GROWING DENDROBIUM ORCHIDS IN HAWAII

Production and
Pest Management Guide

Edited by
Ken Leonhardt and Kelvin Sewake

C/T/A/H/R
College of Tropical Agriculture & Human Resources
University of Hawaii at Manoa

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Edited by

Ken Leonhardt and Kelvin Sewake

The authors and their affiliations

Kent Fleming, *extension economist, Department of Horticulture, College of Tropical Agriculture and Human Resources (CTAHR), University of Hawaii at Manoa*
John Halloran, *extension economist, Department of Horticulture, CTAHR*
Arnold Hara, *specialist in entomology, Department of Entomology, CTAHR*
Trent Hata, *research associate, Department of Entomology, CTAHR*
Ken Leonhardt, *specialist in horticulture, Department of Horticulture, CTAHR*
Edwin Mersino, *county extension agent, CTAHR*
Kelvin Sewake, *county extension agent, CTAHR*
Janice Uchida, *plant pathologist, Department of Plant Pathology, CTAHR*

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Table of Contents

Introduction

The dendrobium orchid industry is one of the fastest growing agricultural industries in Hawaii. Strong market demand in recent years, especially for potted dendrobium plants, has resulted in increased awareness of and interest in commercial dendrobium production and marketing.

The dendrobium orchid industry is currently one of the fastest growing agricultural industries in Hawaii.

In 1969, the first year statistics on dendrobium were published by the Hawaii Department of Agriculture, 19,000 dozen cut sprays sold for a wholesale value of $50,000. In 1997, the wholesale value of dendrobium sales was approximately $10 million. Cut dendrobium sales totaled $3.3 million from 80 acres, from which 368,000 dozen sprays ($2.6 million) and 25 million individual lei blossoms ($0.7 million) were harvested. Revenues from cut sprays and lei blossoms averaged about $41,000 per acre for the 56 producing farms.

Producers of potted dendrobiums marketed 1.4 million pots in 1997 from 30 acres, generating $6.4 million in revenues, an average of over $200,000 per acre for the 63 farms having sales. Dendrobiums accounted for about two-thirds of the $15.5 million in revenues from the sale of Hawaii-grown orchids in 1997. Other important orchid genera include *Phalaenopsis*, the *Oncidium*, *Vanda*, and *Cattleya* alliances, and *Cymbidium*.

The increased interest in dendrobium production has resulted in greater public demand for information and technical assistance from the University of Hawaii at Manoa's College of Tropical Agriculture and Human Resources (CTAHR) and its Cooperative Extension Service (CES). Farmers are constantly seeking better ways to control insect, disease, and weed pests, to obtain new cultivars to meet consumer needs, and to learn better cultivation techniques based on scientific research. In addition, new farmers need assistance in developing business plans, obtaining loans, and getting advice on starting an orchid business.

Growers need guidelines that allow optimum crop protection and production while addressing environmental concerns and fostering good land stewardship. Information that fulfills these needs is preferably based on reducing dependence on agricultural chemicals. Integrated pest management (IPM) strategies, which emphasize the use of non-chemical pest control practices, can be used to achieve these goals.

This manual was developed to provide concise, accurate, and current information on IPM for the dendrobium industry. Its purpose is to educate the reader in the general concepts of IPM as well as recommend specific applications of IPM principles.

The Cooperative Extension Service provides technical assistance and public information through its offices located throughout the state of Hawaii and through the CTAHR Publications and Information Office (808-956-7046, ctahrpub@hawaii.edu). Diagnostic services including plant disease identification, insect identification, soil analysis, and plant tissue analysis are provided by CTAHR's Agricultural Diagnostic Service Center (808-956-6706). For assistance in obtaining these services, contact the CES office in your area.

The authors hope that this IPM production manual for dendrobium orchids promotes the responsible care of our natural environment while being practical and helpful to you in reaching your goals as a commercial orchid grower or hobbyist.

Kelvin Sewake

What is integrated pest management?

The IPM approach

Integrated pest management (IPM) is a multifaceted, systems approach to reducing pest damage to crops based on predicting the incidences and severity of pest outbreaks and employing holistic approaches to plant health. Its goal is to manage pest populations for maximum crop yield and quality while being good stewards of the environment. IPM is an overall strategy that emphasizes utilizing tactics that are practical, effective, safe for humans and the environment, and cost-effective. These tactics include growing plants that are genetically resistant to pests, releasing and encouraging natural predators and parasitoids of pest organisms, and modifying crop environments and cultural practices in ways that favor the crop while creating an unfavorable situation for the pest. IPM maximizes the use of non-chemical control practices and decreases reliance on and use of chemical pesticides.

IPM pest control strategies are based on predicted needs for a control measure and its subsequent ecological consequences. Currently, all pest control disciplines, including entomology, plant pathology, nematology, weed science, rodent control, bird control, and mollusk control, are developing and implementing IPM strategies for commercial crop production, home gardening, and landscape maintenance.

IPM maximizes the use of non-chemical control practices and decreases reliance on and use of chemical pesticides.

In the years since the publication in 1962 of Rachel Carson's landmark book, *Silent Spring*, which shocked the nation with its revelations of environmental damage caused by the chlorinated hydrocarbon pesticide DDT, there has been a change in the attitudes of farmers, gardeners, politicians, and the general public regarding the use of chemical pesticides. People are increasingly aware of the problem of overuse of chemical pesticides and its consequences to humans, other organisms, and the environment.

Chemical pesticides have been widely used in crop production in an attempt to ensure high yields. After the surge in development of the petroleum-based chemical industry during World War II, a wide variety of new synthetic pesticides became available. These products are easily applied, work rapidly, and are often effective against more than one pest, but some also kill beneficial organisms. Overuse and misuse of pesticides has led to negative consequences, including health risks, environmental contamination, and the development of resistance in the targeted pests. Since the days when use of pesticides was the panacea to solve almost any crop production problem, pest control approaches have changed. Farmers have realized that there are better, less environmentally harmful ways to manage crops and crop pests, and consumers have come to demand more pesticide-free products.

IPM, an old concept, employs strategies and principles that have been part of agriculture throughout history. Before development of synthetic pesticides, pests were managed in many and various ways, including

- applications of mineral oils, soaps, and plant extracts
- use of natural predators, barriers, traps, and trap crops
- modification of irrigation, crop rotation, and other cultural practices affecting crop environments
- utilizing strict sanitation and quarantine (isolation) practices

The IPM approach advocates the continued use of such management strategies, along with scouting for and forecasting pest occurrences, and prudent selection and use of pesticides when necessary. "Prudent" implies that chemical pesticides are used only to avoid significant economic damage to the crop, and used in a manner to minimize undesirable consequences to beneficial organisms and the crop environment.

Considerations for implementing an IPM program

Know the enemy and predict its occurrence

Become aware of potentially injurious organisms and determine their status as pests in your crop. Identify the key pests and establish an economic threshold for each one. A key to IPM programs is to predict pest occurrence and implement tactics to keep the pest population density below the level where cost of control exceeds the cost of damage. In today's social environment, ecological and environmental considerations are as important as economic ones.

Pest populations are dynamic, as are weather conditions, crop growth, and populations of natural enemies.

Monitor climatic conditions and pest populations. Pest populations are dynamic, as are weather conditions, crop growth, and populations of natural enemies. Devise a scouting schedule and design data sheets to record data. Include counts of flying insects, such as white flies, thrips, and blossom midges from several sticky-cards suspended within and above the plant canopy. Make random inspections of canes, foliage, spikes, flowers, roots, and media for non-flying pests such as aphids, beetles, caterpillars, mites, mealybugs, weevils, bugs, snails, slugs, and mice. Record the data for each pest and beneficial organism to determine whether a population is building or declining.

Growers can be alerted to the presence of pests even if they are not seen, because many pests produce damage symptoms or other evidence of their presence, such as cast skins and droppings. Know the activity patterns of pests and when to look for them. 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, use a flashlight to examine plants, containers, benches, and the ground for snails and slugs. Slime trails are easily seen in a flashlight beam. You may see roaches and other running vermin flee the light.

Distribute several "indicator plants" about the nursery. An indicator plant is a plant found to be more desirable to a particular pest than dendrobiums. Examine these indicator plants regularly for early signs of infestations. Aglaonemas and chamaedorea palms, for example, are particularly appetizing to mealybugs and are appropriate indicator plants for these pests.

For plant diseases, inspect plants weekly for any signs of rotted shoots or young leaves, yellowed or spotted leaves or flowers, blemishes on sheathes, browning of roots, or development of aerial shoots. Monitor the temperature and humidity, and be alert for the conditions that favor specific disease pathogens. For example, diseases caused by *Botrytis* and *Colletotrichum* are favored by cool, damp conditions, while diseases caused by *Phytophthora*, *Erwinia*, and *Pseudomonas* are favored by warm conditions and high relative humidity. When these conditions exist, increase monitoring frequency, be on the look-out for early symptoms of the specific disease, and, if possible, adjust cultural practices to reduce the disease potential. Early identification of disease problems will allow you to prevent pathogen movement through the field. Make notes of suspicious symptoms and increase monitoring of the plants in the area. Use the monitoring data, the action thresholds set, and your experience to decide if a control measure should be taken.

Devise schemes for reducing populations of key pests to below economic threshold levels. Various management approaches, used singly or in combination, can produce this reduction. These approaches include cultural, biological, and chemical control practices, as described in the following sections.

Cultural control practices

Agricultural practices and physical devices can modify the environment to exclude, divert, or make conditions less favorable for a pest organism. These practices and devices are often preventive measures, put into effect before the pest or pathogen is present. Some examples of "devices" include traps, trap crops, barriers, exclusion netting for birds, solid-covered structures for rain protection, quarantine areas to isolate newly introduced plants, fans, and sanitation equipment.

The use of weed mats is another example of a physical control. Weeds can harbor aphids, whiteflies, thrips, nematodes, pathogens, and other pests. Weeds can compete with the crop for nutrients and sunlight, and they are also unsightly. And, weeds and weed propagules can be a quarantine problem when shipping potted plants out of state.

Cultural controls include interventions that destroy or impair the pest's breeding, feeding, or shelter habitat, such as field sanitation and weed control. Another example is attracting pests with a trap crop and then spraying the trap crop with pesticide. Choosing among alternative ways of doing things can have large effects on pest organisms; for example, modifying irrigation set-ups to deliver water but keep the crop's leaves dry can make the crop's micro-environment less conducive to plant disease organisms.

When interventions with pesticides become necessary, adjusting cultural practices can sometimes alter the environment of the pest to increase the effectiveness of the pesticide.

The purpose of cultural control practices in an IPM program is to help maintain an environment that is not conducive to disease. Moisture favors epidemics by enhancing the growth, spread, and infectivity of many pathogens. Moisture must be controlled to reduce and prevent diseases caused by bacterial, fungal, and nematode pathogens. Protecting the plants from rainfall is especially important in high-rainfall areas. Providing good airflow by the use of fans or creating good cross-ventilation can also help in reducing the incidence of diseases.

The purpose of cultural control practices in an IPM program is to help maintain an environment that is not conducive to disease.

Starting with a pest-free and pathogen-free growing area is of utmost importance—especially when growing young plants, which are the most vulnerable. 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 moved to clean benches or growing areas free of other plants and not integrated with older plants on benches having sporadic areas of free space.

Use of clean propagation material is another critically important cultural practice. Disease-resistant and insect-resistant dendrobium varieties are a long-term solution, but these options presently do not exist. The seed-propagated dendrobium cultivars developed at the Department of Horticulture, University of Hawaii at Manoa, are initially free of all diseases, including viruses, although they are not virus-resistant. Growers must employ practices that maintain the plants free of virus. 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 creates 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. Keep the production area free of fallen leaves, flowers, dead or dying canes, weeds, and other host plants. These can be reservoirs of viruses, fungi, bacteria, insects, mites, and other pests. Have a weekly schedule of removing these from the production area and eliminating them from the property. A pile of half-dead orchid plants and debris just outside the shadehouse is a perfect place for pests and pathogens to survive before making their way back into the production area.

Neglecting rigorous sanitation will mean a substantially larger investment later in controlling run-away pest and pathogen populations. The added benefit of strict sanitation is the impression it conveys to customers that you are a careful and meticulous grower of quality plants and flowers.

Biological control practices

Beneficial parasitoids such as parasitic wasps, predators, and diseases can help to control pest organisms. These allies may occur naturally, or they may be introduced. Use of biocontrol organisms that do not occur naturally requires precise timing of applications. At the present time there are no commercial biological control organisms available in Hawaii because of the strict quarantine regulations in place to protect our unique, isolated environment from introductions of harmful organisms.

Phytoseiid mites are important predators of spider mites. The rapid movement of these predators distinguishes them from their prey. Using a miticide may kill not only the pests but also their pyhtoseiid predators. Predatory lady beetles, aphid lions, and green lacewings control aphids, as do a number of parasitic wasps that lay their eggs in the aphids. *Bacillus thuringiensis* (Bt) has long been used to control caterpillars. This bacterium, when consumed by larvae, enters the gut, creates a toxin, and causes the caterpillar to stop feeding and die.

New biological control organisms such as fungi, bacteria, and nematodes are being developed as commercial products and utilized for controlling whiteflies, thrips, and a number of other insects.

New biological control organisms such as fungi, bacteria, and nematodes are being developed as commercial products and utilized for controlling whiteflies, thrips, and a number of other insects. Because of Hawaii's insular nature, new biocontrol products face rigorous testing before being permitted entry to the state; however, a number of formulations of Bt are available in Hawaii.

The use of biological controls has in the past meant that some level of the pest must be tolerated. The use of chemical pesticides often results in the death of the various predators and parasites. Sometimes growers can increase the effectiveness of the control agents by using pest-specific instead of broad-spectrum pesticides. The use of feeding stations for beneficial organisms has been practiced in a number of crops. Although there are some biological controls for a number of plant diseases, there are none that have been found to be effective against orchid diseases.

Chemical control practices

Chemical control is a component of IPM. When cultural and biological controls do not bring about the desired results, chemical pesticides may be required. The choice of pesticide, application rate, method of application, and frequency of application, must be carefully coordinated to minimize hazards to workers, the crop, non-target organisms, and the environment. Select pesticides that are the most effective while being the least toxic. To minimize the possibility of resistance developing in the target pest or pathogen, rotate pesticides from different chemical classes. Check with your County Extension Service or chemical supply dealer for information about newly registered chemicals that have minimal impact on beneficial organisms and the environment.

Many pest organisms have times in their life cycle when they are particularly susceptible to pesticides, for reasons relating to their physiology or habitat, and applications should be made strategically at these times. Conversely, the pests may have times in their life cycle when they are relatively immune to pesticides, or cannot be reached, and applications at these times are not as effective. For example, only the adult stage of the blossom midge is vulnerable to contact foliar insecticides, and systemic insecticides do not translocate to orchid buds to affect blossom midge maggots. Insecticides applied as a drench can target the pupal (maggot) stage of the midge, which burrows into the soil. Likewise, contact insecticides are effective only against the adult stage of orchid weevils, because the grub feeds within the cane for about four months before emerging as an adult.

The goal of an IPM program is to maintain pest populations below an economically damaging level as well as at or below the level that your customer will accept.

A case study: IPM in practice

In the following paragraphs, one of Hawaii's more experienced orchid growers describes how his nursery benefited from implementing several IPM strategies.

"In 1990 a serious problem was developing in our nursery. It can be best described as 'nursery decline.' Disease problems were becoming more numerous. Damping-off of community pots was increasing. Despite using more pesticides than ever before, up to 50 percent of the plants were not in saleable condition. What was most depressing was that the problem was getting worse, and we did not think we could survive as a business.

"The UH-CTAHR Cooperative Extension Service recommended that we take a more systems approach to cultivating orchids, from deflasking to the finished product. More attention to disease prevention and stricter sanitation measures, they advised, would reduce many of the problems.

"We revised our production procedures and began to adopt many integrated pest management strategies. The compot area was cleared, and the benches were painted so they could be easily sanitized between crops. Young plants were never again placed near older plants. Plants were moved in blocks of the same age. At all times, diseased plants were discarded. More attention was given to weed and snail control, both under benches and outside the shadehouse. We no longer guessed at what a disease was but rather obtained a correct diagnosis. This was a critical step. We had spent several years trying to battle various fungal diseases with the wrong chemicals, lack of attention to sanitation, and a lack of understanding that springtails, snails, fungus gnats, mites, and other pests can quickly transport disease organisms throughout the nursery. I used to look at compot foliage every week for early disease symptoms. Now I look at compot roots every week, and I can spot a potential problem much earlier. I also look at the medium for its drainage and aeration properties, and I adjust irrigation, shading, and airflow accordingly.

"I think improved sanitation and keeping our newly planted compots and 2-inch pots away from older plants has solved 90 percent of our problems. Up to 1992 we were having an epidemic every month in one part of the nursery or another, and we were losing 5000 to 8000 compots per year. Since 1993, three years into adopting IPM strategies, we have not had a single epidemic, and our compot losses are under 100 per year. And today we spray only a small fraction of the amount of pesticides that we used in 1990."

"The UH-CTAHR Cooperative Extension Service recommended that we take a more systematic approach to cultivating orchids, from deflasking to the finished product."

Dendrobium cultivars recommended for commercial production

The Department of Horticulture in the College of Tropical Agriculture and Human Resources at the University of Hawaii at Manoa has an international reputation for developing improved varieties of tropical fruits, vegetables, and ornamentals. One of its most outstanding research programs has been the dendrobium genetics and breeding program developed by Professor Emeritus Haruyuki Kamemoto.

In 1950 a basic research program on dendrobium cytogenetics was initiated. The fortuitous discovery of the chance occurrence of tetraploid species hybrids (species x species—also known as primary hybrids) and the use of colchicine induction of tetraploid species hybrids made it possible to investigate the theory of uniformity in seedling progeny from amphidiploid (double diploid) parents. Amphidiploids are 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. The theory was demonstrated to work for dendrobium, and in 1966 a program was initiated to breed amphidiploid dendrobium hybrids with characteristics suitable for commercial cutflower production. The program has been based largely on combining the genomes of two species, *D. phalaenopsis* from the section *Phalaenanthe* and *D. gouldii* from the section *Spatulata* (formerly *Ceratobium*). A wide variety of seed-propagated cultivars has been developed. Seed propagation provides growers with uniform, virus-free, affordable plants.

UH initiated a basic research program on dendrobium cytogenetics in 1950.

The concept of genome breeding is important to an understanding of how the UH cultivars were developed. A genome is a set of a chromosomes. A diploid species has two chromosome sets (2n). In breeding, a form of sexual reproduction, the pollen carries one chromosome set (n) and the ovule carries one chromosome set (n). When an ovule is fertilized, it results in an embryo that reconstitutes the diploid (2n) condition in the new seedling. Some plants have four genomes (4n) and are referred to as tetraploids. Triploid (3n) plants often result when diploids and tetraploids are crossed.

The different genomes, or chromosome sets, are symbolized by letters that indicate the taxonomic category (the botanical "section") to which the species belong. *Dendrobium phalaenopsis* and *D. bigibbum* are members of the section *Phalaenanthe*, and their genome is represented by P. The species *D. gouldii*, *D. grantii*, *D. antennatum*, and *D. stratiotes* are members of section *Spathulata* but are represented as C, for the former section name *Ceratobium* (the C designation was retained because of its wide use before the section's name was changed to *Spathulata*). The P and C genomes represent significant contributions to the differences expressed by hybrid combinations in dendrobiums.

Species in the section *Phalaenanthe* (P genome) have large, fully formed, showy flowers on medium-length sprays. As cutflowers, their postharvest characteristics do not meet commercial standards. Species in the section *Spathulata* (C genome) are vigorous plants that produce abundant, long lasting sprays of medium to long length with many small flowers having twisted petals.

The table of recommended University of Hawaii seed-propagated cutflower cultivars lists the genome type of each cultivar. The several *D.* Jaquelyn Thomas cultivars and *D.* Jaq-Hawaii have a PPCC genome composition. These are amphidiploid (tetraploid, 4n) hybrids that combine the best characteristics of their parental sections. The cultivars with PPPC genomes, *D.* Nellie Sugii and *D.* Tessie Amore, have more shapely and fully formed

Recommended seed-propagated dendrobium cultivars developed at the University of Hawaii

Cutflower cultivars

UH no.	Name	Color	Genome type
44	Jaquelyn Thomas 'Uniwai Blush'	blush	PPCC
232	Jaquelyn Thomas 'Uniwai Supreme'	lavender two-tone	PPCC
306	Jaq-Hawaii 'UniwaiPearl'	white	PPCC
503	Jaquelyn Thomas 'Uniwai Prince'	purple	PPCC
507	Jaquelyn Thomas 'Uniwai Princess'	light purple	PPCC
800	Jaquelyn Thomas 'Uniwai Mist'	white	PPCC
1002	Jaquelyn Thomas 'Improved Uniwai Blush'	blush	PPCC
1081	Uniwai Royale	purple	PPCC
1233	Nellie Sugii	pink	PPPC
1276	Tessie Amore	pink	PPPC
1299	Manoa Ruby x Jaquelyn Thomas 'D192'	purple	PPCC
1426	Jaquelyn Thomas	lavender two-tone	PPCC
1427	Jaquelyn Thomas	purple	PPCC
1430	*D. superbiens* x Jaquelyn Thomas	purple	PPCC

Potted-plant cultivars

UH no.	Name	Color	Genome type
613	Lynne Horiuchi	purple	PPL
921	Caesar	lavender	PC
988	Samarai	white with purple lip	CC
999	Susan Takahashi	purple	PPCC
1121	Miyoko Azuma	purple	PPPC
1182	Pua 'ala	purple	PCL
1208	Betty Nakada	purple	PPE
1221	Cathy Beck	lavender	PCE
1307	Remy Hartmann	lavender	PCE
1323	Manoa Sunrise	red-purple	PPCC
1382	Lim Chong Min	lavender	PPC
1392	Louis Bleriot	purple	PPC
1419	Sharon Sewake	purple	PPPE
1420	Mari Marutani	purple	PPPC
1577	Lorrie Mortimer	lavender	PCCC

flowers but are not as high yielding as the amphidiploid cultivars. Growers are encouraged to cultivate a range of cultivars to meet market demands for various flower types and seasonal availability.

The meristem culture technique, adapted for dendrobium by Dr. Yoneo Sagawa and co-workers at the University of Hawaii, gave added impetus to the breeding program, as outstanding selections could now be increased rapidly to obtain large numbers of plants with identical genetic characteristics. In addition to the seed-propagated dendrobium cultivars, a few clonal selections have been released by the program.

When well adapted new materials are discovered, be sure the plant tests virus free before cloning.

The seed-propagated cutflower dendrobium cultivars released by UH can be generally characterized as vigorous plants with high yields of 10–20 or more sprays annually, having attractive sprays 24–36 inches long with 15–25 or more well spaced flowers, a long vase life of 12–18 days, and bud drop not exceeding 5 percent. The heavy flowering period is early summer through late fall, generally peaking in August. There is scattered light flowering throughout the winter and spring months. All of the varieties released for cutflower production are also cultivated for lei flowers. The UH varieties of *D.* Jaq-Hawaii and *D.* Jaquelyn Thomas become large plants, usually attaining 4 ft tall within five years from deflasking. The exception is *D.* Jaquelyn Thomas 'Uniwai Prince', which has the most compact stature.

Seed-propagated cultivars have advantages over mericloned cultivars in that they are easier, faster, and cheaper to produce and initially are free of viral infections (plants are not virus resistant, and it is incumbent upon the grower to use the appropriate cultural practices to maintain virus-free plants).

Given the advantages of seed propagation, there is still sufficient variation in yield, individual flower quality, spray length, plant stature, and other characteristics important to a commercial producer, that we recommend that growers closely examine their plantings to identify particularly outstanding individuals and clone them if they can be diagnosed to be virus free. For example, in 1986–87 yield data was collected from a commercial planting of 990 plants of UH 306 (*D.* Jaq-Hawaii 'Uniwai Pearl') during the first 15 months of production. The plants were grown in 32-cm (12-inch) grow-bags and given ample space (planting density of 32,100 plants per hectare, or 13,000 plants per acre). The data showed that the average yield for all plants during the first 15 months of bearing was 26.5 sprays per plant. Of particular noteworthiness was the analysis of individual plant yields, which identified 19 plants (1.9% of the plants examined) that yielded 50 to 64 sprays each during the 15-month period! Unfortunately, all of these plants tested positive for cymbidium mosaic virus and none were cloned. But similar variation occurs in all plantings of the UH seed-propagated varieties, and the prudent grower should identify such outstanding individual plants for potential cloning for replanting material.

Outstanding plants should be advanced-tested for one or more flowering seasons to determine if the observed improved characteristic, whether it be yield or a quality characteristic of the plant or its flowers, has a genetic base and is stable and predictable. This is necessary because some characteristics that appear to be improvements may be only chance occurrences or induced by unusual weather and not repeatable. Once it has been determined that the improved characteristic is of genetic origin, the grower must decide if the additional cost of clonal propagation over seed propagation is warranted.

The UH cutflower cultivars come in a limited range of colors, which does not include yellow, green, red, candy stripes, or art shades. Accordingly, some growers have experimented with cultivars from Asia and seedlings and cultivars from local Hawaii breeders. Such screening may yield important new materials, but caution is advised against large-scale plantings of materials unproven in Hawaii. Some cultivars of importance in Singapore,

Cutflower cultivars


UH 44


UH 232


UH 306


UH 503


UH 507


UH 800


UH 1002


UH 800


UH 1081


UH 1233


UH 1299


UH 1426

Potted-plant cultivars


UH 613


UH 921


UH 1121


UH 1182


UH 1208


UH 1221


UH 1307


UH 1323


UH1392


UH 1419


UH 1420


UH 1577

Malaysia, and Thailand have not performed acceptably in Hawaii. Such trials are encouraged, but not in numbers exceeding what the grower is willing to lose. When well adapted new materials are discovered, be sure the plant tests virus free before cloning.

Genome breeding has been used to produce a wide range of seed-propagated cultivars for the production of dendrobium potted plants. In addition to the P and C genomes, potted-plant cultivars utilize the L and E genomes. *Dendrobium macrophyllum* and *D. spectable*, with their uniquely shaped, long lasting, heavy textured flowers, are members of the *Latourea* section (L genome). *Dendrobium canaliculatum* of the section *Eleutheroglossum* (E genome) is familiar to growers because it has been used extensively in recent years to produce floriferous miniature dendrobium hybrids. *Dendrobium carronii* is a closely related, floriferous, more diminutive species of the *Eleutheroglossum* section. It has been used in the development of three outstanding UH potted-plant introductions, *Dendrobium* Betty Nakada, *D.* Cathy Beck, and *D.* Remy Hartmann, which are triploid (3n) hybrids with one E genome. They are short statured (often flowering on 2-inch pseudobulbs), precocious, free-flowering hybrids.

Among the UH potted plant cultivars, the range of plant and flower characteristics is broad. Some are round *D. phalaenopsis* types, while others are dwarfish plants with antelope-type flowers, having been bred from such species as *D. canaliculatum*, *D. antennatum*, and *D. carronii*. Some of the potted plant cultivars, such as *D.* Susan Takahashi, *D.* Pua'ala, and *D.* Louis Bleriot, are also cultivated for lei flowers. All of the varieties introduced for cutflower production are also produced as potted flowering plants. The recently introduced *D.* Ethel Kamemoto 'Splendor' is a clonally propagated cultivar. It is unique in that the lip is more similar to the two petals than a traditional dendrobium lip, giving the flower a pansy-like appearance.

Site selection and structures

Temperature

Dendrobiums 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 Hawaii, dendrobium plants are less productive and their flower sprays are weaker than those grown near sea level.

Site selection considerations

When choosing a site for a dendrobium farm, consider the following characteristics of an ideal location:

- land cost and property taxes are affordable
- level topography with good drainage
- presence of natural windbreaks (tree line or hill) but not so near as to cast a shadow on the property
- bright sunlight
- warm temperatures with nighttime lows not dropping below 65°F
- low to moderate rainfall not exceeding 4 inches monthly
- good air movement but without regular strong winds
- a reliable source of good quality water
- proximity to utilities and roads

The most common shadehouse structures in Hawaii use a rigid framework of posts and cables to support panels of shadecloth.

The site should be sufficiently large to accommodate growing structures, an office, storage and service buildings, access drives, loading and parking areas, and, if desired, a dwelling. An area for a holding pond will be necessary in regions where catchment irrigation is used. Consideration should also be given to future expansion.

Structures

In Hawaii, dendrobiums are grown in shadecloth-covered structures. In high-rainfall areas it is advisable to use structures covered with polyethylene film in additional to shadecloth (Fig. 1.1). The side walls of both types of structures should be covered with shadecloth. The basic function of these structures is to provide a protective environment for crop production. They reduce the intensity of bright sunlight and provide some protection from strong winds, heavy rains, and large pests.

The most common shadehouse structures in Hawaii use a rigid framework of posts and cables to support panels of shadecloth (Fig. 1.2, 1.3). Galvanized steel pipe is most often used for posts, but telephone poles and treated

1.1. Plastic-covered structures with open sides for maximum ventilation allow best management of moisture in the nursery environment. Modern aluminum-frame structures are durable and relatively inexpensive.

Ventilation and air movement inside the structure improve with structure height—taller houses are cooler.

1.2. A typical pipe-and-cable shadehouse structure with diagonal side curtains. The diagonal cable connects the top of each perimeter pole to an anchor.

timber have also been used. Ventilation and air movement inside the structure improve with structure height—taller houses are cooler. Taller houses are also more prone to damage by high winds. The ability of the structure to withstand high winds is largly due to its anchors. Anchor rods are placed around the perimeter of the structure and secured into the ground with concrete. A heavy cable connects an anchor rod to the top of each perimeter post. If the anchor holes are not deep enough or if too little concrete is used, a strong wind can cause the cable to pull the anchors out of the ground resulting in colapse of the structure or a portion of it.

Knitted shadecloth material is recommended over woven material because of its superior strength and flexibility. Knitted fabrics resist linear separation and will not unravel when cut, and the material can be made into panels and grommeted without hemming. Knitted cloth provides a better hold for grommets, which tend to rip out of woven cloth when high winds cause a vertical wave movement and flapping motion of the fabric. Many growers do not use grommets with knitted cloth, opting instead to attach the cloth to the cables with flexible plastic-coated wire. The fabric should be fastened close enough to the cables to prevent the entry of birds. Another way to seal the structure from birds when grommets and S-hooks are used is it to sew a strip of fabric to both shadecloth panels and over (or under) every cable.

Post-and-cable shadehouse structures vary greatly in design, but none of them allow for the attachment of solid coverings or polyethylene plastic film.

Greenhouses are rigid structures with transparent coverings of fiberglass, fiberglass reinforced plastic, or polyethylene plastic film. Shadecloth should also be attached to create the appropriate light level. The big advantage of greenhouse coverings is that they allow for total protection from rain. Plants remain dry through the night, and irrigation is done at the discretion of the grower. This results in a significant reduction in the incidence and severity of diseases. The benefits include healthier plants with higher yields, and less money spent on fungicides and labor to apply them.

1.3. Pipe-and-cable shadehouse structure with vertical sides. Interior diagonal steel braces replace the cable-to-anchor design of structures with diagonal side curtains. Vertical sides allow better use of nursery floor space at the perimeter, but the structure is more prone to wind damage.

The growth and yield of dendrobium plants is best when light is at the optimum level.

Freestanding greenhouses and gutter-connected greenhouses both are suitable for dendrobium cultivation. Air movement through a freestanding greenhouse is better because the ratio of perimeter area (side walls) to cubic volume is greater than with gutter-connected greenhouses. Another advantage is that Worker Protection Standards can be more easily met in freestanding greenhouses where spraying is confined to clearly separated areas. It is also easier to establish isolation areas in physically separated houses. Gutter-connected greenhouses may allow for more efficient use of labor due to 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.

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 today are of better quality than those of a few years ago, but they do not last as long as rigid sheeting. Polyfilm comes in various thicknesses and have one- to three-year ratings, reflecting their durability and resistance to degradation from ultraviolet radiation. Polyfilm is available in clear, white, and colors. Inexpensive commercial polylocks are used to secure the polyfilm to the greenhouse frame.

The growth and yield of dendrobium plants is best when light is at the optimum level. Shadecloth fixed in place 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, that density of shadecloth provides too much shade in the morning and late afternoon and at most other times of the year. With greenhouses, the grower has the additional option of using retractable shade. Several motorized systems with solar radiation detection lenses are on the market. Shade panels are automatically drawn or retracted in response to changing light levels, generally at 15 or 30 minute intervals. Such systems can provide near optimum light levels for more hours of the day and for more days of the year.

Nursery practices

Orchid propagation—proper care for young plantlets

All cultivated dendrobium orchids, whether seedlings or clones, are started in flasks. The flask environment provides the plantlets with ideal conditions for early growth. Nutrients and water are provided to the plantlets in measured amounts 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. The proper care of plantlets from flasks through the compot stage is critical to their optimum growth, development, and productivity.

2.1. Plantlets in sterile flasks being conditioned to the light and temperature of the community-pot area.

When flasks are received from a lab, they should be placed in a higher light 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 will be placed, so that the light level before and after deflasking is the same (Fig. 2.1). Do not expose flasks to direct sunlight for even a brief period. Direct exposure will raise the temperature inside the flask and may kill the plantlets.

2.2. Plants in 2¼-inch pots at near-flowering size, ready for transplanting.

Do not disturb the rubber stopper until it is time to deflask. The point of contact between the glass and rubber is the seal that maintains sterility inside. When this seal is broken due to careless handling, fungal and bacterial pathogens and mites can enter and multiply quickly, often weakening or killing the young plants.

The optimum time for deflasking varies among cultivars and is largely dependent on the cultural practices and environmental conditions provided to the community pots or plug trays. Some growers have excellent success with plantlets that are only ½ inch tall and having one or two small roots, while others prefer plantlets to be nearer to 2 inches tall with three or four roots of 1 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 reestablish quicker than a weakened plantlet in its new environment.

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

There are two ways to remove plantlets from an unbroken flask. The preferred way is to use a bent wire or similar tool to fish out the plantlets. The bent wire is hooked around the base of the plantlet, which is pulled out base first. It may seem time-consuming at first, but with a little practice it can be done very quickly with minimum damage to the plantlets. The other method is to pour water into the flask and shake it until the roots become dislodged from the agar. The plantlets are then poured out, or fished out with the bent wire. This method is more rapid but causes considerably more damage. The damage may not be noticed at first, but an injured root or a cracked leaf weakens the plant and is a point of entry for pathogenic organisms. Since the goal is disease prevention, extra care taken to minimize damage in deflasking is recommended.

Another way is to break the flask to gain easier access to the plantlets (expect to forfeit your flask deposit). If this method is chosen, first wrap the flask in newspaper. One clean blow with a hammer will break the flask with a minimum of splinters. When deflasking from a Thai whiskey bottle, a glass cutter may be used to score the bottle, thereby producing fewer fragments. The recent development of autoclavable wide-mouth plastic containers and plastic bags makes this potentially hazardous procedure unnecessary.

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 good moisture holding capacity for the tender young roots and good drainage and aeration to prevent anaerobic conditions that will suffocate root tissue and promote the growth of certain bacteria, algae, and other micro-organisms. Available materials include perlite, styrofoam, and charcoal which, from new bags, are generally free of pathogens. These are often mixed with other materials such as chopped tree-fern fiber, peat, fine bark, coir, and sphagnum moss, all requiring pasteurization, which can be accomplished with hot water at 180°F for a minimum of 30 minutes (60 minutes is better). The prudent grower will allow the media to cool, stir it, and repeat the pasteurization process. Although pasteurized, contamination of these materials will occur if they are not properly stored. Media should be stored in sealed containers or bags in a clean storage area out of contact with the ground. When preparing compots, coarse materials are often placed in the pot first, with finer materials placed on top. This is generally not done when filling plug trays.

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 agar medium must be completely washed from the plantlets. A minimum of two washings is recommended. Many growers wash three times to ensure complete removal of the agar medium. This is, again, another practice to minimize incidence of disease. After washing, the plantlets may be dipped in an approved fungicide solution. Some growers do this only during the winter months, when conditions for diseases are more favorable.

Plantlets should be graded by size after washing. Plant plantlets of similar size together in the same compot or plug tray. When plantlets of different sizes are planted together, the finished product will lack uniformity, and mortality is increased by excessive drying of the smaller plants that need more frequent but shorter exposures to misting.

Hold the plantlet upright and gently press the roots to the medium with a planting stick, usually a chopstick or pencil. Some growers bury the roots, and others leave roots mostly exposed. This is determined by such factors as choice of media, relative humidity, size of roots, misting frequency, and grower experience. What works the best for one grower may not be the best for another, just as what works the best for one clone or seedling cross may not be the best for others. Try different combinations and methods until you are satisfied.

Compots and plug trays should be placed pot-to-pot on sanitized wire-covered benches 30 or more inches tall so that splash from the ground cannot reach them; these conditions are in compliance with Hawaii Department of Agriculture standards for export certification. This area of the nursery should have a solid roof to protect the plantlets from rain and shade cloth to provide subdued light. It should have a fog or mist system to create a high relative humidity. Good air movement is essential (Fig. 2.3). If natural air movement is inadequate, fans should be installed. This should be the most sanitized area of the farm, because the humid environment favors disease and because this is the stage of plant de-

2.3. *Wire benches allow maximum aeration and drainage, aiding disease prevention.*

velopment most susceptible to infection. Benches should be surface disinfected between crops, and only new pots and trays should be used. Never use recycled media for such tender plants.

The frequency of misting or watering is determined by the daily weather. During long, warm, dry days, new compots may require several mistings daily. Older and deeper rooted plants require less misting but heavier watering. Do not water so late in the day that foliage remains wet through the night. Knowing when to water and when to withhold water is an art that takes time and daily observations to learn.

After 2–3 weeks, a dilute (about ¼-strength) solution of liquid fertilizer can be applied. As new root activity increases, shade should be decreased and misting should be discontinued in favor of several hand-waterings per day. As plants adjust favorably to the higher light, the concentration of liquid feeding can be increased. The young plant nursery area should be observed daily for any signs of disease infection. A single plantlet showing suspicious symptoms in a compot is cause to discard the compot. Do not try to salvage other plantlets in that compot. Adjacent compots should be removed to an isolation area, and that portion of the bench should be surface-sanitized. A suspicious plantlet in a plug tray should be discarded along with all adjacent plantlets, the tray should be removed to the quarantine area, and that portion of the bench should be surface-sanitized.

The young plant nursery area should be observed daily for any signs of disease infection.

Most cultivars and seedling crosses of dendrobium require 4–6 months growing time in compots or plug trays before they can be sold or shifted into the next size, usually a 2- or 2¼-inch pot. When shifted into the next size, the entire population should be moved together to a sanitized bench and kept at a distance 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.

Media

The primary purpose of a planting medium is to provide support for the plant and a healthy environment for root development. The root system is of critical importance because its function is to absorb and assimilate nutrients and water. A poorly developed or poorly functioning root system cannot take up adequate nutrients and water to support healthy plant growth and acceptable flower yields.

The parent species of modern dendrobium cutflower hybrids are epiphytes in their native habitats. They grow clinging to trees and rocks where drainage and aeration are optimal. They are not found growing in the soil or forest litter. Growers must attempt to simulate such good drainage and aeration conditions in cultivation. For a cutflower grower, repotting mature plants is impractical; thus the growing medium must provide good drainage and aeration for the entire productive life of the plant.


2.4. Commercial planting of UH306, 'Uniwai Pearl'. Plants are in bluerock in 12-inch poly bags set out on a 3-inch bluerock base.


2.5. This four-year-old planting of UH232 shows excellent leaf retention (110 leaves per plant), which supported a yield of 32 sprays per plant per year.

The most widely used growing medium throughout Asia for cutflower production stock is coconut husk and fiber in one form or another. This is satisfactory only for short-term cultivation. The fibers of the coconut attract and retain water, but within two years the medium partially decomposes and begins to restrict drainage and aeration. Within three years, anaerobic conditions may result in root tissue breakdown and conditions favoring diseases. Three flowering cycles is all that Asian growers expect from their plants.

In contrast to Asian practices, the Hawaii grower expects seven to ten years of production from cutflower plants without repotting them. The Hawaii grower must therefore use an inorganic medium that resists decomposition. Plants can be grown on the ground in beds or in containers, or on a strong low bench. The preferred medium in Hawaii is basaltic gravel, known locally as "blue rock" (Fig. 2.4, 2.5). It should be screened to stones ranging in size from 1½ to 2¼ inches, referred to by quarry processors as "number 3" size. It is important to remove the smaller stones and fine particles that would impede drainage and aeration after roots have penetrated and occupied the spaces between aggregates. Basaltic gravel is readily available, inexpensive, durable, and has high porosity. However, it has a low nutrient-holding capacity, and the plants will require a continuous nutrient supply.

Producers of dendrobiums for local potted plant sales also use blue rock, but it is usually screened to a smaller size. Potted dendrobiums shipped out of state are often grown in a 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 Hawaii, where it is available locally.

Spacing

A wide range of planting densities is used for dendrobium cutflower production. In earlier times, up to 35,000 plants were planted per acre. It was learned, however, that as the plants grew larger, the dense tangle of canes prevented good airflow. This hindered adequate penetration and coverage of pesticides, and insect and disease control became a problem. It also resulted in a high percentage of bent, unmarketable sprays.

Currently, the common practice is to plant between 15,000 and 22,000 plants per acre. Any number of patterns can be used for laying out the planting beds (Fig. 2.6, 2.7). The spacing of the beds and aisles depends on the spacing of the shadehouse supporting members, the length and width of the structure, and other infrastructure conditions. Typically, aisles are not less than 4 ft wide, and beds are 4–5 ft wide. The spacing of the plants in the beds is determined by the size of the bags or pots (if they are used), the size of the beds, the predicted life span of the plants, the availability of plants of appropriate size, and the plant density desired.

A high density of plants means a higher initial cost for planting material and a higher initial return from production. This must be balanced with the longer crop cycle of a less dense planting. The lower the plant density, the longer the potential crop cycle. However, a lower density means that the grower has to wait longer before the crop reaches its peak production in terms of yield per area. Factors such as cost-recovery time for the capital investment need to be considered. Every grower has a unique situation, and the decision must be based on it.

2.6. Gravel-bed planting with two irrigation lines per bed. Gravel beds can be used in place of pots or bags only when the soil beneath them has excellent drainage. Plantings in beds are most common on the island of Hawaii, where lava fields provide such conditions.

2.7. Two-year-old UH306, Uniwai Pearl, grown in coarse bluerock in 12-inch bags on 18-inch centers for a low planting density of 13,000 plants per acre. Plants given adequate space respond with high yields, in this case about 26 sprays per plant during the first 15 months of flowering.

Planting

Dendrobiums are planted into the field when they are about 12 inches tall. When they are planted into containers, plastic bags that are 8–12 inches in diameter are frequently used in preference to hard plastic pots, which are more expensive. With either pots or bags, it is recommended that many large extra holes be added to the sides to ensure good drainage and aeration. The plants will perform equally well in pots or plastic bags. Bags are much cheaper, but if there is a secondary market for large potted flowering dendrobiums, pots have a better appearance, are more easily moved, and have better free-standing stability.

Some growers plant the orchids into beds of medium instead of individual containers. Using bed culture increases the likelihood of disease spreading from plant to plant. In addition, it is more difficult to remove infected plants from bed culture than removing individually potted plants. Plants grown in containers can be spaced so that air can move between the root masses, allowing them to dry and thereby reducing the disease potential.

Replanting

“When to replant?” is the one question each grower eventually has to answer for himself or herself. From the biological perspective, the optimum time to replant is after the plants have reached their peak and begun to decline. This occurs sometime after the fourth year after planting. The incidences of disease infection and insect infestation are the greatest limiting factors of the life span of the cut dendrobium flower crop. Controlling these from the beginning, along with proper nutrition give the greatest potential for a long-lived crop.

Ideally, growers should stagger their plantings so they can maintain a continuous supply of flowers for their customers. If they wait too long to start replanting after the plants begin to decline, they may face a period when production in the old plantings begins to drop off seriously before the new plantings begin to produce.

When calculating the optimum time to replant, the costs of removing and replacing the planting and other economic factors must be considered. For example, the near-term income derived from keeping a declining bed in production is greater than the income derived from replacing and starting a new planting, because in the first couple of years' net income from the new planting is negative. Also, money today is more valuable than the same amount of money received in the future. The grower is therefore required to make some estimates of yields, prices, and costs to be expected over the projected lifetime of a new planting. Good record-keeping is essential to making good management decisions, and good management decisions are required for the enterprise to enjoy maximum profitability.

Replanting should be done in blocks. One section of the shadehouse should be completely cleaned of old plants and material before replanting it. Avoid planting new plants among older plants that are declining due to disease or insect infestation.

Over many years of production, the ground may be thoroughly inoculated with pestiferous organisms including fungal spores, weed seeds, bacteria, snails, slugs, and insects, as well as viruses remaining in fragments of plants. Therefore, the ground should be sanitized as much as possible before replanting with clean plants.

Removing the old plants and all plant parts is essential. Used media should also be removed, but some growers use the old gravel media in the aisles or as a base for the new planting rows. If used media is to be left in the nursery; it should be free of weeds, leaves, flowers and roots. Industrial vacuums and blowers may help in removing these contaminants. Furthermore, the used media should be treated to eliminate bacteria and fungal spores. Steam or chemical fumigants can be used. Finally, the ground should be covered with a weed mat to reduce the possibility of any remaining contaminants infecting the new crop.

2.8. This water-conserving irrigation set-up in an orchid nursery uses 180 ° spray heads on the perimeter of the bench, rather than down the middle, in order to minimize irrigation of isles.

Irrigation

Dendrobiums must be irrigated for optimum production, especially during dry periods. Since dendrobiums are grown in porous media that hold little water, they should be irrigated whenever the media and root mass become dry. In dry, hot areas with basaltic gravel as a media, daily irrigation may be necessary. In humid, cooler areas, irrigation may be done once to three times per week, depending on the season and weather.

The common practice at present is to mount rotating sprinkler heads above the plants. This practice encourages the spread of foliar diseases. It is better to design an irrigation system to apply water to the root system and keep the foliage dry. Spitters mounted on risers 12–24 inches above the ground can accomplish this. In addition, this type of system conserves water because irrigation water can be directed only to the plants, and aisles and peripheral areas can be kept dry (Fig. 2.8). Drip irrigation is seldom used because the large pore spaces of the most commonly used growth mediums do not allow capillary action to wet the entire root mass.

Fertilizer

Fertilizer application practices vary widely within the commercial dendrobium industry. Dendrobiums can be grown successfully using many different fertilizer formulations, amounts, and application schedules.

Young plants just out of flasks need not be fertilized immediately upon planting. They can simply be planted in the medium in a compot and watered for the first 10–14 days. After that, they can be fed a dilute solution of soluble fertilizer once a week after the plantlets have hardened off. This weekly application can be increased to twice a week after new roots and leaves appear. A soluble fertilizer with a 1:3:1 or 1:3:2 ratio of nitrogen, phosphorus, and potassium (N-P-K) used at ¼–½-strength is desirable. Because plants taken out of flasks do not have a well developed cuticle, the main objective at this point is to let the plants harden off without burning them. Plantlets injured by fertilizer are more susceptible to diseases, in addition to the obvious physical damage caused by high salinity.

Dendrobiums can be grown successfully using many different fertilizer formulations, amounts, and application schedules.

As dendrobiums get larger and are re-potted individually from compots, a controlled-release fertilizer (1:1:1 ratio) supplemented with phosphate is commonly applied. Growers often use magnesium ammonium phosphate (MagAmp®) to provide the additional P. MagAmp breaks down slowly and is released over a long period of time. Solid fertilizers should not be placed directly on the canes or leaves, where they could cause burns. Media should not be pre-mixed with fertilizers and kept for a long period of time in moist conditions, because salts will leach out and build up in the media, possibly causing root burn upon planting.

Controlled-release fertilizers are normally re-applied sooner than the interval stated on the fertilizer label in dendrobium production. The reason for this is that high temperatures in Hawaii, especially when coupled with high rainfall, contribute to faster release of fertilizer nutrients.

In fertilizer programs using controlled-release fertilizers, soluble fertilizers can be provided as a supplement. Used full strength once a week, soluble fertilizers can supply many of the micronutrients that plants need. Read the fertilizer container label to make sure that the soluble fertilizer contains micronutrients, because some contain only N-P-K without micronutrients. Soluble fertilizers should be applied by spraying the solution onto the foliage until it runs off. Leaves and roots will absorb the fertilizer in solution. Some growers never use solid fertilizers, using only soluble fertilizers applied with every irrigation.

A fertilizer trial on *Dendrobium* Jaquelyn Thomas '0580' conducted by UH-CTAHR indicated that the greatest yield of sprays, the longest sprays, and the largest numbers of flowers per spray resulted from growing plants in gravel beds and fertilizing with a slow-release 14-14-14 fertilizer applied at a rate of 1050 lb/acre/year.

Frequent visual monitoring of plants for leaf color, growth rate, new shoot activity, root activity, and spray yield and quality can help you to detect nutritional disorders. Dendrobium leaves should be light green for maximum yield. Excess nitrogen will cause the canes to be thick and the leaves to become dark green, but yields may suffer. Leaf tissue can be tested for levels of nutrients by an analytical laboratory to help you determine the optimum fertilizer program for highest yields and also to identify possible nutrient disorders or imbalances.

Several CTAHR researchers have reported results of fertilizer trials attempting to correlate analyses of elements in dendrobium leaf tissue with crop performance. Independent studies have been conducted on Dendrobium Jaquelyn Thomas 'Uniwai Blush', Jaquelyn Thomas 'Uniwai Supreme', and Jaq-Hawaii 'Uniwai Pearl'. The conditions in each study varied in terms of location, culture, nutrients, and experimental design, in addition to cultivars, making it difficult to produce anything other than generalized recommendations for ranges of levels of elements in leaf tissue of the UH cutflower varieties. Table 1 provides a summary of sufficiency ranges for macro- and micro-elements in leaf tissue of several UH cutflower varieties based on the analysis of the third mature leaf of a dendrobium cane (pseudostem). The selection of leaf to sample is important, because leaves of different ages and leaves on canes of different ages will have different elemental contents. The ranges in the table are based on and intended to be compared with elemental contents in the third most recently matured leaf of a mature cane, or in the third most recently matured leaf of an immature cane that has produced at least six mature leaves. The table is not a reliable gauge for young plants with fewer than six mature leaves.

Frequent visual monitoring of plants for leaf color, growth rate, new shoot activity, root activity, and spray yield and quality can help you to detect nutritional disorders.

A mature cane has had its growth in height terminated, usually with the emergence of an inflorescence at the cane apex. An immature cane has not terminated its growth and is still putting on new leaves at its apex. An immature cane is characterized by a bunched appearance of leaves at the cane terminal, and the stem cannot be seen between these leaves. The "first mature" leaf is the most recently fully expanded leaf and is easily identified because the stem can be seen below this leaf but not above it. Once the first mature leaf has been identified, the older leaves below it are numbered sequentially, and the third leaf can be found (Fig. 2.9).

Table 1.
Sufficiency ranges of elements in the third most recently matured leaf of University of Hawaii dendrobium cutflower cultivars.

Macronutrients	Sufficiency range (percent)
Nitrogen (N)	1.45 – 1.90
Phosphorus (P)	0.15 – 0.22
Potassium (K)	1.75 – 2.40
Calcium (Ca)	0.65 – 1.00
Magnesium (Mg)	0.40 – 0.80
Sulfur (S)	0.15 – 0.50

Micronutrients	Sufficiency range (parts per million)
Manganese (Mn)	30 – 100
Iron (Fe)	50 – 150
Copper (Cu)	8 – 15
Zinc (Zn)	50 – 150

2.9. The arrow indicates the leaf to be sampled for nutrient analysis.

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. Lilies, poinsettias, chrysanthemums, and dahlias are examples of plants that are routinely manipulated by growers to achieve more attractive potted plants or make plants flower out of season. John Kunisaki and Joanne Imamura-Licty, University of Hawaii at Manoa, and Bill Sakai, University of Hawaii, Hilo, have conducted experiments with plant growth regulators on dendrobium for these purposes.

Lilies, poinsettias, chrysanthemums, and dahlias are examples of plants that are routinely manipulated by growers to achieve more attractive potted plants or out-of-season flowering.

Growth retardants

Kunisaki reported that the plant growth regulators Ancymidol, applied at 0.16 milligrams active ingredient (a.i.) per 4-inch pot, and EL-500, applied at 0.33 milligrams a.i. per 4-inch pot, had the best results among several concentrations tested on the cultivar *D.* Jaquelyn Thomas 'UH 232'. Both of these chemicals caused new dendrobium shoots to have reduced internode length without reducing the number of potential flowering buds. The height suppression effects were most pronounced on shoots that developed soon after the application of the plant growth regulators. Shoots that developed weeks later were less influenced due to the dissipation of the plant growth regulators. Imamura-Licty has experimented with applying growth retardant carried in "kitty litter," which appears to prolong the effectiveness of the growth retardant. Flower size was not affected by either growth retardant.

Injection of cytokinin-gibberellic acid mixtures

Sakai evaluated the effects of injecting strong concentrations of benzyladenine (BA) and gibberellic acid (GA3) into pseudostems of *D.* Jaquelyn Thomas 'UH 800' and *D.* Jaq-Hawaii 'UH 306'. The peak flowering period for both of these hybrids is summer and fall, on stems in both their first and second year of growth. Stem injections made in November caused dormant lateral buds to develop into inflorescences that flowered in late January to early February, the off-season.

In the original study, 0.1 milliliter of a solution of 22,500 ppm BA in sodium hydroxide was injected into the center of the stem below the two top-most unflowered lateral buds. This was repeated five times at alternate internodes down the stem. In first-year stems treated just after harvesting the terminal flower spray, injection treatments resulted in the production of 8.92 sprays per stem vs. 0.52 from the untreated controls, and in leafless second-year stems injection treatments resulted in 6.32 sprays per stem vs. 0.24 for controls.

Because some deformed flowers resulted from the use of BA alone, GA3 was added to the treatment solution. The current recommendation is to prepare the solution using the commercially available chemicals BAP 10 (100,000 ppm BA) and Pro-Gibb (40,000 ppm GA3). The recommended injection solution is 10,000 ppm BA and 5,000 ppm GA dissolved in rubbing alcohol (isopropyl alcohol).

This injection treatment, although labor intensive, allows dendrobium cutflower growers to time flowering of the 18 or more dormant lateral buds on each stem. Flowering of induced sprays occurs about 3 months following treatments, so that fall and winter treatments result in forcing spray production for the high-demand periods during spring. There is also a reduction in summer flowering. Current research is adapting this injection treatment method for timing the flowering of potted dendrobiums.

Spray application of mixtures of cytokinins and gibberellic acid

The reason that night application is effective is because this is the time of day that stomata of dendrobium orchids are open.

Spray applications of BA and GA to dendrobiums have been ineffective in the past. This is presumably due to lack of penetration of the spray through the cuticle of the epidermis or through the stomatal openings. Sakai recently applied BA + GA3 spray solutions during the night with good results. The reason that night application is effective is because this is the time of day that stomata of dendrobium orchids are open. Dendrobiums are adapted to arid conditions because they mostly grow as epiphytes on branches in their native habitats and have evolved to have a crassulacean acid metabolism (CAM) pathway of photosynthesis. Most plants open their stomata during the day to exchange gases and transpire water. CAM plants are unique in that their stomata are closed during the day and open at night as a water conservation mechanism. At night they take in carbon dioxide and store it as malic acid, then in the day they use the stored carbon dioxide in photosynthesis.

Nighttime applications of BA + GA3 use the same concentrations as for the injection treatment but are dissolved in 50% isopropyl alcohol in water to slow evaporation. Initial results of nighttime applications show increased numbers of sprays from shoots that have reached full growth and are in the process of initiating sprays. Modification of the concentration and ratio of BA to GA3, use of other growth regulators, and use of surfactants may make this spray application method as effective as the injection method. This would reduce labor costs and increase its use by growers.

Drenching with cytokinins

Drenching rhizomes and roots with a 500 ppm BA solution (prepared by dilution of BAP 10 with water) has induced growth of new shoots of D. Jaq-Hawaii 'UH 306'. Drench treatments resulted in the production of 2.4 shoots per plant vs. 0.7 shoots for untreated controls. It appears that this BA drench treatment may have application in a cutflower operation to increase the density of flowering canes. It may also have application in a potted plant operation to shorten production time by increasing the number of growing and flowering shoots. Since these new shoots normally flower about 6 months following initiation, BA drenches may also be used to modify seasonal flowering behavior and force flowering during peak market demand periods.

Pests and pest management

Orchid growers in Hawaii wage continual battle with an increasing number of alien pests of orchids. "Alien" pests are species that arrive in Hawaii with the help (usually inadvertent) of humans; these immigrant organisms are also referred to as nonnative, exotic, nonindigenous, or introduced. They can arrive in many ways, including through the violation of plant importation regulations by people who bring plants to Hawaii without the proper approvals and inspections. Despite the best efforts of the regulatory agencies that try to protect Hawaii's environment from alien introductions, new pests keep coming. In each recent year, for example, the state of Hawaii has suffered the arrival of from 10 to 28 new insects. Because of the threat to Hawaii's environment posed by alien organisms, imports and exports of dendrobiums are subject to various regulations requiring permits, inspections, and in some cases quarantine, as briefly described in the chapter on the dendrobium orchid business (p. 69).

Dendrobiums and other orchids are themselves alien introductions. They might not have found any serious pests among the organisms that were present in Hawaii before the arrival of man, and dendrobium crops likely would be relatively pest-free, were it not for other alien species. The alien species that qualify as pests of dendrobium orchids include certain insects, mites, snails, birds, mammals, weeds, and disease pathogens.

The alien species that qualify as pests of dendrobium include insects, mites, snails, birds, mammals, weeds, and disease pathogens

Many of these aliens have become *serious* pests of dendrobium orchids. Most alien pests leave their natural enemies back in their native homeland, and without these natural enemies, the organisms often spread freely and develop large populations in Hawaii. The Hawaii Department of Agriculture has historically attempted "classical" biological controls against serious pests, involving the deliberate introduction of specific natural enemies. It is often difficult, however, to locate effective and specific natural enemies in the native home of the pest and to be sure that these natural enemies do not have undesirable effects on Hawaii's native flora.

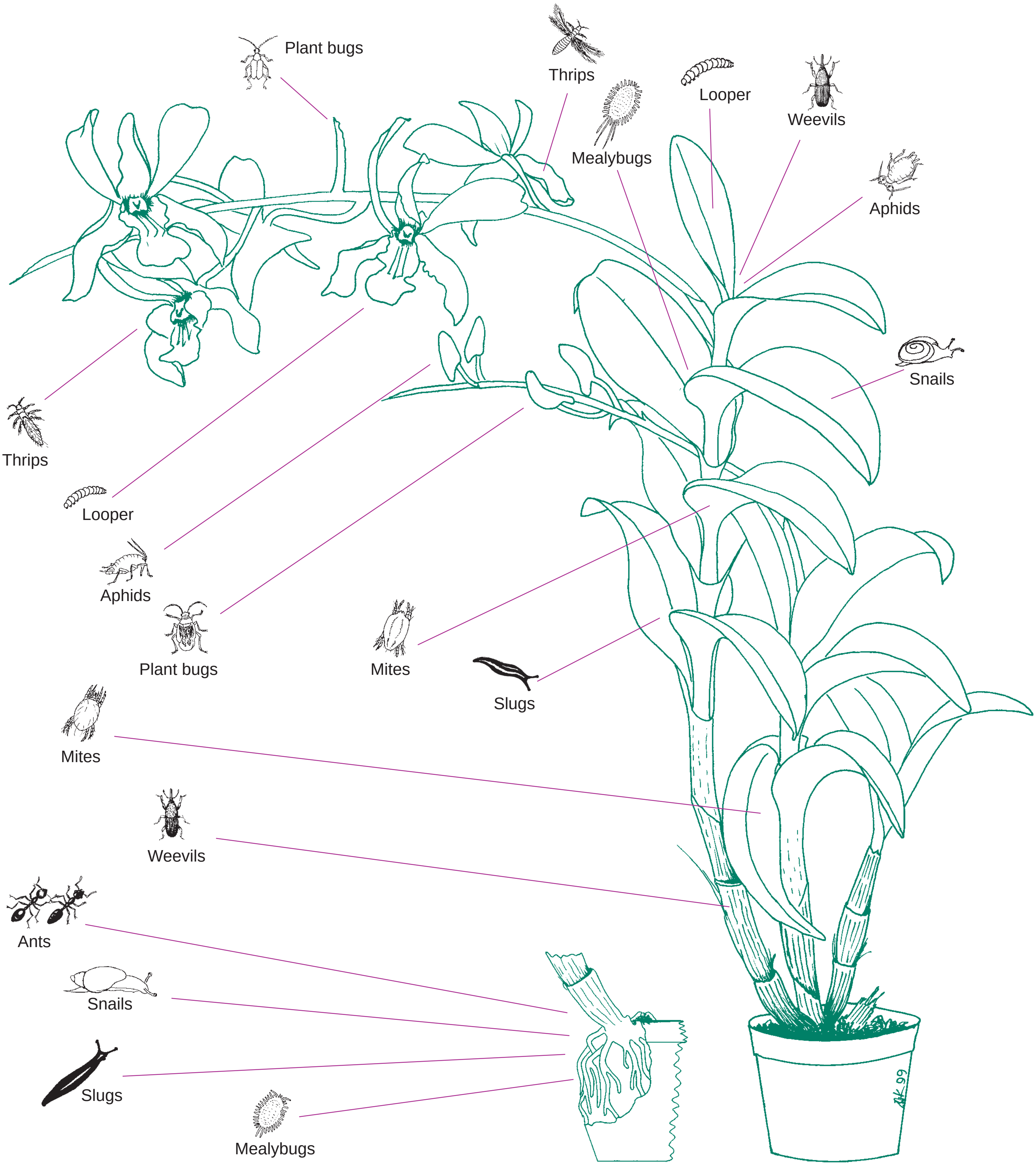
Although most of the major alien pests of orchids have natural enemies that occur in Hawaii, the normally monocultural orchid production environment in shadehouses and greenhouses may encourage alien pests and discourage their natural enemies. The use of broad-spectrum chemical insecticides especially discourages natural enemies.

In this chapter on dendrobium pests and their management, the recommendations are intended to maximize the use of biological, cultural, and physical control measures and minimize the use of broad-spectrum chemical pesticides. Also, an integrated pest management program should emphasize the use of "biorational" pesticides—pesticides that are effective against insect pests but not toxic to natural enemies of the pests, not harmful to humans, and do not cause pollution of the environment.

Insects, mites, and other pests

Some of the pests that infest dendrobiums are illustrated in the drawing on the next page. These and other dendrobium pests are described in detail in the following sections.

Some of the places to look for orchid pests*



*Pests not drawn to scale.

Aphids (Order: Homoptera, Family: Aphididae)

Cotton aphid, *Myzus persicae* (Sulzer)
Fringed orchid aphid, *Cerataphis orchidearum* (Westwood)
Green peach aphid, *Aphis gossypii* Glover
Orchid aphid, *Macrosiphum luteum* (Buckton)

3.1. Aphids on dendrobium leaves.

Aphids colonize dendrobium leaves (Fig 3.1) and flowers (Fig. 3.2). They have sucking mouthparts and feed on plant juices causing reduced plant vigor, stunting, leaf and flower deformities, and bud drop. Aphids are about 1⁄16 inch in size, can be either winged or wingless, and have a pair of horn-like structures (cornicles) on the posterior end of the abdomen. 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 host, the aphid), and this defense results in larger aphid populations. In Hawaii, all aphids are females that give birth to live young, which allows their population to increase rapidly. No male aphids have been observed in Hawaii due to our mild climate.

Pest management. Beneficial insects, including ladybird beetles, lacewings, syrphid flies, and parasitic wasps, can significantly reduce aphid populations. Parasitic wasps cause mummified aphids (Fig. 3.3), from which adult wasps emerge. Controlling ants that tend aphids will reduce aphid populations. 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 (Fig. 3.4). If chemical insecticides are applied, at least two weekly applications are needed for effective control.

3.2. Aphids on a dendrobium flower.

3.3. Mummified aphids from which parastitic wasps emerge.

3.4. Injury to flower caused by insecticidal soap.

Ambrosia beetles (Order: Coleoptera, Family: Scolytidae)

Black twig borer, *Xylosandrus compactus* (Eichoff)

The most important management practice is removal of infested plants or plant parts from the premises.

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. Besides the mechanical damage caused by the beetle boring, the associated ambrosia fungus (*Fusarium solani*) is pathogenic to plant tissue and causes discoloration and death of the cane. Entire plant death has been reported in severe infestations.

The black twig borer completes its life cycle from egg to adult within the cane. Life cycle stages include egg, larva, pupa, and adult. Eggs are oval, white, and laid on the ambrosia fungus (Fig. 3.5) cultivated by the female beetle. Larvae are white, legless grubs with distinct head capsules (Fig. 3.6) and feed entirely on the ambrosia fungus. The newly formed pupa is white and changes to light brown with black wings as it approaches maturity (Fig. 3.7). Female beetles are shiny black and about 1/16 inch long (Fig. 3.8)). The female adults emerge from galleries and disperse by flight in search of a suitable host to construct a new gallery. Male beetles are brown, smaller than the female, and flightless (Fig 3.8).

Pest management. The most important management practice is removal of infested plants or plant parts from the premises. Infested plants contain live beetles. Place all infested materials in a trash bag or a sealed container and dispose of them. This beetle is known to attack plants that are suffering from water, nutritional, or other stresses. Maintain plants in good health to minimize attacks by the black twig borer.

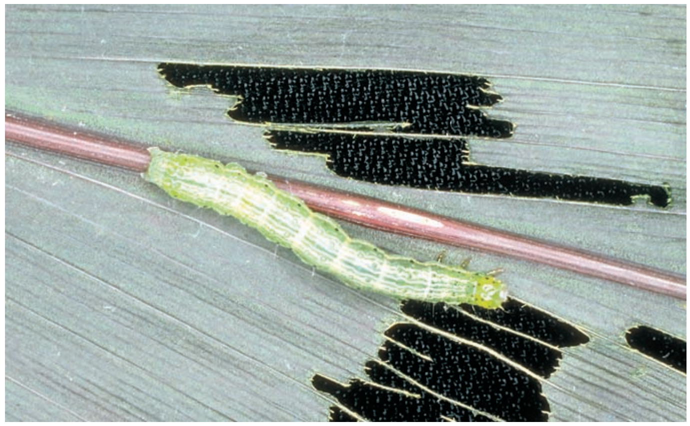
3.5. Eggs of the black twig borer laid on ambrosia fungus in the cane.

3.6. White, legless grubs in a gallery of the black twig borer.

3.7. Pupae in the gallery of the black twig borer.

3.8. Adult male (left) and female (right) of the black twig borer.

Caterpillars (Order: Lepidoptera, Family: Noctuidae)
Green garden looper, *Chrysodeixis eriosoma* (Doubleday)
(Family: Tortricidae)
Mexican leafroller, *Amorbia emigratella* Busck



3.9. Caterpillar on ti leaf.

Moths are nocturnal and active during the evening hours.

The terms "looper" and "leafroller" refer to the immature larval or caterpillar stage (Fig. 3.9) of certain moths. Moths are nocturnal and active during the evening hours. The characteristics of their feeding damage on plants depend upon the caterpillar age and species. Younger loopers feed on one side of the leaf, leaving a window-like appearance on the other side, while older larvae eat holes completely through the leaf or flower. In Hawaii, their life cycle lasts 33–35 days. The mature larvae spin a thin, white, silken cocoon and pupate within the cocoon. Cocoons are most commonly attached to the underside of leaves or within folded leaf edges of leaves. Adult females can deposit up to 280 eggs during their lifespan.

The Mexican leafroller attacks many kinds of plants including shrubs and fruit trees. The leafroller or caterpillar stage rolls the edges of leaves or flowers (especially young growth) or webs together leaves or flowers. The leafroller feeds for 28–35 days and then pupates within the folded leaf or flower. The adult emerges in about 10 days.

Pest management. Naturally occurring wasp and fly parasitoids are usually very effective against caterpillars, and therefore caterpillars seldom become a problem pest on ornamentals. Products utilizing the bacterial organism *Bacillus thuringiensis* ("Bt"), are effective against most caterpillars and have the added benefit of being non-toxic to natural predators and parasites. Caterpillars that feed on Bt do not die instantly, but they stop feeding and eventually die of starvation.

False spider mites (Order: Acariformes, Family: Tenuipalpidae)

Red and black flat mite, *Brevipalpus phoenicis* (Geijskes), *Tenupalpus pacificus* Baker

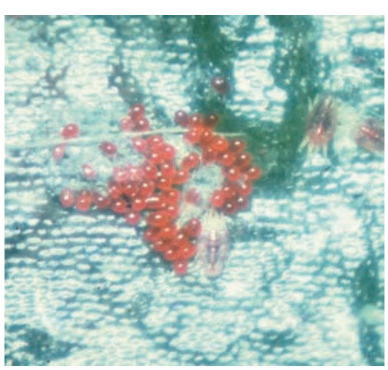
3.10. False spider mite feeding injury on a dendrobium leaf.

False spider mites are a major pest of dendrobium. Unlike spider mites, false spider mites do not spin a silken web. Plant injury is characterized by stippling, a silver-ish or bleached appearance (Fig. 3.10) resulting from mites sucking on plant sap and chlorophyll with their needle-like mouthparts. As the injured plant tissue oxidizes, the mite injury turns to brown and black (Fig. 3.11). False spider mites can be found on upper and lower leaf surfaces, stems, petioles, and flowers (Fig. 3.12). Life stages include egg, larva, nymph, and adult. The eggs are oval, bright red, and usually found on both leaf surfaces (Fig. 3.13). The larvae are about 1/200 inch long, are bright red, and have six legs. Nymphs have eight legs and are larger than the larvae. Adult mites are red and about 1⁄100 inch long (Fig. 3.14). The development time from egg to adult is about 29 days. Each female lays about 50 eggs in her lifespan of 34 days. False spider mites have a wide host range and also feed on allamanda, azalea, chrysanthemum, coffee, citrus, daisy, guava, hibiscus, mango, papaya, passionfruit, and other orchids.

Pest management. Early detection of the false spider mite is critical for effective control. Look for any tiny red specks associated with silvering of leaves, and confirm the presence of mites with a 10–15X hand lens. Fast moving, predatory mites, thrips, and ladybird beetles may control large populations of false spider mites. If miticides are used, apply two to three applications of a registered miticide at 2-week intervals. Sprays should be directed to the underside of leaves and flowers.

3.11. False spider mite feeding injury after plant tissue oxidizes.

3.12. False spider mite feeding injury on flower spike.



3.13. False spider mite eggs are oval, bright red, and usually found on both leaf surfaces

3.14. False spider mite adult (1⁄100 inch long)

Mealybugs (Order: Homoptera, Family: Pseudococcidae)

Longtailed mealybug, *Pseudococcus longispinus* (Targioni-Tozzetti)
Obscure mealybug, *Pseudococcus affinis* (Maskell)
Dendrobium mealybug, *Pseudococcus dendrobiorum* Williams
Jack Beardsley mealybug, *Pseudococcus jackbeardsleyi* Gimpel & Miller

Integrated pest management (IPM) is a systems approach to reducing pest damage to crops.

Mealybugs are difficult to control because they are protected by white, waxy secretions and aggregate in cryptic habitats such as leaf axials and roots. Mealybugs have piercing-sucking mouthparts, feed on sap, and secrete honeydew. Feeding damage on dendrobium results in deformed flower spikes (Fig. 3.15). Mealybugs are also found on roots and are a major cause of quarantine rejections for exported potted orchids. 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.

3.15. Jack Beardsley mealybug infestation causing deformed flower spike.

Pest management. Early detection is the key to successful pest management. Observe leaves and spikes for signs of mealybugs and remove plants from pots to inspect roots for mealybugs. Slow-growing plants or pots that are root-bound are more likely to become root-infested). Remove and dispose of flower spikes that are infested and deformed (unmarketable). If plants are heavily infested with foliar or root-infesting mealybugs, place them in trash bags and remove them from the farm. For foliar mealybugs, apply weekly applications of an insecticide approved for the use 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, but every effort should be made to prevent infestations. The following practices are recommended to prevent mealybug establishment and spread:

1) Inspect roots of all orchid plants, including newly purchased plants, by removing the plant from the pot.
2) Avoid root-bound plants by re-potting as needed; root-bound plants encourage mealybugs.
3) Use clean pots and media; if infested, wash with a detergent.
4) Treat or remove alternate hosts from your premises.
5) Do not allow water from infested areas to drain into clean areas; crawlers are transported by water movement.

Midge (Order: Diptera, Family: Cecidomyiidae)

Blossom midge, *Contarinia maculipennis* (Westwood)

The maggot stage of the blossom midge feeds inside unopened flower buds, causing deformity and aborted bud development.

The blossom midge has been in Hawaii since the early 1900s. The maggot stage of the blossom midge feeds inside unopened flower buds, causing deformity and aborted bud development (Fig. 3.16). Severely infested dendrobium buds rot and/or drop off the plant. As many as 30 maggots may be found infesting a dendrobium bud. Eggs are deposited inside the bud by the female. Maggots crawl and feed in the bud, bathed in fluids from the damaged tissue (Fig. 3.17). Maggots are able to leave the buds by "jumping" and burrowing into soil to pupate. Late stage pupae are active, burrowing up to the soil surface in preparation for adult emergence. Adult emergence from pupae usually occurs in the early evening hours. Adult blossom midges are very tiny, somewhat mosquito-like (Fig. 3.18). The life cycle from egg to adult is about 21 days, with 14 days spent in the soil. 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) (Cruciferae), bitter melon *(Momordica charantia)* (Cucurbitaceae), and pikake (Oleaceae).

3.16. Buds deformed by blossom midge.

Pest management. 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. Only the adult stage is vulnerable to contact foliar insecticides, and systemic insecticides are not translocated to orchid buds to affect the maggots. Insecticides applied as a drench can target the pupal stage of the blossom midge. To date, no parasitoids have been specifically introduced by Hawaii Department of Agriculture to control the blossom midge. Adults are vulnerable to general predators, such as web-spinning spiders.

3.17. Blossom midge maggots inside a bud.

3.18. Blossom midge adult (1⁄25 inch long).

Orchid weevils (Order: Coleoptera, Family: Curculionidae)

Orchid weevil, *Orchidophilus aterrimus* (Waterhouse)
Lesser orchid weevil, *Orchidophilus perigrinator* (Buchanan)

Orchid weevil larvae and adults have chewing mouthparts (Fig. 3.19) and feed on orchid flowers, stems, leaves, and exposed roots (Fig. 3.20). The adult female chews a hole in the canes or leaf and deposits an egg. After hatching, the grub 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 $\frac{1}{16}$ inch in diameter (Fig. 3.21) 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. *Orchidophilus aterrimus* is the largest of the orchid weevils in Hawaii, which range from $\frac{1}{8}$ to $\frac{1}{4}$ inch long. The lesser orchid weevil, *Orchidophilus perigrinator*, is at the lower end of the orchid weevil size range.

The adult female chews a hole in the canes or leaf and deposits an egg.

3.19. Adult orchid weevil and grub in orchid stem.

3.20. Orchid weevil feeding injury on leaves and stem.

3.21. Emergence hole of the adult orchid weevil.

Pest management. There are no reported specific parasitoids or predators of the orchid weevil. General predators, including spiders, toads, and birds, can be expected to feed on orchid weevils. Because of the orchid weevil's long life cycle of 5 months, sanitation is the most important management measure. Plants or plant parts with feeding damage and adult emergence holes should be placed in trash bags and taken from the premises. If sanitation is done soon enough, the spread of weevil infestations will be prevented. 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. Potted plants with feeding damage and other symptoms of orchid weevil infestation should not be marketed.

Plant bug, seed bug, and stink bug

(Order: Hemiptera, Family: Miridae)
Plant bug, *Taylorilygus pallidulus* (Blanchard)
(Family: Lygaeidae)
Seed bug, *Nysius* spp.
(Family: Pentatomidae)
Southern green stink bug, *Nezara viridula* (Linnaeus)

3.22. The southern green stink bug, Nezara viridula.

Plant bugs, seed bugs, and stink bugs develop from eggs into nymphs and then adults.

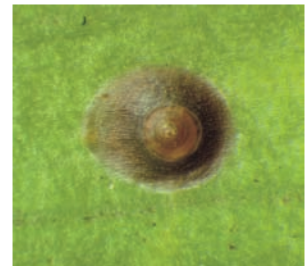
Plant bugs, seed bugs, and stink bugs (Fig. 3.22) have been associated with bud drop on dendrobium. Although there are other causes for bud drop, including physiological, nutritional, and environmental causes, these insects possess piercing-sucking mouthparts to feed on developing flower buds and cause 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. Plant bugs, seed bugs, and stink bugs develop from eggs into nymphs and then adults. The nymph appears slightly different from the adult because nymph wings are undeveloped, exposing their abdomen. The life cycle (egg to adult) of these sucking bugs is completed in about 30–45 days.

Pest management. The most important management measure is to locate the breeding host plants adjacent to the orchid production area. If practical, remove host plants or minimize their occurrence. 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.

Scales (Order: Homoptera, Family: Diaspididae—armored scales)

Boiduval scale, *Diaspis boisduvalii* Signoret
Florida red scale, *Chrysomphalus aonidum* (Linnaeus)
Proteus scale, *Parlatoria proteus* (Curtis)
Furcaspis biformis
(Family: Coccidae—soft scales)
Brown soft scale, *Coccus hesperidum* L.
Stellate scale, *Vinsonia stellifera* (Westwood)

The two types of scale insect are armored scales and soft scales. 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. The armor may be circular, semi-circular, oblong, or pear-shaped and varies in color from white to red to dark brown (Fig. 3.23). The adult female is always wingless and legless, while the adult male has functional wings and looks very much like a small gnat. 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. Armored scales do not excrete honeydew and are not tended by ants.



3.23. Furcaspis biformis, *an armored scale.*

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, although soft scales do excrete honydew and are tended by ants.

Pest management. Scale insects are very difficult to control with insecticides, especially in severe infestations. The best control method is to destroy all severely infested plants or plant parts. Because armored scales are spread chiefly through movement of nursery stock, only propagation material that is free of scales should be planted. Ladybird beetles (ladybugs) and parasitic wasps have been introduced and have become established in Hawaii to control armored scales. Scale covers that look chewed and have no insect underneath are signs that predators have been feeding on the scales. A tiny circular hole on the covering indicates that a parasitic wasp developed and emerged from the scale insect. Scraping and scrubbing to remove scales from plants are effective mechanical control tactics.

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 modern insecticides act on contact, and therefore only the crawler stage of the armored scale is susceptible to insecticides; the other stages are protected from contact insecticides because of the armor covering. 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.

Soft scales are easier to control. Eliminating ants foraging for honeydew will lower soft scale populations, and most contact insecticides are effective against soft scales. Horticultural oils have been shown to be effective against exposed eggs and crawlers of the armored scale and various stages of the soft scales. Early detection of incipient infestations is a key to successful scale insect control, because established scale insect infestations are very difficult to manage.

Thrips (Order: Thysanoptera, Family: Thripidae)

Banded greenhouse thrips, *Hercinothrips femoralis*
Dendrobium thrips, *Dichromothrips dendrobii* Sakimura
Greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouche)
Hawaiian flower thrips, *Thrips hawaiiensis*
Melon thrips, *Thrips palmi* (Karny)
Onion thrips, *Thrips tabaci*
Vanda thrips, *Dichromothrips corbetti*
Western flower thrips, *Frankliniella occidentalis* (Pergande)
Yellow flower thrips, *Frankliniella shultzei*
(Family: Phlaeotrhipidae)
Black flower thrips, *Haplothrips gowdeyi* (Franklin)

Small populations of thrips on open blossoms often go unnoticed because of the insect's small size.

Many species of thrips attack the leaves and flowers of dendrobium orchids, causing feeding damage with their rasping-piercing-sucking mouthparts. Greenhouse thrips and banded greenhouse thrips cause silvering of leaves (Fig. 3.24), which turn brown with time. Dendrobium thrips and vanda thrips attack flower buds and spikes, causing deformity and death (Fig. 3.25); these thrips also attack the young terminal leaves, causing dieback (Fig. 3.25). A complex of thrips species infests open blossoms, the most prevalent being the western flower thrips, *Frankliniella occidentalis*, yellow thrips, *F. schultzei*, and melon thrips, *Thrips palmi*. Large populations of thrips on open blossoms are usually recognized by feeding damage characterized by white streaks on petals occurring as narrow, irregular white lines and blotches (Fig. 3.27). Small populations of thrips on open blossoms often go unnoticed because of the insect's small size.

3.24. Greenhouse thrips feeding injury.

3.25. Dendrobium thrips injury to flower spike.

Melon thrips (Fig. 3.28) is a quarantine action pest of the U.S. Department of Agriculture, Animal and Plant Health Inspection Service (APHIS), with a zero tolerance into continental U.S. Because immature thrips are almost impossible to distinguish among species, quarantine inspectors will reject dendrobium blossoms infested with immature thrips that appear similar to melon thrips. Western flower thrips and yellow flower thrips have immature stages that appear similar to melon thrips. Thrips life stages include egg, two immature larval instars, prepupa, pupa, and adult. Eggs are oviposited into plant tissue. Immature larval stages and adults are the feeding stages. 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.

Pest management. Chemical control of thrips is very difficult because almost all stages are found inside flowers, and thrips are resistant to or tolerant of many insecticides. Therefore, non-chemical control of thrips should be emphasized. The first step in effectively managing thrips is early detection by monitoring. All dendrobium growers should construct or purchase a modified Berlese funnel to monitor thrips. A simple apparatus, the Berlese funnel, separates thrips from orchid blossoms. Briefly, a brooder lamp is placed on a galvanized funnel containing blossoms, and the heat from the lamp drives the thrips down the funnel into a jar containing alcohol (see Appendix A for construction details). With the Berlese funnel, low population levels of thrips can be detected, and this is the stage when control measures must be implemented. All infested flowers and plants should be removed and placed into trash bags. Insecticide application should be applied both to leaves and the ground. Foliar application targets immature and adult thrips, and ground application targets the pupal stage of thrips. Due to the difficulty in controlling thrips with insecticides, growers may want to take advantage of natural enemies of thrips. In Hawaii, pirate bugs (*Orius* spp.) have been observed in dendrobium blossoms heavily infested with western flower thrips. Under high humidity conditions, entomopathogenic fungi such as *Beauvaria bassiana* and *Paecilomyces fumosoroseus* may control thrips.

The first step in effectively managing thrips is early detection by monitoring.

3.26. Dendrobium thrips cause die-back of terminal leaves.

An educational video was produced by CTAHR to help growers identify and control thrips problems. It can be borrowed from Cooperative Extension Service county offices.

3.27. Damage to flowers caused by melon thrips.

3.28. Melon thrips on a dendrobium flower.

Whitefly (Order: Homoptera, Family: Aleyrodidae)

Silverleaf whitefly, *Bemisia argentifolia* Bellows & Perring
Sprialing whitefly, *Aleurodicus dispersus* Russell

Silverleaf whiteflies have been found infesting orchid flowers, causing aesthetic and quarantine problems.

Silverleaf whitefly has been distinguished as one of the most economically destructive pests of agriculture. Although silverleaf whitefly is the most serious pest of poinsettia, dendrobium orchids do not escape infestations. Silverleaf and spiraling whiteflies have been found infesting orchid flowers, causing aesthetic (Fig. 3.29) 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. Silverleaf whitefly resembles the sprialing whitefly (Fig. 3.30) and is so similar to the greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), that it can be distinguished only by microscopic examination of the pupal stage. The entire life cycle from egg to adult may range from 15 to 70 days, depending on temperature and the plant host.

3.29. Spiraling whitefly egg track.

3.30. This spiraling whitefly closely resembles the silverleaf whitefly.

Pest management. Whiteflies were very difficult to control chemically until the registration of imidacloprid (Marathon®, Merit®). However, overuse of imidacloprid will render it ineffective against the silverleaf whitefly. In recent years, lower populations of the silverleaf whitefly in Hawaii have been associated with higher occurrence of parasitic wasps specific to whiteflies. Therefore, whitefly control on dendrobium should not be problematic if proper pest management measures are followed. Most important is early detection of whiteflies and implementing control measures when the population is low to moderate. Whiteflies are tolerant of or resistant to many insecticides, and therefore effective insecticides in different classes (e.g., oils, soaps, pyrethroids, organophosphates, chloronicotinyl) must be rotated to prevent the development of resistance. Oils and soaps are effective against whiteflies, although depending on their concentration, the formulations may be phytotoxic to dendrobium orchids.

Birds

Red vented bulbul, *Pycnonotus cafer*; **red whiskered bulbul,** *P. jacosus*
Common sparrow, *Passer domesticus*
Rice bird, *Munia nisoria*
White-eye or **mejiro**, *Zosterops palpebrosus japonica*
Kentucky cardinal, *Richmondena cardinalis*

Birds are a severe problem in orchids, especially in September through December in Hawaii. 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 (Fig. 3.31), 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.

3.31. Flower buds damaged by birds.

Birds are a severe problem in orchids in Hawaii, especially in September through December.

Pest management. Birds develop feeding habits and learned behaviors. Therefore, fields should be frequently monitored for birds so early action can be taken. Total enclosure by screening the crop area is the most effective method to reduce damage. The odor of certain insecticides and fungicides is also known to repel birds, but repellence is short lived. 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. 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.

Mice

House mouse, *Mus musculus*

Mice 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 outbreaks and damage to crops usually occur during a drought period when wild food and water sources dwindle.

Mice can vary in color from tan to gray and are 6–7 inches from nose to tail. The tail is as long or longer than the head and body combined. A mouse has a slender body, large ears, small eyes, and a pointed nose. Nests are built just about anywhere, including under rocks, boards, and vegetation, and each female can produce as many as 50 young per year.

Pest management. Mice, like other rodents, are mainly nocturnal but occasionally feed during the day. There are many types of effective non-chemical mouse traps on the market including sticky traps, snap traps, and cage traps. Rodenticides contain a food bait and a chemical toxicant, and because rodents are mammals, these rodenticides are also highly toxic to humans and domestic animals. Rodenticides are divided into either single-dose or multiple-dose rodenticides.

As the name implies, multiple-dose rodenticides require repeated feedings before death occurs. Multiple-dose rodenticides are safer to non-target mammals than single-dose rodenticides. The majority of multiple-dose rodenticides are anti-coagulants, which causes death by internal bleeding. Single-dose rodenticides are used for quick knock-down of mouse populations. When using single-dose rodenticides, bait shyness may cause ineffectiveness, and rotation with multiple-dose rodenticides is recommended.

Slugs and snails

(Family: Limacidae) **Marsh slug**, *Deroceras laeve* (Muller)
(Family: Veronicellidae) **Brown slug**, *Vaginulus plebeius* Fischer,
Two-striped slug, *Veronicella cubensis* (Pfeiffer)
(Family: Bradybaenidae) **Small garden snail**, *Bradybaena similaris* (Rang)
(Family: Achatinellidae—cone spiral shell) *Tornatellides* sp.
(Family: Helicarionidae) *Liardetia doliolum* (Pfeiffer)
(Family: Zontidae—flat spiral shell) *Zonitoides arboreus* (Say)

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 are found hidden 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, *Vaginulus plebeius* (Fig. 3.32), and the two-striped slug, *Veronicella cubensis* (Fig. 3.33), first reported in Hawaii in 1978 and 1985, respectively. Since then, high population levels of these slugs have resulted in severe damage to many ornamental, vegetable, and landscape plants in Hawaii.

The brown slug and the two-striped slug range in color from beige to dark brown. The two-striped slug is easily recognized by the two longitudinal stripes on its back. These veronicellid slugs are hermaphroditic, with a single slug having both male and female reproductive organs. However, mating is usually required between two individual slugs and both may lay eggs. Depending on the species, 10–200 eggs are laid, which hatch in 14–30 days. Juveniles reach sexual maturity in 3–5 months and may live for as long as 2 years.

In recent years a native snail (*Tornatellides* sp., Fig. 3.34), and the introduced snails *Liardetia doliolum* and *Zonitoides arboreus* (Fig. 3.35) have become of quarantine significance on ornamentals, including dendrobium. These snails occur primarily on roots in the media and on leaves and are tiny (⅛–½ inch) and therefore may go unnoticed. *Z. arboreus* has been in Hawaii since at least 1928, and its presence has been confirmed on Oahu, Maui, and Hawaii.

Pest management. The control of snails and slugs must first include sanitation, that is, the destruction of hiding places and removal of plant debris. An effective physical control is the use of barriers in the form of copper flashing, copper screen, or copper hydroxide. Copper is highly repellent to snails and slugs, and continuous contact with copper will cause their death. Copper flashing can be affixed to bench legs to inhibit snails and slugs from reaching bench tops from the ground.

Most molluscicides contain metaldehyde and a bait to attract snails and slugs. Metaldehyde acts as a contact and stomach poison. After absorption or ingestion, metaldehyde disrupts the lining of the gut and causes excessive mucus secretion. For best results, molluscicides should be applied after rainfall when slugs are actively foraging. Although pelleted and granule formulations provide high initial mortality immediately after application, effectiveness rapidly declines with rainfall. On the other hand, liquid paste formulations increase in effectiveness with rainfall for 4–6 days after application before decreasing in effectiveness. For controlling tiny snails on plants, a liquid spray-on metaldehyde molluscicide could be used.

These mollusc pests are among a group that is spreading around the world. For example, at least 34 alien snail and slug species are currently on the island of Hawaii, and many were likely introduced on horticultural products. Strict observance of quarantine inspection requirements will minimize the accidental import and export of mollusc pests.

3.32. Brown slug.

3.33. Two-striped slug.

3.34. Tornatellides *sp., a native snail.*

3.35. Zonitoides arboreus, *an introduced shail.*

Diseases

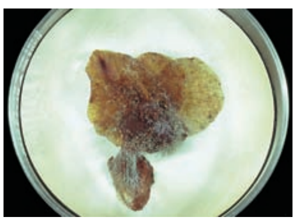
Environmental conditions in the tropics are frequently conducive to disease development. Plant pathogens proliferate in Hawaii's warm, moist environment and impact Hawaii's ability to economically produce dendrobium for the world market if appropriate pest and disease control measures are not practiced. Also, importation of ornamental plants and cut flowers from elsewhere in the world continually 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. Dendrobium diseases that are commonly encountered in Hawaii are discussed below.

Monoculture, the practice of planting large fields of the same clone or similar clones, favors rapid disease spread.

Diseases caused by fungal pathogens

Botrytis blossom blight, or gray mold

Botrytis cinerea commonly causes spots and soft rots or blights of flowers (Fig. 4.1–4.3). 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 moist periods, specialized fungal threads called conidiophores are produced on the surface of diseased flowers. Large quantities of spores are formed on these conidiophores. Spore masses are gray, and individual spore clusters resemble small sand grains (Fig. 4.1). Spores are spread by air movement, splashing, or through contact. *Botrytis* spores germinate on healthy flowers when moisture is present 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 may land, germinate, and penetrate in close proximity to each other, which favors establishment of the pathogen and eventual spot formation. Although less common, single spores can also initiate spot development.



4.1. Botrytis *spores on a rotting vanda blossom.*

4.2. Flecks caused by Botrytis *on a phalaenopsis flower; large spots or blights do not develop from these flecks.*

4.3. Blight of dendrobium flowers caused by Botrytis.

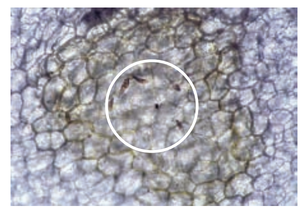
Floral buds are also infected, but leaves and stems are not. Most commercial dendrobium and vanda cultivars are susceptible to *Botrytis*, but cattleyas, cymbidiums, and phalaenopsis are more tolerant (Fig. 4.2). Unlike diseases caused by many tropical pathogens, temperatures must drop below 70°F (21°C) before botrytis blossom blight becomes much of a problem. Thus, development of this disease is favored during cool, moist winter periods.

Pest management. Greenhouses and fields should be monitored frequently. At the first sign of this disease in the greenhouse, remove diseased flowers from the nursery. Do not discard infected flowers at the nursery, because spores will develop on diseased blossoms and can be blown onto healthy flowers. If diseased flowers must be disposed of at the nursery, deep burial or bagging and disposal with refuse is recommended. Control moisture levels by using solid-covered greenhouses, and reduce humidity by providing good air circulation and plant spacing. Irrigate in the morning and avoid wetting the foliage or flowers. Fungicides are available for disease control (see Appendix B). Carefully follow all label directions when using any pesticide.

Blossom flecks and small spots

During the summer, outbreaks of botrytis blossom rot are extremely rare because temperatures above 80°F (27°C) inhibit growth and sporulation of *Botrytis*. However, blossoms can be covered with tremendous numbers of small spots and flecks, which render them unmarketable. These flecks and small spots are tan to dark brown, oval to circular, sometimes sunken, and about 0.04 inch (1 mm) or less in diameter. The small spots are 0.12–0.20 inch (3–5 mm) in diameter and do not expand. Blossom flecks are common on dendrobiums that are grown in open fields and under shadecloth-covered structures. Potted orchids grown in shadehouses also suffer from blossom flecks and spots.

4.4, 4.5. Bipolaris *has caused numerous flecks on these dendrobium flowers.*



4.6. The brown area in this photomicrograph of a dendrobium petal is a fleck caused by Alternaria. *The spores (in circle) have germinated, the fungus has entered the host tissue, and the cells are dying.*

Blossom flecks and spots (Fig. 4.4 and 4.5) are caused by several fungi including *Alternaria alternata*, *Exserohilum rostratum*, *Bipolaris setariae*, *Bipolaris sorokiniana*, and other *Bipolaris* species. 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 (Fig. 4.6). 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.

Pest management. Weed control in and around the greenhouse, sanitation (removal of dead plant debris), and moisture control are important in managing blossom spots and flecks. Fungicides can reduce disease levels by preventing infection (see the list of fungicides in Appendix B).

Blossom flecks are common on dendrobiums grown in open fields and under shadecloth-covered structures.

Colletotrichum

A *Colletotrichum* species highly pathogenic to dendrobium cultivars has been isolated and tested in Hawaii. Several important diseases are caused by this pathogen, including leaf spots, shoot blight, blossom spots and blights, spike and bud rots, and damping-off of young seedlings.

Small seedlings and young growth on mature plants are very susceptible to this pathogen. The fungus will infect leaves, sheaths, or canes (stalks) 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 (Fig. 4.7). The fungus also causes sheath rots that lead to leaf yellowing and loss (Fig. 4.8 and 4.9). Loss of new canes or stalks greatly impacts production for the next few years. Spots on expanding leaves are circular to oval, dark brown (Fig. 4.10), and in time may be surrounded by a wide chlorotic area. Blossom and bud rots may resemble those caused by *Botrytis*. However, development of blossom blights (Fig. 4.11 and 4.12) are slightly slower with *Colletotrichum*. In addition, more browning of the diseased tissue occurs, and numerous smaller spots may also be present.

Advanced rots caused by Colletotrichum *may have salmon-colored spore masses on the surface of rotted tissue.*

Dark, oval rots develop on stems of floral sprays (Fig. 4.13). 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. 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 this *Colletotrichum*. Rots and blights are common during the winter, and prolonged periods of moisture during this cool period can foster such high disease levels that entire fields are defoliated (leaves lost) (Fig. 4.14).

4.7–4.14. Damage to dendrobium plants caused by Colletotrichum.

4.7. Young leaves infected and killed.

4.8. Sheath spots and rots.

4.9. Sheath rot and loss of leaves.

4.10. Leaf spots.

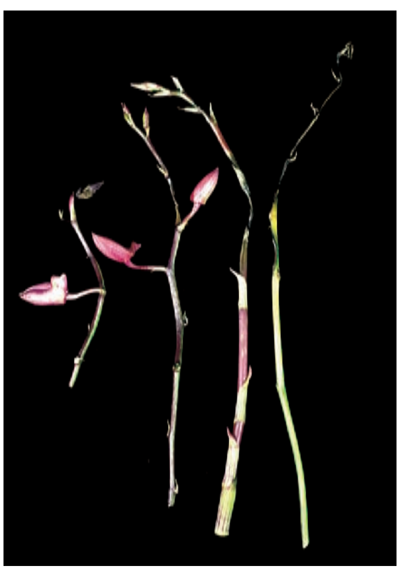
Pest management. Fungicide use will reduce disease levels (see Appendix B). Many other diseases caused by *Colletotrichum*, such as anthurium anthracnose, are controlled by thiophanate methyl fungicides, but the *Colletotrichum* occurring on orchids cannot be controlled with these fungicides. Potted plants produced for retail sale should be cultivated under solid cover to prevent moisture retention on plants during cool periods. Adequate air movement should be provided to reduce humidity levels. Overhead irrigation should be done during the early morning to allow leaves and shoots to dry during the day. Diseased plants or plant parts should be collected and removed.

On the island of Hawaii, the bamboo orchid (*Arundina bambusifolia*) commonly has leaf spots and blights. These spots are caused by *Colletotrichum* and will contaminate dendrobium plantings. Be sure that the border surrounding the field is free of bamboo orchid. Vanda and oncidium orchids are also hosts of this fungus.

On the island of Hawaii, the bamboo orchid (Arundina bambusifolia) *commonly has leaf spots and blights.*

4.11. Blossom rot.

4.12. Blossom rot on nobile dendrobium.



4.13. Stem rot of floral sprays.

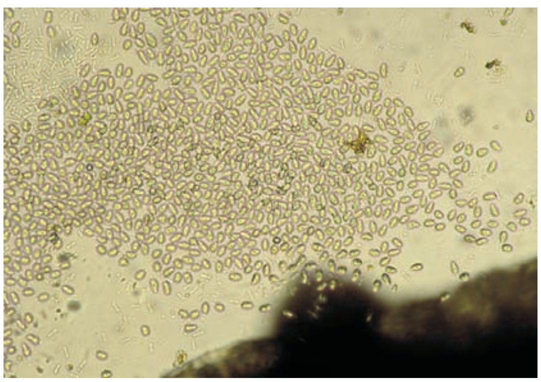
4.14. General defoliation.

Phyllosticta capitalensis

4.15. Yellow and black leaf spots caused by Phyllosticta.

Several important diseases of dendrobium are caused by *Phyllosticta*, which produces circular yellow spots on leaves (Fig. 4.15). 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. 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) (Fig. 4.16). 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 perithecia. 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, which look alike.



4.16. Photomicrograph of spores released by a pycnidium of Phyllosticta.

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 parts of the day. These symptoms do not occur on infected white blossoms. Blue spots become brown only after the flowers are harvested. Within 24 – 48 hours after harvest, the spots develop into a rot, and spore-producing bodies are formed in a few days. These dark brown rots are especially common in boxed flowers exported from Hawaii.

Recently, potted blooming dendrobiums have become very popular. Unfortunately, plants with *Phyllosticta* leaf spots ship poorly and also decline in most garden-shop environments. Yellow spots represent 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.

As the leaf becomes older, yellow spots become tan spots, and fungal growth within the tan spots greatly increases.

Pest management. No chemical treatment has been found that eliminates *Phyllosticta* once it has penetrated the leaf and the yellow spot has developed. Thus, disease management must be focused on prevention of fungal infection. Inoculations of healthy plants have demonstrated that young shoots are very susceptible and that symptoms take 2–5 months to develop. Preventive control measures can be accomplished in the following ways:

- sanitation: keep the nursery clean and spore levels low by continuously removing all dead and dying leaves from the field or greenhouse
- moisture control: reduce moisture by watering early in the day and spacing plants for good air movement
- fungicides: apply fungicides that will prevent spore germination (see Appendix B); follow label directions carefully

Fusarium rot

Fusarium proliferatum causes flower spots, leaf spots, 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 (Fig. 4.17 and 4.18). Leaves are infected when young, and the severity of the disease depends on shoot age and moisture levels. Spots on mature leaves are commonly small, dark, and sunken. A common characteristic of *Fusarium* spots is the rows of three to four spots across the leaf blade, usually close to the cane (Fig. 4.18). This distribution reflects the infection time, when high moisture levels allowed fungal establishment in the young folds of new leaves on emerging shoots.

4.17. Blossom spots caused by Fusarium.

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.

Fusarium is most damaging to seedlings. Young plants in community pots are rapidly killed by this pathogen. Surviving plants continue to suffer from the infection as they mature.

4.18. Leaf spots caused by Fusarium.

Pest management. *Fusarium* is a prolific sporulator. Large number of spores are continually produced on dead and infected tissues. Even small black spots are sources of many spores. Sanitation through removal of infected plant parts is highly recommended. *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 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.

Once a plant is infected, it is very difficult 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. Seedlings should be grown in a separate, clean propagation house used only for new seedlings. Plants should be obtained in flasks, grown clean, and kept healthy. If seedlings are purchased in community pots or large 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. Seedlings purchased from different growers should not be mixed. Keep them separated on different benches and by solid plastic barriers if possible.

Once a plant is infected, elimination of Fusarium *is nearly impossible.*

Moisture control is crucial to disease prevention and control. The greenhouse should have a solid roof. Overall plant growth and vigor will be improved under solid-covered greenhouses. This recommendation also applies to other fungal and bacterial diseases.

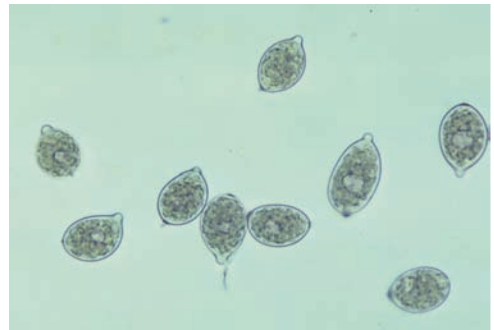
Many species of *Fusarium* are saprophytic, and among those tested in Hawaii thus far, only *Fusarium proliferatum* has been pathogenic to orchids. When this fungus was collected from diseased plants at commercial nurseries, the pathogen was resistant to thiophanate methyl fungicides. *Fusarium proliferatum* has been isolated from diseased cattleya hybrids, ascocendra, catasetum, and vanilla.

Phytophthora

In the tropics, diseases caused by *Phytophthora* are common. Once these pathogens are introduced into a tropical environment, the warm temperature and high humidity favor their growth, spread, and infectivity. Several species of *Phytophthora* have been isolated from diseased orchids in Hawaii. *Phytophthora palmivora* and *Phytophthora nicotianae* have been the most common.

4.19. Blossom rot caused by Phytophthora.

The major diseases on dendrobium caused by *Phytophthora* are leaf spots and blights, root and stem (cane) rots, damping-off of seedlings, and occasional flower blights (Fig. 4.19). *Phytophthora* infections require high humidity or periods of high moisture. *Phytophthora* species produce specialized spores called sporangia that are microscopic in size, lemon-shaped, and hyaline (clear) (Fig. 4.20). These spores produce a germ tube that penetrates into the leaf, stem, flower, etc. The sporangia will also produce zoospores (swimming spores) when water is present on the leaf surface. Zoospores swim short distances in water, encyst (spores lose their flagella or tail and become spherical), germinate by producing a germ tube, and penetrate the host by growing into the leaf. Leaves are often penetrated through stomata, the natural openings on the leaf epidermis that allow gas and water exchange between the plant and the atmosphere.



4.20. Photomicrograph of Phytophthora.

4.21. Dying plants on the left were inoculated with Phytophthora *five days earlier; healthy plants at right were not inoculated.*

In moist, warm weather, infected plants less than a year old can be killed in a few weeks by Phytophthora.

In moist, warm weather, infected plants less than a year old can be killed in a few weeks by *Phytophthora* (Fig. 4.21). Leaf spots are initially olive-green to greenish yellow and darken to brown or black rots as the leaf dries (Fig. 4.22 and 4.23). Defoliation is common (Fig. 4.24). In older plants, leaf infections progress into canes, leaves become yellow (Fig. 4.25), and the disease gradually reduces plant size and vigor. Cane rots are dark and wet in young canes (Fig. 4.26) and lighter brown, dry, and fibrous in mature canes (Fig. 4.27 and 4.28). Root rots are severe in potted plants and in the field during rainy seasons or if drainage is poor (Fig. 4.29). Root rots cause plant decline, and plants are killed if the pathogen moves into stems. *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 (Fig. 4.30). Sporangia are usually spread by splashing water, plant-to-plant contact, and movement of spores by insects, slugs, snails, and plant handlers.

Pest management. Sporangia are produced on the surface of rotted plants. Control strategies must include removal of all diseased leaves and canes and the complete removal of severely diseased plants. As with other fungal diseases, moisture reduction through better air circulation and proper irrigation management will also reduce *Phytophthora* spore formation and the rapidity of disease initiation. Without splashing water, movement of sporangia is limited. Potting media should not be reused because the fungus survives in dead roots and the media for many months. Fungicides to prevent or reduce disease levels are available (see Appendix B).

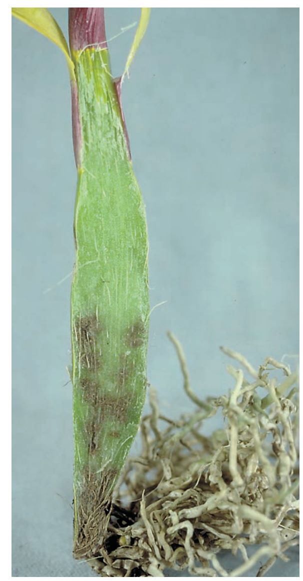
4.22. The leaf rot on this young plant developed under moist conditions.

4.23. Compared to the plant in Fig. 4.22, this leaf rot developed in a drier environment.

4.24. Potted dendrobium defoliated by Phytophthora.

4.25. Typical Phytophthora *disease symptoms on a potted plant; note the yellow leaves and dead shoot.*

4.26. Young stem with black rot caused by Phytophthora.



4.27. Internal cane rot caused by Phytophthora *begins from root rot and moves unevenly up the stem.*

4.28. Advanced cane rot caused by Phytophthora*; the dead tissue is dry, fibrous, and irregular in occurrence.*

4.29. Root rot of a young plant; healthy roots are completely white.

4.30. When seedlings are closely packed in trays, Phytophthora *spores are easily spread from plant to plant.*

Pythium root diseases

Lack of vigor, slow decline, and reduced productivity are effects of pythium root rot.

Several *Pythium* species cause root rots of potted and field-grown dendrobiums. Infected plants have brown, rotted roots, or less 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. Growers should avoid potting media that retains moisture excessively. In high-rainfall areas or on soils with poor drainage, dendrobiums should be planted on mounds to ensure good drainage. Wound injuries and burns from fertilizer salts may predispose roots to *Pythium* infection. Use of fungicides may aid disease prevention and control (see Appendix B).

Seedling rot caused by *Calonectria ilicicola* (*Calonectria crotalariae*)

This fungus has been repeatedly associated with dead seedlings in community pots. *Calonectria ilicicola* 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, so all dead plants should be removed promptly. Effective fungicides are listed in Appendix B.

Rhizoctonia root rot

The fungal pathogen Rhizoctonia solani *is known to attack many types of plants throughout the world.*

The fungal pathogen *Rhizoctonia solani* is known to attack many types of plants throughout the world. It 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).

In the past, growers who received diagnostic reports of root rots caused by *Rhizoctonia solani* generally applied thiophanate methyl or benzimidazole fungicides, but given the current uncertainty about the pathogenicity of different forms of this fungus, this practice appears less advisable. The significance of determining the nuclear state (binucleate or multinucleate) to identify *Rhizoctonia solani* is a fairly recent development. Previously, *Rhizoctonia solani* was identified by characteristics such as the brown fungal growth it produces and the type of branching it forms. Scientists now recognize that these are also characteristics of non-pathogenic binucleate *Rhizoctonia solani*-like fungi. Until a comprehensive study can be made, the exact role of these closely related organisms will not be known.

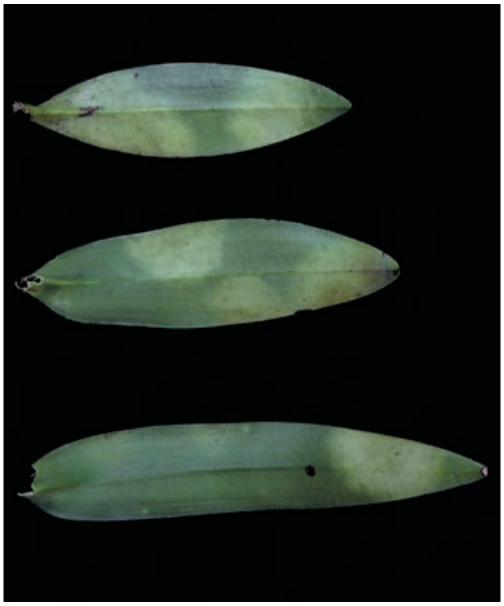
Leaf diseases caused by *Pseudocercospora* species

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 (Fig. 4.31). Premature defoliation occurs, and the yellow, detached leaves have brown spots. Other species of *Pseudocercospora* cause smaller, irregular blemishes (Fig. 4.32). These are 0.12–0.20 inch (3–5 mm) in diameter and generally occur in large numbers. A general mosaic pattern occurs when large sections of the leaf are diseased. Low disease levels occurring in field-grown dendrobium do not affect yield, but high disease levels will reduce yield. 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.).

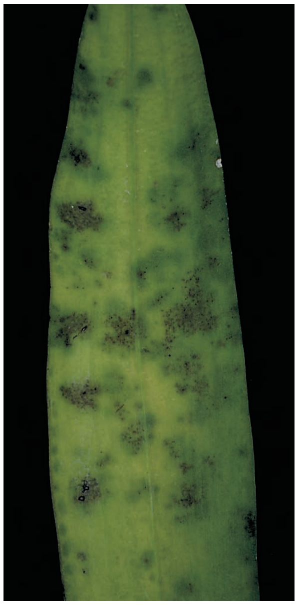
To reduce disease levels, regularly remove all dead leaves to lower inoculum (spore) levels.

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 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 (skin). Growth and lesion development of this fungus is very slow. Other members of *Pseudocercospora* require several weeks after penetration before the first symptom of infection is evident.

Pest management. To reduce disease levels, regularly remove all dead leaves to lower inoculum (spore) levels. If the disease is severe, apply a fungicide (see Appendix B) after removing all infected leaves.



4.31 Circular leaf spots caused by a Pseudocercospora *species.*



4.32. A different Pseudocercospora *species caused these numerous, small spots.*

Diseases caused by bacterial pathogens

Bacterial plant pathogens occur worldwide and attack many crops. The most famous bacterial pathogen in Hawaii is *Xanthomonas campestris* pv. *dieffenbachiae*, which causes anthurium blight and resulted in huge losses in the Hawaii anthurium industry. Food crops including cabbage, onions, tomatoes, potatoes, and many others are also attacked by bacteria, which cause foul-smelling soft rots.

The two major bacterial pathogens that have been identified on dendrobium in Hawaii are *Erwinia chrysanthemi* and *Pseudomonas gladioli* pv. *gladioli*. The symptoms caused by these bacteria are similar. Leaf spots begin as small, water-soaked, dark green areas that rapidly enlarge into soft rots (Fig. 4.33). The surrounding tissue may be yellow, while the center of the spot becomes tan to brown (Fig. 4.34). The entire leaf is invaded by bacterial cells, and soft, flaccid, yellow leaves are a common result (Fig. 4.35). 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 (Fig. 4.36).

The two major bacterial pathogens identified on dendrobium in Hawaii are Erwinia chrysanthemi *and* Pseudomonas gladioli *pv.* gladioli.

Bacteria commonly enter plants through wounds, but wounds are not necessary for infection. Young tissues (e.g., new shoots) are very susceptible.

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, which is actually necessary for their successful colonization of host tissue.

Diseased plant tissue contains billions of bacterial cells. The bacteria can be observed as an ooze in microscopic examination of diseased plant parts. Any natural opening or break in the epidermis of a diseased plant will allow huge quantities of bacteria to accumulate on its surface. These bacterial cells are then spread to other plant parts or to healthy plants by splashing water or direct contact. Bacterial cells can contaminate pots, trays, plant tags, clothing, gloves, clippers, and anything else that comes into contact with a diseased plant. Water that drains from diseased sections

4.33. Bacterial rot of a dendrobium leaf.

4.34. Bacterial rot with gray to tan center and a surrounding chlorotic (yellow) zone.

4.35 Advanced stage of a bacterial leaf rot.

of the field will also carry bacteria, as will used potting media and soil or gravel from infested fields.

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.

Prolonged periods of high moisture favor development of bacterial diseases. In Hawaii, certain wet areas have environmental conditions that make disease control difficult.

Pest management. Strategies for effective bacterial disease management include the following:

Select a nursery site that is conducive to good plant growth. Land may be cheaper in wet areas, but disease management will always be more expensive. Growers producing dendrobiums in wet areas should seriously consider solid-covered greenhouses. Design and situate nursery structures and the position of benches (spacing between rows, direction of rows, etc.) for good air movement to keep foliage as dry as possible. Unless windbreaks are necessary, keep trees and other plant growth around the shadehouse to a minimum to provide good air circulation and adequate light and discourage insect breeding.

Chemical treatments to cure bacterial diseases are not available.

Prevention. Disease prevention is crucial for control. Once a nursery is contaminated, it is virtually impossible to eradicate bacterial pathogens economically. 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. Maintain new plants in an area separate from production areas and monitor for the presence of pathogens. Immediately discard diseased plants.

Clean up the nursery. Place all dead and dying plants in waste containers and remove them from the field—do not dump them in a pile at the nursery. Remove all dead leaves and stalks. It is impossible to cure a dendrobium plant that has a bacterial infection, so all infected plants should 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.

***Chemical treatments to cure bacterial diseases are* not *available*.** Bacteria become systemic and are protected inside diseased plants. Thus, most chemicals never come in contact with the bacteria. 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.

4.36. Typical leaf drop and broken cane caused by bacterial infection.

Diseases caused by nematodes

Most nematodes are microscopic, have long slender bodies, and reproduce by producing eggs.

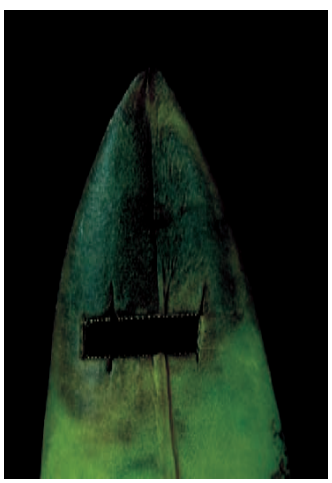
Plant parasitic nematodes belong to a group of organisms known as roundworms. Most nematodes are microscopic, have long slender bodies, and reproduce by producing eggs. The most common plant parasitic nematodes attacking orchids are *Aphelenchoides besseyi* and other *Aphelenchoides* species. These foliar nematodes are active swimmers and can move in a thin film of water on the external surface of the plant. They migrate into plant leaves and feed on the cells by using a spear-like structure in their mouth called a stylet. On dendrobium, 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 (Fig. 4.37) and become darker brown as the leaf turns yellow and dies (Fig. 4.38). Development of these blotches is relatively slow, and green leaves can remain blotchy for several weeks.

Foliar nematodes are active in wet environments. During dry periods, they reside in the roots of the plants. After sufficient rain, irrigation, or dew formation, they swim up the plant and enter leaves. Once inside, they feed and multiply.

Foliar nematodes have been recorded on commercial dendrobiums in the Hilo area. It has also been discovered on nobile dendrobium, causing elongated dark lesions surrounded by yellow leaf tissue (Fig. 4.39), and on oncidium, destroying buds and producing long black streaks on leaf sheaths.

Pest management. There are no registered chemicals that effectively control foliar nematodes. Crop contamination must be prevented. Keep nursery and production areas clean, and remove any plant with symptoms of nematode infection, such as leaf spots. Dry environments prevent nematode migration and rapid population increases, while wet environments are highly conducive to disease development.

4.37. Leaf blotch symptom of nematode infection (white mark at lower left is not part of symptom).



4.38. Advanced stage of nematode infection (section of leaf was removed for nematode assay).

4.39. Leaves of nobile dendrobium infected with nematodes display long, dark leaf spots.

Diseases caused by viruses

Viruses are extremely simple organisms—many are composed only of genetic material covered by a protein coat. The two most common viruses affecting dendrobiums are cymbidium mosaic virus (CyMV) and odontoglossum ring spot virus (ORSV). These viruses only multiply within the plant and are usually 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.

Viruses are extremely simple organisms; many are composed only of genetic material covered by a protein coat.

Symptoms of viral infection include brown streaks on the lips of white dendrobium cultivars (Fig. 4.40), 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 can also result from viral infection. Infected plants may not show disease symptoms for various reasons, which include the following:

Cultivar. Some cultivars such as Louis Bleriot harbor viruses but do not show symptoms. These plants serve as symptomless reservoirs of viruses (hidden sources of inoculum). The common Joaquin vanda orchids are all infected with CyMV and are apparently symptomless.

4.40. Flowers with black lip blemish caused by virus.

Time. After infection, the virus must multiply within the plant and reach a minimum population level before symptoms are expressed. The presence of large amounts of viral particles can trigger cell death and the formation of white or dark necrotic tissue, observable as streaks or blemishes on flowers and leaves. 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 (virus particles) that infected the plant.

Management and control of virus diseases is simple but extremely difficult.

Environment. In Hawaii, 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. Orchid plants are commonly infected when the virus is transferred from diseased plants to healthy plants, often in contaminated sap. Any operation that transfers sap from a diseased plant to a wounded healthy plant will transmit the disease, and this includes insect activities and harvesting flowers, trimming leaves or canes, and other mechanical means. CyMV is a relatively stable virus that is easily transmitted among orchid plants.

Pest management. Management and control of virus diseases is simple but extremely difficult. The virus within diseased plants cannot be eliminated with chemicals, and infection is permanent. Diseased plants must be discarded to prevent further spread. Growers and hobbyists are frequently faced with the difficult choice of destroying rare species, expensive hybrids, or large fields of established plants. By clinging to these precious but infected plants, sources of viral inoculum are maintained. In some cases, rare species can be salvaged by seed production, but during this process all infected plants must be removed to a separate greenhouse.

Recommendations for managing plant virus diseases

Construct a small, clean propagation house to grow disease-free plants from flask. This structure should have a solid roof. The walls should be made of a fine screen or woven fiber to allow good air movement. In cool or windy environments, walls can be completely or partially solid. The ground should be covered with gravel or cinder and should be properly constructed to provide immediate and rapid drainage out of the house. Cement floors or walk-ways are preferred. The walls must meet the ground, and there should be no openings (e.g., between the roof and the walls) in the structure. These are the minimum requirements. Growers need to modify the design to fit their environments. For nurseries that already have large, mature fields of infected dendrobium, the location of this propagation house must be carefully considered. Wind direction, drainage patterns, utility lines, and roads must be factored into the plans.

Grow only clean plants in a propagation house. Only plants established from flasks should be grown here. If community pots are purchased from a wholesaler or another grower, these plants must *not* be placed in the propagation house—they may be carrying pathogens. Likewise, any large or mature specimen plant, regardless of its cost, should not be placed in the propagation house for safe-keeping. Mature plants are potential sources of pathogens.

There should be absolutely no weeds, trash in the aisles, insects, or animals in a propagation house.

Restrict activities before working in the propagation house. Do not handle large mature plants and then work in the propagation house without a bath and change of clothing. By handling large plants, clothing is easily contaminated with viral, bacterial, or fungal pathogens. The aisles in the propagation house should be sprayed periodically with a 20% household bleach solution. There should be absolutely no weeds, trash in the aisles, insects, or animals in a propagation house.

Purchase plants that have been seed propagated or tissue cultured by a reputable firm. Plants to be clonally propagated should first be tested for viruses. Purchase plants in flasks, and establish them in the propagation house to produce disease-free seedlings. New nurseries should avoid starting with cheap “left-over” plants collected from various sources. For instance, declining, over-grown plants can be revived and will produce flowers within a few months, providing the grower with early production and some revenue, but these plants will be a source of many fungal, bacterial, and viral pathogens that will plague the business forever. Major movement of pathogens occurs when such poor-quality plants are sold at low prices. Ultimately, cheap plants will not be the bargain that they seemed to be.

Practice sanitation. Keep the propagation house free of any dead leaves or seedlings that have not survived transplanting from flask. Dead plants serve as organic matter that can harbor pathogens. For the entire nursery, remove and discard any dendrobium plant with viral symptoms. Suspect plants can be checked by the Agricultural Diagnostic Service Center (ADSC) at the College of Tropical Agriculture and Human Resources (CTAHR).

Monitor the nursery. Regular and careful inspection of all plants in the nursery is crucial. Early detection of pathogens, irregular plant growth, or insect and mites is needed for control strategies to be effective. Undetected pests will multiply without restrictions, thereby increasing the difficulty of pathogen and pest control.

Beware of mixed orchid production—it may be unwise. Nurseries that initially produced dendrobium sprays are now increasing their productivity by growing other orchids such as oncidiums or vandas. If oncidiums are grown, they must be from flasks and virus-free. Since all Joaquim vandas have CyMV, these plants must be grown at another location. Any new crop must be checked for virus if it has been clonally propagated.

Special circumstances in managing virus diseases

Example 1. A grower discovers that his or her field is heavily infected with virus. The field may produce marketable-quality flowers in the summer only. The grower does not have enough funds to start over with clean plants. *Recommendation:* The questions this grower must answer are (1) How long am I going to remain in business? (if this person is close to retirement, replacing the field is unfeasible or unnecessary) and (2) Am I willing to accept this lower level of productivity and lack of flowers for the winter market? (if yes, keep the field).

Example 2. The more difficult situation is a grower who has a large virus-contaminated field yet is hoping to make his business better. If this grower hopes to export flowers or expand his market, he needs to be a reliable provider of high-quality flowers. To reduce or eliminate the viral pathogens and also increase productivity, specific recommendations must be developed for each grower. In addition to construction of a clean propagation house, location of new fields and a source of new plants, and the gradual destruction of older fields, employee education and implementation of new nursery procedures will be crucial for success. Without strict adherence to a proper, comprehensive plan, new fields will succumb to pathogens from older, infested fields.

Management practices that control viral diseases also apply to other plant pathogens.

Management practices that control viral diseases also apply to other plant pathogens. Using clean stock, maintaining good sanitation, testing suspect plants, and destroying infected plants are the best methods to manage all pathogens. In the future, orchids that have been genetically altered may express resistance to some orchid viruses and serve as a basis for development of virus-resistant cultivars.

Weeds

Weeds are a problem in orchid cultivation for several reasons. Weeds can harbor pests and diseases. 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. Removal of weeds by hand can damage orchid roots and break tender root tips. The damage can be especially serious when the weeds pulled 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 thousandfold.

The importance of weeding when the weeds are immature cannot be over-emphasized.

Many weed species have seeds or spores 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.

Research conducted at CTAHR evaluated six chemical herbicide formulations in 10 treatments on dendrobium against hand-weeded and unweeded plots. Data were collected on weed control, phytotoxicity, yield, flower spray length, number of flowers per spray, and bud drop in *Dendrobium* Jaquelyn Thomas. Under the conditions of the test, Ronstar® at 4 lb/acre a.i. (active ingredient) resulted in the best weed control with no apparent detrimental effects on the dendrobium plants or the horticultural characteristics of their sprays or flowers.

These research results do not authorize or imply the legal use of the herbicides mentioned. At one time, Princep® had a Special Local Needs (SLN) registration for use on dendrobium in Hawaii. That registration has expired. Ronstar and Karmex® were never registered for use on dendrobium in Hawaii. One or more of Hawaii's organizations of professional orchid growers could apply to the Environmental Protection Agency (EPA) for SLN registration of these herbicides.

In the experiment referred to above, it should be noted that Ronstar applied at 2 and 8 lb/acre a.i. had results inferior to the recommended treatment of 4 lb/acre. This underscores the importance of accurate applications. Too little herbicide will result in ineffective weed control, and too much herbicide can result in phytotoxicity, environmental pollution, and money wasted. Since many growers use a knapsack sprayer for herbicide applications, a procedure to calibrate a knapsack sprayer is described in Appendix C.

Postharvest handling

Factors affecting postharvest life

The postharvest life of dendrobium sprays is dependent on both preharvest and postharvest conditions. Sprays from Hawaii growers typically last two to three weeks before wilting and shedding flowers. This is especially true with University of Hawaii dendrobium cultivars. However, if handled improperly after harvest, sprays can exhibit short vase life, scattered flower abscission, drooping, and sleepiness. Seasonality also affects vase life, as sprays harvested in late summer have a shorter vase life compared to sprays harvested in cooler months. Other factors that affect postharvest life include the preharvest conditions under which the plants are grown and the spray maturity at harvest.

Sprays from Hawaii growers typically last two to three weeks before wilting and shedding flowers.

The symptoms characteristically associated with short vase life suggest that the main cause of premature wilt is disruption of water absorption due to microbial contamination of cut stems. The stem ends of wilted sprays are often slimy and smelly, indicating unwanted microbial growth. Decreased water absorption caused by microbial plugging of vascular tissues leads to petal drop, wilted flowers, and weak stems. Growth of pathogenic bacteria within stems causes stem rots.

The storage condition of sprays also affects postharvest life. Dendrobium sprays are sensitive to cold temperature, and chilling injury will occur when sprays are exposed to 50°F for more than four days or 46°F for more than two days. Petal and bud discoloration or drying and flower shedding can result from storage at 41°F for just one day.

Current postharvest handling practices

Sprays are generally harvested with four to six unopened buds, although the number of buds depends on the length of the spray and the number of flowers on it. Growers commonly harvest sprays with 70–75 percent of the lower flowers fully open. This stage of harvest helps to ensure opening of the remaining. Growers may also harvest sprays with only half of the flowers opened if the market dictates or if the sprays are needed during high-demand periods such as holidays.

For best disease control, harvest from the cleanest fields first and finish with the most contaminated fields. This will minimize mechanical spread of pathogens, especially viral and bacterial organisms. Harvest in the early morning or late afternoon, and avoid harvesting during the hot midday periods.

Sprays are harvested by either snapping the sprays off by hand or using a cutting tool. With either method, the possible spread of viruses must be considered, and strategies must be implemented to reduce or prevent this. If hand harvesting, washing your hands with soap and water between rows or portions of a field helps to reduce the chances of carrying virus particles from an infected section to a clean section. If harvesting with a cutting tool, use a 3–5% household bleach solution and dip the tool after harvesting each plant. This will minimize the spread of viruses between plants. It may be a good idea to use two or several tools and alternate them with each cut to allow adequate soaking time for the solution to take effect on the virus particles that are on the tool surface. Be sure that the tool's cutting edge is completely submerged in the solution, and periodically check the level of the solution in the container. Other materials and methods for disinfecting tools are discussed on page 65.

Harvested sprays should be immediately placed in clean buckets filled with clean water, with the cut ends submerged about 2–3 inches. Buckets should be cleaned thoroughly each week using bleach or another disinfecting solution. The water in these buckets should be replaced daily. The sprays are then taken to a cool, shaded packing area. Some growers soak sprays in water for approximately 5 minutes to reduce excess field heat and to restore turgidity, even though soaking has little direct effect on vase life. Other growers mist or spray flowers lightly with water, a preferable treatment to soaking. Misting or water sprays are better than a soak, because pathogenic fungal spores and bacteria can contaminate flower sprays in a water bath. (See below for details on postharvest disinfestation procedures for diseases).

Harvested sprays should be immediately placed in clean buckets filled with clean water, with the cut ends submerged about 2–3 inches.

Sprays are then graded according to length (see the section below on standards for dendrobium sprays) and bundled in sets of 5, 6, 10, or 12 sprays, as determined by the customer. A rubber band is used to hold the bundles in place, and the ends are re-cut, sometimes under water. A water-soaked cotton ball is placed around the stem ends and covered with a small clear polyethylene bag, which is secured with a rubber band. Some growers soak the cotton balls in a floral preservative solution. Each bundle is sleeved in clear plastic, which may have microperforations that allow the sprays to "breathe." This may reduce the incidence of fungal or bacterial growth in transit. Excess water on the blossoms or the packing materials increases the chances for fungal and bacterial growth. If moisture or water droplets form between petals and the plastic sleeve, water-soaked areas will develop on the petals, reducing marketability and vase life. Therefore, sprays should be packed with minimum free water on them. Packing and insulating materials should also be dry.

Boxes range in size from small gift boxes to large "master" cartons. Packing materials typically include sheets of newspaper lining the boxes and newspaper shreds used to cushion bundles, especially on the stem ends. Flower bundles must be packed firmly to prevent movement and damage in transit. Box edges should be completely sealed with tape to prevent insects from crawling into the box after packing.

Flowers are transported by air freight and remain in transit for from one to three days to markets in the mainland United States and foreign destinations.

Upon receipt by customers, flowers should be immediately unpacked and the stems should be re-cut under water. They should not be exposed to temperatures of 50°F or lower for more than four days. Storage of sprays at 72–86°F with high relative humidity will extend vase life and flower quality. Because some customers may not be familiar with postharvest handling procedures for dendrobiums, information on proper care and handling should be included in the boxes.

Sprays may be dipped in an approved insecticidal solution for insect disinfestation and plant quarantine security before shipping. A major target pest is thrips. Coupled with good field monitoring and insect control practices to keep field populations low, insecticide dips can be very effective. See your Cooperative Extension Service agent for currently recommended pesticides.

Harvesting and postharvest disinfestation procedures for diseased fields

Care of flowers

If a viral disease is suspected anywhere in the field, it is recommended that sprays be harvested by snapping them off. If a cutting instrument is used, it should be disinfected as the harvester moves from plant to plant. Physan®, Naccosan®, or other quaternary ammonium products can be used as a dip for cutting tools. Another method of sterilizing cutting tools is to flame them with a propane burner. Disinfecting tools is time-consuming and slows down the harvesting process. If the production field was started with clean, seed-propagated plants from flask, and if good sanitation and pest management have been practiced continuously, it should not be necessary to disinfect tools between each plant. We do advise growers to randomly check plants for virus and bacteria by submitting samples to the UH Agricultural Diagnostic Service Center for diagnosis. If no viral or bacterial pathogens are found, clippers can be used with occasional dipping.

If bacterial disease is suspected or known to be present in a field, harvested sprays can be placed in containers of a freshly prepared solution of 2–5% household bleach or 30 ppm AgribromR. This may prevent movement and multiplication of bacterial pathogens in the holding water. However, bleach solutions may also reduce the vase life of the sprays.

Avoid placing harvested sprays directly into a tub of plain water.

If flowers have dust or soil on them, rinse them in running tap water, or prepare a bath with a small amount of detergent. Dip the flowers on the sprays into the bath while keeping the cut ends above water. This is to avoid the release of bacteria into the water, which could contaminate the bath and sprays later placed into it. Gently move the flowers under water to dislodge dust and soil particles. If insects are suspected or known to be infesting the harvested sprays, an approved insecticide can be added to the bath. Remove sprays after a minute or less, dip into clean water, and rinse immediately in running tap water. Be sure that the front of each flower is rinsed, or the pollen pack may die, causing premature wilting of the flower. Place clean sprays in buckets of clean water and allow the flowers to dry before packing. Check for phytotoxicity when using detergents and soaps on flowers.

Care of plants

Potted dendrobiums generally ship very well and tolerate the shipping period without damage. The biggest problem has been 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, the process by which the plant converts light energy into chemical energy. During transit in boxes the plants are in the dark, no photosynthesis occurs, and fungal growth occurs rapidly. The packaging holds the relative humidity high, favoring pathogen growth. In a few days, many leaves become chlorotic and often drop from the cane. 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.

Dendrobium grading standards

Grading standards help producers and marketers more effectively communicate product descriptions to each other, which helps ensure orderly delivery through the marketing channel of a consistent, high-quality product to the consumer. The purchase price must reflect the quality or grade of the product and be perceived as reasonable and fair by the purchaser. Hawaii dendrobiums are of very high quality, and therefore consumers are generally willing to pay more for Hawaii-grown dendrobiums than those grown elsewhere.

To help maintain the reputation for quality products, the Hawaii Department of Agriculture has developed grading standards for dendrobium exporters. Although grading standards have been developed, no compliance laws bind exporters to the standards. In practice, most exporters use their own grading standards, frequently developed in conjunction with their principal wholesalers and retailers. These grading standards may differ from one exporter to the next. In any case, it is important that exporters effectively communicate with customers regarding their grading standards. This is particularly important with new customers, who may be accustomed to another exporter's grading standard. Because of differences in grading standards among exporters, accurate and complete communication with customers is essential for a clear understanding of the expectations regarding product grades. Grading standards developed by the Hawaii Department of Agriculture for the sale of dendrobium blossoms, cut sprays, and potted plants are described below.

To help maintain a reputation for quality products, the Hawaii Department of Agriculture has developed dendrobium grading standards for exporters.

Standards for individual dendrobium orchids

(a) As used in this section:
"Size" means the greatest dimension of the flower, measured in a straight line and with the various parts of the flower in normal position; and
"Well formed" means the flower is symmetrical and its form is typical of the variety.

(b) Hawaii Fancy dendrobium orchids consist of individual dendrobium orchids which are well developed, clean, well formed, intact, fresh, firm, well colored, and free from injury caused by disease, insects, birds, or mechanical or other means.

(c) Hawaii Standard dendrobium orchids consist of individual dendrobium orchids which are well developed, clean, well formed, intact, fresh, firm, well colored, and free from damage caused by disease, insects, birds, or mechanical or other means.

(d) Size of dendrobium orchids may be specified in connection with the grade, based on the following size classifications:
(1) Small, under two inches;
(2) Medium; two to three inches; or
(3) Large, over three inches.
In order to allow for variations incident to proper sizing, not more than a total of ten percent, by count, of the flowers in any lot may vary from the size specified, but not more than one-half of this amount, or five percent, shall be permitted for flowers which are more than one-fourth inch smaller than the size specified.

Standards for dendrobium orchid sprays

(a) As used in this section:
"Dendrobium orchid sprays" means the racemes of the various dendrobium orchids, consisting of the stalk, stems, and flowers;

"Firm" means the flowers and stems are turgid and firmly attached to the main stalk;
"Intact" means all flowers present are whole and not more than two damaged flowers have been removed from the spray, provided that the appearance or shipping quality of the spray is not appreciably affected by such removal of damaged flowers;
"Properly trimmed" means the stalk has been cut off cleanly; removed flowers have been severed neatly; and the distance from the lowermost flower to the cut end of the stem is no less than four inches;
"Well developed" means at least sixty percent of the flowers on the spray have attained full bloom; and
"Well formed" means the general structure of the spray and the shape of the individual flowers are typical of the variety, and the flowers are symmetrical.

(b) Hawaii Fancy dendrobium orchid sprays consist of dendrobium orchid sprays which are well developed, clean, well formed, intact, fresh, firm, well colored, properly trimmed, and free from injury caused by disease, insects, birds, or mechanical or other means.

(c) Hawaii Standard dendrobium orchid sprays consist of dendrobium orchid sprays which are well developed, clean, well formed, fresh, firm, well colored, properly trimmed, and free from damage caused by disease, insects, birds, or mechanical or other means.

(d) The applicable spray length classification for dendrobium orchid sprays may be specified in connection with the grade, as follows:
  (1) Short, nine to thirteen inches;
  (2) Medium, fourteen to twenty inches; or
  (3) Long, twenty-one or more inches.

In order to allow for variation incident to proper sizing, not more than a total of five percent, by count, of the sprays in any lot may vary from the length specified.

Integrated pest management (IPM) is a multi-faceted, systems approach to reducing pest damage to crops.

Standards for dendrobium orchid plants

(a) As used in this section:
"Healthy" means the plant is free from disease and does not show any evidence of chlorosis or other discoloration; and
"Well grown" means the plant is free from tipburn and serious damage caused by pests, chemical, or mechanical or other means and has canes that are sturdy and reasonably straight and upright; leaves that are of normal size, shape, color, and texture; and a vigorous root system.

(b) Hawaii Fancy dendrobium orchid plant consists of dendrobium orchid plants which are clean, healthy, and well grown.

(c) Hawaii Standard dendrobium orchid plant consists of dendrobium orchid plants which fail to meet the requirements of subsection (b).

The dendrobium orchid business

Importing and exporting dendrobium orchids

The importation of orchids to Hawaii is regulated by both the Animal and Plant Health Inspection Service (APHIS) of the United States Department of Agriculture (USDA) and the Hawaii Department of Agriculture (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 U.S. mainland. Both agencies must inspect incoming shipments, and HDOA holds shipments from certain points of origin in quarantine.

The exportation of orchid plants from Hawaii to the U.S. mainland is regulated by HDOA's Plant Quarantine Branch, which also inspects orchid nurseries to ensure that they meet export certification requirements. Orchid cutflowers exported to the U.S. mainland are inspected by USDA for pests designated "federal quarantine action pests."

International movement of orchid plants to and from Hawaii are subject to provisions of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) regulations. Additional information can be obtained from USDA-APHIS.

Growers are advised to contact both HDOA and USDA-APHIS for the most current information on regulations governing importing and exporting orchid plant materials.

Marketing dendrobium orchids

To be commercially successful, dendrobium orchid producers must give careful consideration to how and where they market their products. The global flower market accounts for billions of dollars in trade. Due to its size and increasing sophistication, this global marketing system is varied and complex. The decisions about where and how to market are probably the most important ones you will make in running a dendrobium product business.

To be commercially successful, dendrobium orchid producers must give careful consideration to how and where they market their products.

Before making these decisions, you must have a commitment to delivering the product that consumers want, which may not necessarily be what you most want to grow. Successful marketing is as much a product of your commitment to the customer as it is of your marketing style or the attributes of your product. Marketing has often been described as the creation and keeping of a customer, and it is your job to ensure that these goals are accomplished. Many firms have failed on both accounts. This philosophy is crucial to your success regardless of whether you personally conduct all or only some of the marketing functions.

To implement this philosophy, you need to understand what the consumer wants. Identifying consumer wants can be a complex task requiring much information, and although the subject is beyond the scope of this brief chapter, we recommend that you conduct at least a basic market analysis. In this analysis, try to answer the following questions:

- Who is buying cutflowers or potted orchids (their age, sex, income, education, and location)?
- What are the trends in flower consumption (are people buying more dendrobium orchids)?
- Who is your competition?
- What are your costs of production?
- What are your capabilities?
- What are consumers paying for dendrobium orchids?

Your market analysis is the key element of your business. Each of these questions can be answered with a small investment of your time. Getting the answers may determine whether or not your business is successful.

If you do not have a business plan, you should develop one. A business plan is a guide to how you organize and operate your business. It is for your use in defining your goals, to help educate key employees about your objectives, and to show to outside investors (if applicable) and lending institutions (who will require one).

A marketing plan is part of the business plan. The marketing plan describes how you intend to sell the product and includes such factors as distribution, advertising, and the target market.

The following three sections provide a brief overview of the marketing system for cutflowers and potted orchids. The information will be helpful to you if you plan to develop a new marketing plan or revise your current one. If you want more information regarding business plans, contact your local Cooperative Extension Service office or Small Business Administration office. Another useful source of information is the CTAHR publication *This Hawaii Product Went to Market*, which compiles a wealth of information and resource contacts for developing a business in Hawaii.

The marketing system in cutflowers and potted plants has developed over time in order to meet the needs of the final, retail consumer, who desires a wide variety of high-quality flowers at reasonable prices. In general, the flower producer receives a small portion of each dollar a consumer spends on flowers. There are several reasons for this, but the single greatest reason is that the lion's share of the consumer's dollar spent on cutflowers is spent on marketing services or functions. When a consumer purchases a flower, the price represents not only the costs of producing that flower but also the associated functions involved with getting it to the consumer. Some of these functions—which are all part of marketing—include grading, packing, postharvest handling, storage, transportation, labeling, extension of credit, selling, buying, advertising, and promotion. It should also be remembered that the price consumers are willing to pay for your flowers is determined by how much they value them.

Marketing channels

This broad overview of the marketing system for cutflowers and potted orchids includes the most typically used marketing alternatives or channels. Each marketing alternative has its own advantages and disadvantages. A producer must evaluate these factors and select that alternative(s) which best matches his or her capability and offers the most profitability. Some of the more common criteria in selecting a marketing alternative include the following.

Costs. Each marketing alternative entails a set of costs. Some of the more common costs are selling, transportation, grading, packing, postharvest handling, and extension of credit. The major difference among marketing alternatives is the degree to which each of these costs is incurred. Obviously, if a producer incurs higher marketing costs, higher prices must be obtained as well to maintain profitability.

Risk. Nothing in life is certain, and different marketing alternatives have different sources and levels of risk associated with them. Some sources of risk are product damage, legal obligations (including phytosanitation, customs, and labeling requirements, liability, etc.), production, non-payment, and price risk. Price risk refers to volatility in prices, especially downward price movements. A producer should evaluate the risk of each alternative and determine whether he or she can bear the risks or take steps to minimize them. Risk is a cost of doing business.

Trends. Over time, many marketing alternatives become less viable, while others gain in use. For example, 50 years ago, centralized wholesale markets located in most major cities were a dominant marketing institution. Today, this role is greatly diminished. If one concentrates on an alternative that is declining in use, one runs the risk of decreased sales and prices.

Terms of trade. In general, each marketing outlet has its own set of terms of trade, which cover such items as packaging, insurance, damaged goods responsibility, product specifications, and, of course, price and payment schedules.

Ability to service. The size of your operation and the breadth of your product line will dictate to a large degree which marketing alternatives are best suited to your capability. Many smaller producers do not have the volume or product line to supply large accounts, such as mass merchandisers (supermarkets). However, they may do very well selling to a grower-shipper or local retail florists.

Profitability. Ultimately, you will want to choose the outlet that offers your business the greatest profit. To determine this, you need to know your costs of production and marketing and evaluate all of the above factors. Don't be misled by market price alone. A market alternative that offers consistently higher prices may also entail higher costs and risks.

The term "marketing alternative" is used to denote the channel where you sell your product. For example, it could be a grower-shipper or retail florist. When you select a marketing alternative, you are also selecting the marketing functions you will perform and deciding to what degree you will perform them. If your primary outlet is a grower-shipper, you may minimize your own transportation effort; packing may be minimal, as well as your sales effort. In the case of retail florists, most likely your transportation effort and costs (per unit) will be larger, and greater demands may be placed on you for packing, grading and sales. This may be the correct alternative if you are capable of conducting all these functions in a cost-efficient manner and the net return is commensurately greater from the retailer.

The term "marketing alternative" is used to denote the channel where you sell your product.

The diagram on page 72 shows the typical channels flowers move through on their way to the final consumer. In Hawaii, the bulk of cutflowers move from the grower to a grower-shipper, then to a U.S. mainland wholesaler, and finally to a retail florist. However, it is not uncommon for the grower-shipper to ship directly to the retail florist. With the increase in overnight direct-to-door shipping, Hawaii has also seen an increase in gift boxes delivered directly to the consumer. Given the growing popularity and use of the Internet, it is expected that this marketing channel will grow in importance. Relatively few Hawaii flowers shipped to the mainland end up at a mass merchandiser.

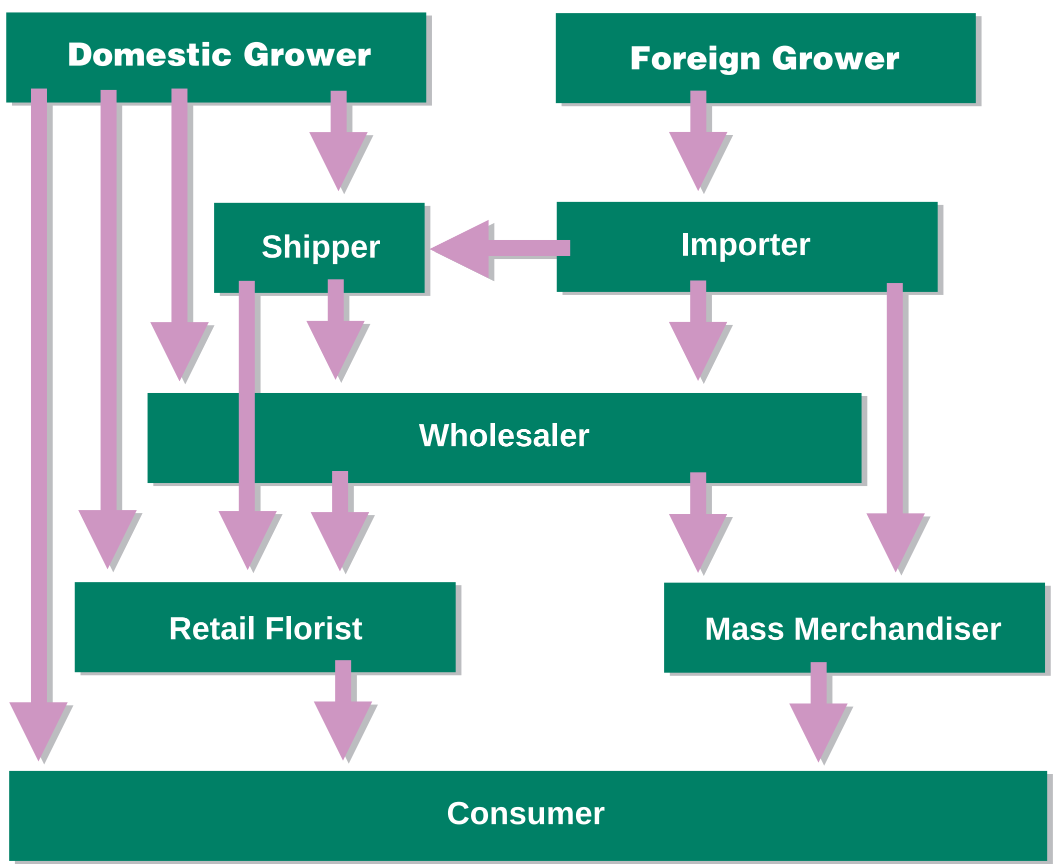
As mentioned above, many marketing functions need to be performed before the consumer purchases your flowers. The present marketing system has evolved to increase efficiency. Thus, the participants in the system have become specialists at what they do. For example, most growers concentrate their efforts on producing high-quality flowers, which requires grading. The grower-shipper, which is typically a larger business than most growers, takes on the additional tasks of assembling, packing, and shipping a large variety and quantity of flowers. The wholesale florist also assembles a larger quantity and a greater variety of cutflowers or potted plants than most growers produce. The wholesaler breaks down the shipments received into smaller quantities to service retail outlets. Most wholesalers service a particular geographical region, using a specialized sales force. The retail florist unpacks the flowers, displays them in bundles or arrangements, makes the final sale, and often delivers the product to the customer.

Some growers bypass the typical channels by shipping floral arrangements direct to the consumer. This practice is expected to grow, but it is not likely to replace the traditional channel. Most growers lack the volume or the product variety to successfully run a mail-order business. Also, when marketing in this channel, the grower is performing all the marketing functions. This means additional costs—especially sales costs. While many growers are tempted to eliminate the "middle-person," few are in a situation to do this successfully.

Some growers bypass the typical channels by shipping floral arrangements direct to the consumer.

According to United States Department of Agriculture 1998 estimates, approximately 54 percent of floral sales are through traditional retail florists. The remaining 46 percent is sold through supermarkets, discount stores, and street vendors. In a 1996 survey of American households, it was found that about two-thirds (67%) of the households purchased their flowers from a florist shop, followed by supermarkets (17%), toll-free numbers (4.5%), street vendors (1.9%), and other sources (9%) (*Floriculture International*, August 1997).

Typical marketing channels for cutflowers and potted orchids in the USA.



Market participants

Who are the major players in the dendrobium product marketing system? The list below provides brief descriptions of the marketing functions (services) each of them performs. Obviously, in some situations a particular individual performs more than one role.

Grower. Growers typically concentrate on production activities. Most will specialize in producing a few varieties or species. Marketing functions performed to various extents include grading, packing, selling, risk-bearing, and transportation. In a minority of cases, growers may have their own retail outlet.

Grower-shipper. This designation is usually reserved for the grower who produces and ships large quantities to floral trade customers in distant locations. The grower-shipper performs the same marketing functions as a grower, and also assembles economically sized quantities and variety mixtures for sale to wholesalers and retailers. They usually have a more developed sales staff than do the growers they buy from.

Importer. Importers specialize in sourcing (finding, buying, importing, and reselling) products. In addition to being familiar with foreign production sites, the importer also is an expert in exchange rates, international transportation, and phytosanitary requirements. Normally, an importer moves the product through a wholesaler.

Wholesaler. Wholesalers specialize in meeting the needs of nearby trade customers. Wholesalers assemble a wide variety of cutflowers from a broad geographic range of sources and suppliers. These deliveries are sorted and recombined into smaller lots according to the needs of retail florists. Most floral crops are purchased outright by the wholesaler for later sale; enterprises doing this are called *merchant wholesalers*. To a lesser extent, floral crops are handled on a consignment basis by *commission wholesalers*, in which case the crop remains the property of the supplier, and the wholesaler acts only as a sales agent. The principal marketing functions performed by a wholesaler, in addition to receiving, reassembling, and selling, are delivery and credit.

Although some other types of retailers have grown in importance, the single most important outlet for floral crops is still the traditional retail florist.

Broker. Brokers are another form of intermediary. Generally, a broker does not physically handle the product or take title to the goods. Rather, the broker seeks out products for buyers or seeks to place products for sellers. Brokers are usually more important in the marketing of potted interior plants in general than of cutflowers or potted orchids in particular, but their role in marketing orchid cutflowers and potted plants is gaining importance as U.S. mainland importers increasingly acquire products from foreign sources.

Traditional flower shop. Although some other types of retailers have grown in importance, the single most important outlet for floral crops is still the traditional retail florist. What distinguishes the traditional flower shop from most other retailers is the service they provide in combining cutflowers and potted orchids with related nonperishable supplies in artistic arrangements. They usually provide delivery and credit.

Garden center. Over the past few years, garden centers have grown in importance as retailers of cutflowers and flowering potted plants. Garden centers have traditionally sold mostly landscape plants. To moderate seasonal fluctuations in sales, garden centers have broadened their product offerings to include cutflowers and potted flowering plants, including orchids. A minority of the garden centers has adopted the format of the conventional retail florist, offering an array of arrangement, delivery, and credit services.

Food and general merchandisers. Discount department stores, drug stores, and supermarkets constitute what is often referred to as “mass markets” or nonflorist retail outlets. Most still only provide a prepackaged product. However, some of the more progressive outlets have installed full-service floral operations in their stores.

In the process of selecting a suitable channel of intermediaries to transfer ownership and possession of the flower or plant, the grower secures a set of marketing services. A marketing channel can be either "short" or "long," which refers to the number of intermediaries involved, not distance. The shortest marketing channel is when a grower sells directly to the consumer. In deciding which marketing channel to use, a grower must consider which marketing services or functions are necessary. Growers who would rather produce a crop than spend time marketing are likely to make use of a longer channel within which other businesses perform the necessary services. Thus, a grower selects the customers who comprise the marketing channel partly on the basis of available resources or personal inclinations.

In deciding which marketing channel to use, a grower must consider which marketing services or functions are necessary.

A grower may also want to choose a channel having a high "intensity" of distribution. For example, a grower who produces an especially unusual and high-priced product would seek a channel that has a very selective distribution, rather than one that provides for the widest possible distribution

With regard to shelf-life considerations, shorter, more direct marketing channels are preferred for most cutflowers and potted plants. In practice, however, the direct-marketing channel is often impractical. The primary characteristic of a long or indirect marketing channel is the use of marketing intermediaries. These relieve the producer of many essential functions in distribution. The "price" the producer pays for the longer channel is a loss of contact with the final consumer. Thus, growers who employ a long marketing channel must keep themselves educated regarding the changing demands of the final consumer.

Market overview for cutflowers and potted flowering plants

The floriculture and environmental horticulture industry is one of the fastest growing and largest segments of U.S. agriculture. In recent years, grower cash receipts have been increasing by $500 million annually. The average net income for growers of $53,000 per operation (USDA, 1998 data), is among the highest of all production specialties. The USA is the world's largest producer of greenhouse and nursery crops and also the world's largest consumer of these products.

Since the late 1980s, growth in the consumption of cutflowers in the USA, Europe, and Asia has been significant. Most experts believe that strong growth will continue in the USA and Europe. It is also hoped that Asian countries will recover from late-1990s recession trends to resume their previous strong growth in consumption. Although the USA is the single largest market in aggregate terms, its per-capita consumption is low compared to members of the European Union or Japan. On a per-capita basis, the U.S. consumer annually spends only about $13 on potted flowering plants about $27 on cutflowers, compared to spending for cutflowers of about $100 in Japan and $50–100 in the European Union, depending on the country. In general, per-capita consumption of cutflowers and potted flowering plants has been increasing in the USA, and cutflower marketers view the U.S. market as a major opportunity to increase sales, given the relatively low per-capita consumption figures.

Because the USA is the world's largest market and provides opportunities for significant market growth, its imports of cutflowers are significant. U.S. growers of roses, carnations, and chrysanthemums have been greatly hurt by imports. Hawaii's dendrobium cutflower growers have also felt the influence of foreign competition (primarily from Thailand). Hawaii's potted-orchid producers have had some protection against foreign competition due to quarantine restrictions. However, the industry has recently had to fight to retain this advantage, and foreign competitors are now able to ship plants into the USA bare-rooted.

Because of a wide disparity in cost structures between U.S. and foreign production environments, there will always be an opportunity for foreign growers. Despite the cost disadvantages faced by local growers, Hawaii's dendrobium orchid industry has flourished because it markets a superior product and provides superior service. In so doing, the industry has been able to create and keep its customers.

Measuring the "profitability" of a dendrobium cutflower enterprise

Is your dendrobium cut flower enterprise profitable? You have probably been asked this question or asked yourself this question many times. How do you answer? If you are like most growers, you probably answer, "Yes, it is profitable," because your gross revenue from the business is greater than all of your cash, out-of-pocket expenses. In other words, the cash flowing into the business is greater than the cash flowing out of the business. The difference between the cash in and the cash out is the "cash flow."

But does simple cash flow necessarily reflect true profitability? No, it does not, but cash flow is relatively simple to calculate, and it is a better estimate of profitability than an uneducated guess. Cash flow can be calculated easily with a minimal set of records. In fact, if one has a checking account devoted exclusively to the enterprise's transactions, and if one deposits all of the money generated by the enterprise and pays all of the bills by check (and never writes a check for any non-business expense), the checkbook balance will be the cash flow. Also, except for the depreciation calculation, it will closely approximate your IRS Schedule F tax liability. All growers must file an IRS return, and therefore this simplest of record-keeping systems is the minimal set of records required. Because most growers do not enjoy keeping records, they usually only keep those records required by law.

We can talk about two kinds of profit. The first kind is the cash flow just described; it is referred to as *accounting* or *financial* profit. For example, if we were considering a proposed project, and we were told that it would be financially feasible, we could assume that this project will have a positive cash flow. The cash flow generated by the enterprise is the return to the owner-operator; it is a return to the operator's labor and management, to risk, and to the owner's capital investment in machinery, equipment, land, and buildings. Financial feasibility, or profit (i.e., a positive cash flow), is necessary *but not sufficient* for business survival. While a positive cash flow may be sufficient for short-term survival, long-term survival usually depends on something more. If a grower is simply trying to survive from month to month—a desperate situation—cash flow or financial profitability becomes the whole picture. This focus is short-sighted but essential, given the goal of surviving. Our preferred goal is sustainability, and this goal requires a different measure of profit.

In order to be sustainable in the long run, an orchid operation must exhibit economic *profitability.*

In order to be sustainable in the long run, an orchid cutflower or potted-plant operation must exhibit *economic* profitability. If we measure enterprise "profitability" by leaving out some of the costs and the risk factor, we will always over-estimate actual profitability. How then will we know if this "profit" is profitable enough to sustain the business? The question we need to ask is, "Is the *return* adequate, is it at least as great as the *value* of the labor, management, and capital resources employed?" The return to a resource is not necessarily the value of that resource. Therefore, if we want a true picture of profitability, we must consider the value of the resource, not simply the return to the resource. Financial profitability is the gross income minus the cash costs; economic profitability is the gross income minus the cash costs *and* the value of the productive resources and an estimate of the riskiness of the enterprise. These resources are not "free"; they have a cost that can be calculated and that must be included along with the cash costs.

Because economic profit includes all expenses, it need only be zero, because at this point all cash costs and the value of all productive resources and an allowance for riskiness will have been covered. Anything above zero will provide for a return greater than the value of these resources and will make the enterprise that much more attractive. An economic profit will encourage expansion by existing growers, and other growers will be encouraged to enter the industry. Similarly, a negative economic profit will encourage exit from and contraction of the industry.

It is often useful to compare the economic efficiency of your orchid production operation with that of the industry as a whole, or foreign competitors. However, if some growers talk about financial profit while others use economic profit, comparisons of efficiency are impossible. For example, if one grower—for whatever reason—already owns his farm outright and another grower has a mortgage, the former will have lower out-of-pocket cash expenses and therefore a higher financial profit. However, only if the former grower deducts the annualized value of his capital investment when determining his profit (that is, calculates the economic rather than the financial profit) can the profitability of the two operations be compared.

It is useful to compare the economic efficiency of your orchid production operation with that of the industry as a whole, or foreign competitors.

There are two kinds of costs: operating and ownership costs. These are sometimes referred to as "variable" and "fixed" costs, respectively. Operating costs (but not ownership costs) vary with small increases or decreases in the scale of production. Operating costs include all of the growing and harvesting costs associated with producing the marketable flowers and getting them to market. For the sake of clarity, all of the labor associated with the various growing and harvesting activities is included under each of the appropriate activity categories. In other words, we assume that all of the labor is "paid labor" and that there is no unpaid family or owner-operator labor. While this assumption does not always reflect the actual situation often found on smaller farms, it does reflect the economic reality of production.

Ownership costs include the value of the productive resources (the management, land, buildings, and equipment) devoted to the enterprise activities. It is appropriate to include the risk factor under ownership costs because it is the owner who bears the risk and will suffer or prosper as the enterprise succeeds to a degree lesser or greater than expected.

A farm often has more than one enterprise, in which case the value of these resources must be allocated among the various enterprises. In the simple case of a one-enterprise farm, the enterprise and whole-farm values are identical. Therefore, for simplicity in the example that follows, we will assume that the example farm has only a dendrobium cutflower enterprise.

The first step in developing a cost-of-production model (see p. 78–79) is to make certain assumptions about dendrobium yield. The yield of 13 sprays per plant used here is a conservative estimate. This variable, like all the other variables in the model farm, can be changed to reflect more closely the actual situation on your farm. Similarly, estimates are included for typical labor wage rates, prices for various grades, and the cost of money. Management is valued at 10% of the gross income. (All of these assumptions are entered in Part I of the model.)

Next, we need to estimate the percentage of the crop that will be Grades 1 and 2 for export and local (retail) sales. With this data, the spreadsheet program will calculate the expected gross income. All results are expressed in terms of income, costs, and profit in cents per spray, dollars per dozen sprays, and dollars per year on a per-acre basis and for the whole farm.

Once the computer spreadsheet for the comprehensive enterprise budget is completed, we have an interactive model of the production process. The example on the next two pages provides the structure for such a model. The figures used to illustrate the example farm, a one-enterprise dendrobium cutflower orchid operation, are typical, but their main purpose is to illustrate the mechanism of the production model. All of the variables can be changed to reflect an actual situation. Because all of the figures are linked in the model, if one variable is altered, the economics of the whole system is altered. This feature allows one to perform "what-if" projections. For example, how will annual economic profitability per spray, per acre, and per farm be affected by increasing the labor wage rate of $8.50 per hour to $9.00 per hour? Given all of the other assumptions of the example model, we can instantly project that increasing this one variable by 50¢ per hour will cause the annual economic profitability to decrease by almost $6,000, or almost 1¢ per spray.

A computer spreadsheet for the comprehensive enterprise budget is an interactive model of the production process.

Finally, we can ask, "Given these assumptions, is the operation profitable?" Clearly, the farm in our example is profitable because the economic profit is greater than zero; that is, the owner-operator is receiving a return that is greater than the value of the resources being used to produce the product. What can this particular owner-operator expect to earn in a year if he or she pays for all of the labor? The management and investment income (MII) is the annual return to one's management, one's equity investment, and to the risk one assumes in organizing and operating this enterprise. The farm in our example is extremely profitable, with an MII of $164,601. The risk appears to be relatively low. With this particular cost structure and yield, the owner-manager can cover all costs (i.e., "break even") as long as the weighted average price is at least 36¢ per spray. Similarly, with the cost structure and prices used in our example, the operation will break even if the yield remains over 166,500 sprays per acre per year.

Hawaii's associations of commercial orchid producers

Four associations of commercial orchid producers in Hawaii promote the interests of the commercial orchid industry. Among their functions are to

- sponsor conferences and workshops in conjunction with the University of Hawaii for the education of their membership
- sponsor or participate in orchid shows and participate in commodity trade shows in Hawaii and on the U.S. mainland to promote Hawaii orchid products
- interact with the U.S. congress and Hawaii legislature and various government agencies in the interest of the Hawaii orchid industry
- provide research grants and scholarships to students
- provide input to the College of Tropical Agriculture and Human Resources, University of Hawaii, on how it can better serve the commercial orchid industry

The Hawaii Orchid Growers Association (HOGA, P.O. Box 2152, Keaau, Hawaii 96749) is a statewide association that promotes the production and marketing of potted orchid plants of all genera. The other three associations are regional, specialty dendrobium producers' associations. The Dendrobium Orchid Growers Association of Hawaii (DOGAH, 2889-D Kalihi St., Honolulu, Hawaii 96819) is based on Oahu. The West Hawaii Orchid Growers Association (WHOGA, P.O. Box 1540, Kailua-Kona, Hawaii 96745) draws its membership from the Kona area of the island of Hawaii. And the Big Island Dendrobium Growers Association (BIDGA, P.O. Box 4153, Hilo, Hawaii 96720) is made up of growers from the eastern part of the island of Hawaii.

Economic profitability of dendrobium cutflower production

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Note to references: HITAHR, the Hawaii Institute of Tropical Agriculture and Human Resources, is an administrative unit of CTAHR, the College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa. The majority of documents in this list of references are out of print and only available in libraries. Many are in the collection of the Hawaii State Library System, and almost all are in the collection of Hamilton Library, University of Hawaii at Manoa. Photocopies of out-of-print documents can be obtained for a fee from the External Services Program, Hamilton Library, 2250 The Mall, Honolulu, HI 96822. Lists of current CTAHR publications and a historical database of agricultural publications of the University of Hawaii can be found at the website <www.ctahr. hawaii.edu/publications>.

Appendix A. Berlese funnel, a tool for monitoring thrips

Thrips are tiny insects that are barely visible without magnification. It is difficult to monitor orchids for thrips by visual inspection. Thrips are especially hard to see when the color contrast between the insect and the flower is not great, when they are not moving, or when they are deep within the blossom or hiding in crevices.

The modified Berlese funnel is a simple apparatus to separate thrips from orchid blossoms. Its use by orchid growers as a pest-monitoring tool in an integrated pest management (IPM) program is highly recommended. The materials needed to construct the device can be found at hardware, automotive, and similar stores.

The funnel is useful for monitoring thrips populations in the field or nursery, testing the effectiveness of insecticide treatments, and checking harvested flowers for export quarantine certification. The funnel also detects other tiny insects, such as aphids.

Tool / Supply List

Materials

- 10-inch metal automotive funnel
- 1 square foot of ¼-inch mesh, galvanized hardware cloth
- 4-ounce jar with screw-on lid (e.g., baby-food jar)
- 10-inch electric brooder lamp
- 40-watt incandescent light bulb (do not substitute a bulb brighter than 60 watts)
- 4 pieces of ¾-inch galvanized plumber's tape, each 4¼ inches long
- 8 ⅛-inch aluminum rivets or 8 sheet-metal screws
- a constuction adhesive

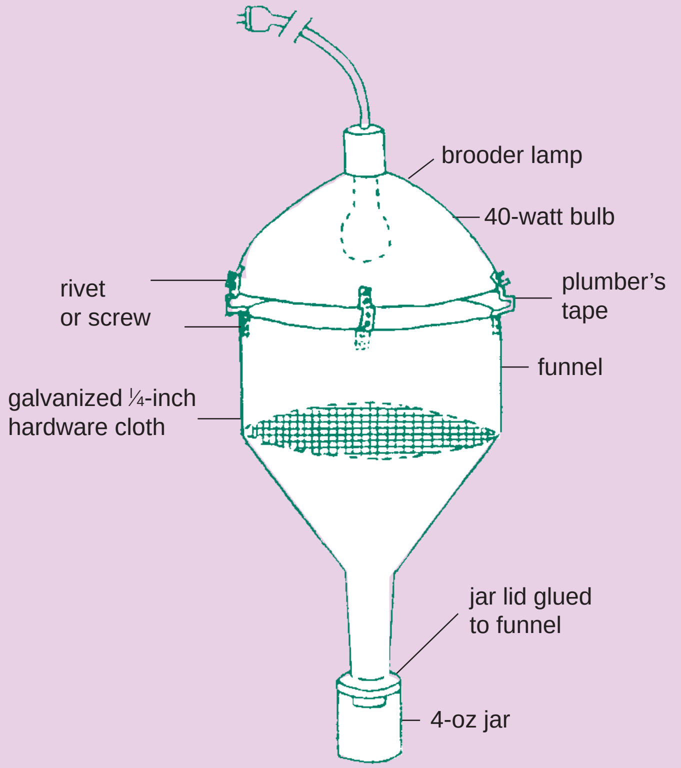
Tools

- electric drill with ⅛-inch drill bit
- hole saw bit the same size as the funnel spout diameter
- rivet gun or screwdriver
- tin snips
- pliers

For monitoring

- hand lens or magnifying glass (10x or more recommended)
- 70 percent isopropyl alcohol
- grower's log for record-keeping

The modified Berlese funnel



Constructing the funnel

1. Remove any filter screen from the funnel.
2. Cut the hardware cloth to fit and place it in the funnel.
3. With the hole saw bit, cut a hole in the center of the jar lid. Use a construction adhesive to glue the lid onto the spout of the funnel about ¼ inch up from the bottom of the spout, so that the jar can be screwed onto the lid.
4. Bend four pieces of plumber's tape so that when evenly spaced around the lamp they will hold the lamp just above the funnel. Drill ⅛-inch holes in the lamp, and secure the plumber's tape to the lamp with rivets or sheet-metal screws. Adjustments can be made by bending the plumber's tape so that the lamp rests just above the funnel.

The funnel cannot stand on the small jar at the bottom— it needs to be supported in a box or bucket. A frame constructed from wood or galvanized pipe can be used to support one or more funnels.

Thrips as they appear in actual size when the jar of alcohol is emptied onto a plate. Without magnification, the thrips look like debris in the alcohol.

Using the funnel to survey for thrips

Pour l–2 fluid ounces of isopropyl alcohol into the jar. Screw the jar onto the lid. If you plan to have the thrips identified, use a mixture of half alcohol + half water, and add a drop of detergent. This keeps the thrips from getting too stiff.

Harvest enough sprays to yield 50–100 blossoms. Remove blossoms from stems. Record the date, cultivar, and number of sprays used in your grower's logbook.

Put blossoms into the funnel, place the lamp on the funnel, and turn on the light. Heat from the bulb drives the thrips downward, and they fall into the alcohol.

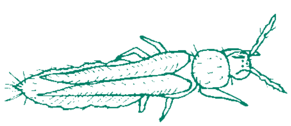
After 8 or more hours, turn off the light and remove the jar. Pour the alcohol into a flat dish. Using a hand lens, inspect the alcohol for thrips. If aphids or mealybugs are on the flowers, they will also be in the jar.

Moths and beetles may be attracted to the light and fall into the funnel. If this occurs, check the fit of the lamp and adjust the plumber's tape to minimize the space between the lamp and the funnel. If the problem continues, cover the space with a strip of wire window screen.

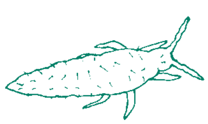
Record the number of thrips caught and divide by the number of sprays to determine the number of thrips per spray. This number, when compared with the numbers from other surveys, shows whether the thrips population is rising or falling.

Finally, clean the funnel and the jar. This is important to avoid contamination of future samples.

Thrips, greatly enlarged



adult



juvenile

Description of thrips

Under a magnifying lens, the adults are usually yellow, brown, or black. They have narrow bodies that taper to a point at the tail end. Adults have wings that may be either partly spread or flat along the top of the body. The wings have a hairy fringe that can be seen with a good lens. The antennas are short and straight.

Juvenile thrips are usually white or pale yellow. Their bodies are smaller and may appear chubby compared with the adults. The juveniles lack wings. Like the adults, they have short, straight antennas.

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Appendix B. Fungicides for Orchids

Pathogen or disease	Chemical name	Trade name	Type, comments
Alternaria	mancozeb	Dithane T/O,* Fore	Contact
	glycophene	Chipco 26019	Contact
Bipolaris	mancozeb	Dithane T/O, Fore	Contact
	glycophene	Chipco 26019	Contact
Botrytis	mancozeb	Dithane T/O, Fore	Contact
	thiophanate methyl	Cleary 3336, Fungo, Domain, SysTec	Systemic
	vinclozolin	Ornalin	Contact
Calonectria	mancozeb	Dithane T/O, Fore	Contact
	thiophanate methyl	Cleary 3336, Fungo, Domain, SysTec	Systemic
Colletotrichum	mancozeb	Dithane T/O, Fore	Contact
	Note: thiophanate methyl fungicides are not effective against this Colletotrichum.		
Exserohilum	mancozeb	Dithane T/O, Fore	Contact
Fusarium	mancozeb	Dithane T/O, Fore	Contact
	glycophene	Chipco 26019	Contact
	thiophanate methyl	Cleary 3336, Fungo, Domain, SysTec	Systemic. Many populations highly tolerant; discontinue use if not effective.
Phyllosticta	mancozeb	Dithane T/O, Fore	Contact
Phytophthora	fosetyl-Al	Aliette	Systemic
	metalaxyl	Subdue	Systemic
Pythium	fosetyl-Al	Aliette	Systemic
	metalaxyl	Subdue	Systemic
Pseudocercospora and *Cercospora*	mancozeb	Dithane T/O, Fore	Contact
Rhizoctonia	thiophanate methyl	Cleary 3336, Fungo, Domain, SysTec	Systemic *Caution:* beneficial fungi that closely resemble pathogenic *Rhizoctonia* will be killed by these fungicides.

*T/O = Dithane M-45 Turf and Ornamental

Other chemicals: Captan, for control of damping-off diseases. Cuproxat (basic copper sulfate) used for bacteria but phytotoxic to flowers in tropical temperatures (90°F). Terrazole and Truban (etridiazole) for *Phytophthora* and *Pythium* control on cymbidiums; residue left on plants. Physan 20, Consan 20, or Green Shield (N-alkyl dimethyl benzyl and ethyl benzyl ammonium chlorides) for disinfestation and cleaning; also used for bacterial control.

This list was compiled as a reference for orchid growers. The mention of trade names is to provide examples and does not constitute an endorsement to the exclusion of other suitable products or a guarantee of product performance. The pesticide user is responsible for reading and following the pesticide label.

Appendix C

Sprayer calibration for herbicide application

A sprayer commonly used on small farms is the 4-gallon knapsack (back-mounted) sprayer. The following method is suggested for calibrating such a sprayer for use with herbicides. The method consists of two steps:

Step 1. Determine the number of gallons of spray applied per acre (Table 1).

Step 2. Read from the tables how much liquid (Table 2) or wettable powder (Table 3) to add to 4 gallons of spray mix.

The most important step in the calibration procedure is to determine the number of gallons being sprayed per acre under field conditions.

The most important step in the procedure is to determine the *number of gallons* being sprayed per acre with the knapsack under field conditions. Step 1 is designed to calibrate a knapsack sprayer regardless of differences in nozzles, pressure, and walking speed.

How to calibrate a knapsack sprayer

Step 1. Determine the total gallons of spray used per acre.

A. Measure off an area 4 ft x 50 ft (200 sq ft).

B. Fill sprayer with water to approximately one-half capacity.

C. Determine the *time* it takes to spray the measured area at a comfortable walking speed and the pumping pressure used in the field. Repeat this at least three times and find the average time.

D. Refill the sprayer to the original level with water and with about the same pressure and pumping speed used in the field, discharge the spray into a container for the average time determined above.

E. Measure the amount of water discharged into the container in a measuring cup and refer to Table 1 for gallons of spray used per acre.

Repeat (D) and (E) three times and take the average reading. For example, Table 1 shows that when 24 fluid ounces are used to cover 200 sq ft, the amount is equal to 40 gallons of spray used per acre.

Table 1. Gallons of spray used per acre.

Nozzle discharge to cover 200 sq ft (fluid ounces)	Spray used per acre (gallons)
12	20
18	30
24	40
30	50
36	60
42	70
48	80
54	90
60	100

Step 2. Determine the amount of chemical to put in the sprayer (4-gallon capacity). Use the value for gallons of spray used per acre determined in Step 1 and the amount of chemical per acre specified on the herbicide label. Refer to Table 2 for liquid formulations and Table 3 for wettable powder formulations. (Tables are from Nishimoto, 1981).

Application of granular forms of herbicides

Granular forms of Ronstar® and some other herbicides are available. The main advantage of granular herbicides is that they are easy to apply and cause little or no injury to the crop if applied when the foliage is dry so that the granules do not adhere to plant parts. Granular herbicides are best applied on moist media followed immediately by applying water at ½ acre inch (13,500 gal/acre). For the amounts of granular herbicide to apply in areas less than one acre, refer to Table 4.

Low-pressure sprayers

The most common item of equipment used to apply pesticides to crops and non-crop areas is the low-pressure sprayer. They are often mounted on the back of a tractor, but they may be on trailers or self-propelled. Low-pressure sprayers use pressure ranging from nearly 0 to about 200 psi (pounds per square inch) to apply pesticides at rates rang-

Table 2. Amounts of emulsifiable concentrate (liquid) to mix in 4 gallons of spray.

Spray used per acre (gallons)	Quarts of emulsifiable concentrate recommended per acre				
	2	4	6	8	10
	Fluid ounces to mix in 4 gallons				
30	8½	17	25¼	34¼	42¾
40	6½	12¾	19¾	25½	32
50	5	10¼	15¼	20½	25½
60	4½	8½	12¾	17	21¼
70	3¾	7½	11	14½	18¼
80	3¼	6½	9¼	12½	15¾
90	2¾	5¾	8½	11½	14¼
100 5	2½		7¾	10¼	12¾

Conversion factors: 1 qt = 32 fl oz, 1 pt = 16 fl oz, ½ pt = 8 fl oz, ¼ pt = 4 fl oz

Table 3. Amounts of wettable powder to mix in 4 gallons of spray.

Spray used per acre (gallons)	Pounds of wettable powder recommended per acre				
	1	2½	5	10	14
	Ounces of wettable powder to mix in 4 gallons				
30	2	5¼	10½	21¼	29¾
40	1½	4	8	16	22½
50	1¼	3¼	6½	12¾	18
60	1	2½	5¼	10½	15
70	1	2¼	4½	9	12¾
80	¾	2	4	8	11¼
90	¾	1¾	3½	7	10
100	½	1½	3¼	6½	9

Conversion factor: 16 oz = 1 lb

Table 4. Granular herbicide application rates for areas less than an acre.

Recommended per-acre rates (pounds)	Application area (sq ft)				
	500	1000	5000	10,890 (¼ acre)	21,780 (½ acre)
	Amount of granular herbicide to apply				
	(oz)	(oz)	(oz)	(lb)	(lb)
20	3¾	7½	35	5	10
28	5	10¼	50	7	14
30	5½	11¼	53	7½	15
37	6¾	13½	67	9¼	18½

The main advantage of granular herbicides is that they are easy to apply and cause little or no injury to the crop if applied when the foliage is dry so that the granules do not adhere to plant parts.

ing from 10 gallons to over 100 gallons per acre. The basic components of a low-pressure spray system are the pump, tank, agitation system, flow-control assembly, and distribution system.

The pump must provide the required flow rate at the desired pressure. It must pump enough liquid to supply the gallons-per-minute output required by the nozzles and the pump agitator. Pump types for spray equipment include roller pumps, centrifugal pumps, and turbine pumps. The choice of a pump depends on factors including cost, tank size, chemicals to be sprayed, maintenance requirements, use frequency, and life expectancy. Sales representatives of spray equipment companies can help you make the appropriate choice.

The spray tank should be large enough that it does not require frequent refilling.

The spray tank should be large enough that it does not require frequent refilling. It should resist corrosion and be easy to clean and maintain. The capacity at various levels should be clearly marked on the tank, or have a sight gage or other means to determine fluid level. Tanks are constructed of many materials, but fiberglass is the most widely used because it is light, strong, durable, non-corrosive, and inexpensive. Stainless steel tanks are very strong, durable, and corrosion-resistant, but they are heavy and expensive. Aluminum tanks resist corrosion and are suitable for many chemicals but they should not be used for solutions of nitrogen with phosphoric acid; a few pesticides also will corrode them. Polyethylene tanks are compatible with most agricultural chemicals and are generally durable, but they must be replaced if cracked or broken, because there is no effective method of repair. Polyethylene breaks down under ultraviolet light, and tanks should be kept out of direct sunlight when not in use. Galvanized steel tanks are not recommended because many chemicals can corrode and rust them. Rust flakes clog strainers, damage pumps, and plug nozzles.

Soluble liquids and powders do not require agitation, but wettable powders, flowables, and emulsions can separate if they are not agitated. Hydraulic agitation keeps the fluid circulating by returning a portion of the pump output to the tank. Mechanical agitatators use paddles or propellers mounted on a shaft near the tank bottom.

The flow-control assembly usually consists of a relief valve, control valve, pressure gauge, and shut-off valve. The relief valve opens with increasing pressure in the system and is designed to prevent damage to the pump and other components. When the control valve and the relief valve are properly adjusted, the spraying pressure is regulated. A pressure gauge is necessary because different spray nozzles are designed to operate within specific pressure ranges.

Hoses, fittings, and nozzles make up the distribution system. Hoses should be durable, flexible, strong enough to withstand the highest selected operating pressure, and resistant to chemicals, oils, sunlight, twisting, and vibration. The proper size and type of nozzle is an important part of pesticide application. The nozzle determines spray uniformity, surface coverage, the amount of spray solution applied to a given area, and the amount of drift. Fan nozzles are used for most broadcast spraying of herbicides, as well as some insecticides when penetration of the leaf canopy is not essential. Cone nozzles are used when spray penetration throughout the foliage is required for effective insect and disease control.

As for most equipment, frequent and proper cleaning and maintenance will help ensure reliable equipment performance and longevity.

Text adapted from L.E. Bode and B.J. Butler (1981), Equipment and calibration: low-pressure sprayers, Cooperative Extension Service, College of Agriculture, Univ. of Illinois at Urbana-Champaign.