P	
Barriers to prevent intrusion by pest carriers		G	G	-	G	G	G	
Worker training: proper sanitation, hygiene, material handling and activity scheduling		-	-	-	-	E	-	

Efficacy rating scale: E = excellent (90–100% control); G = good (80–90% control); F = fair (70–80% control);
P = poor (<70% control); ? = no data, more research needed;
- = not applicable or not used; + = no data, but successful on other related organisms;
X = used but not a stand-alone management tool; * = not enough experience to rate.

Appendix 5: Efficacy of Pest Management Tools for Control of Weed Pests on Potted Orchids in Hawai‘i

Management Tool	Pest			Comments
	Broadleaf weeds	Ferns	Grassy Weeds	
Registered Pesticides (pre-emergence) (*continued*)				
Benefin + Orazylin	-	-	-	
Dimethenamid-P	-	-	-	
Dithiopyr	-	-	-	
Isoxaben	-	-	-	Anecdotal reports of injury to orchids.
Oryzalin	-	-	-	
Oxadiazon	-	-	-	Waiting for label
Oxadiazon+ Pendimethalin	-	-	-	
Oxyfluorfen + Oryzalin	-	-	-	
Pendimethalin	-	-	-	Some products not for use in shadehouses, other structures
Pendimethalin + Dimethenamid-P	*	*	*	
Prodiamine	-	-	-	
Prodiamine + Isoxaben	-	-	-	
Trifluralin	-	-	-	

Management Tool	Pest			Comments
	Broadleaf weeds	Ferns	Grassy Weeds	
Registered Pesticides (pre-emergence)				
Trifluralin + Isoxaben	G	G	G	
Trifluralin + Isoxaben + Isoxben	G	G	G	
Unregistered Materials				
Diuron				
Cultural/Nonchemical Controls				
Hand weeding	G	G	G	
Sanitize potting media	F	F	F	
Clean water	G	G	G	
Weed mats	G	G	G	
Early removal of weeds	E	E	E	
Mulches for top of pots	?	?	?	

Efficacy rating scale: E = excellent (90–100% control); G = good (80–90% control); F = fair (70–80% control);
P = poor (<70% control); ? = no data, more research needed;
- = not applicable or not used; + = no data, but successful on other related organisms;
X = used but not a stand-alone management tool; * = not enough experience to rate.

Disclaimer: Information in this report does not constitute a pesticide label replacement or a recommendation. Before applying any pesticide, applicators must determine if the product under consideration is correct for the intended use site. Users are responsible to read the product labeling to determine if the intended use site is included on the label and to follow all label directions. Mention of a trade or product name does not imply approval or recommendation of the product to the exclusion of others that may also be suitable. The University of Hawaiʻi, the Western Integrated Pest Management Center, the United States Department of Agriculture, the authors and contributors shall not be liable for any damages resulting from the use of or reliance on the information contained here, or from any omissions to this publication