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Diseases of Orchids in Hawaii

Members of the Orchidaceae are terrestrial, epiphytic, or vinelike plants distributed throughout the world in temperate and tropical regions. Close to 200 genera and hybrid genera are cultivated within the 600–800 genera estimated for these strikingly unusual plants (12).

The Orchidaceae is generally considered to be the largest family of flowering plants in terms of the number of species (12), with 17,000–30,000 species representing a highly diverse group. Common commercially cultivated genera include terrestrial *Paphiopedilum* and *Phaius* and epiphytic *Brassavola, Cattleya, Coelogyne, Cymbidium, Dendrobium, Epidendrum, Laelia, Lycaste, Miltonia, Odontoglossum, Oncidium, Phalaenopsis, Vanda*, and *Vanilla*. Hobbyists frequently collect *Aerides, Calanthe, Catasetum*, and *Maxillaria*.

Orchids are propagated by seed, vegetative division, or mericloning. Seed and mericlone propagation both require months of axenic agar culture but yield thousands of new plants. Those propagated by seed have considerable genetic diversity, whereas those propagated by mericloning have almost none.

The commercial value of various orchid crops in Hawaii approximated $11 million in 1990 (2). Included were sales of detached *Vanda, Cattleya*, and *Dendrobium* blossoms, *Cymbidium* and *Dendrobium* sprays, and potted plants of many genera. In 1989, Thailand exported approximately 300 million sprays of *Dendrobium* and Singapore also exported a large number of sprays, with about one-half of the exports from both going to Japan. In 1989, Hawaii exported nearly 3.2 million sprays, mostly to the U.S. mainland, which imported over 5.6 million *Dendrobium* sprays from foreign countries (22).

In Thailand, the world's largest producer of *Dendrobium*, the cultivar Sonia accounts for over 70% of the *Dendrobium* grown, whereas University of Hawaii cultivars dominate production in Hawaii. The estimated 3-year cost for a 1.5-acre farm in Hawaii (excluding land cost of $30,000–$150,000/acre) exceeds $200,000, whereas a similar farm costs less than $4,000 in Thailand (22). Hawaii's growers receive higher wholesale prices for products of better quality than those from competing nations (22).

The climate range in Hawaii is conducive to the growth of many orchid genera, allowing for large collections among hobbyists and stimulating commercial production. Several commercial orchid nurseries in Hawaii breed and propagate a wide variety of species and hybrids. Plants are sold locally to other nurseries or hobbyists and also are exported nationally or internationally. Orchid plants are sold in axenic flask culture, in multiplant community pots, as individual young plants, or as mature plants with flower buds. A tremendous number of genera are grown in the state, including a number of species that thrive in cooler areas, for example, cultivars of *Cymbidium, Dendrobium*, and *Phalaenopsis*. Over 100 nurseries in Hawaii produce orchids, with many specializing in selected genera of potted plants or in flower production (1).

In the United States, fungal pathogens frequently associated with common orchid genera include: *Aecidium graebnerianum* Henn., *Alternaria* spp., *Bipolaris* spp., *Botrytis cinerea* Pers.:Fr., *Cercospora* spp., *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. in Penz., *Fusarium oxysporum* Schlechtend.:Fr., *Lasiodiplodia theobromae* (Pat.) Griffon & Maubl., *Phoma* spp., *Phyllosticta capitalensis* Henn., *Phytophthora cactorum* (Lebert & Cohn) J. Schröt., *Phytophthora palmivora* (E.J. Butler) E.J. Butler, *Pseudocercospora* spp., *Puccinia cypripedii* Arth. & Holw., *Pythium splendens* H. Braun, *Pythium ultimum* Trow, *Rhizoctonia solani* Kühn, *Sclerotium rolfsii* Sacc., *Septoria* spp., *Sphenospora kevorkianii* Linder, and *Uredo* spp. (5). These organisms are associated with flower blights, leaf rots or spots, stem or pseudobulb rots, root rots, plant decline, and seedling damping-off.

Some of these pathogens have been noted to occur in other parts of the world (11,16). Geographic isolation and state agricultural quarantine regulations have prevented the establishment of rusts in Hawaii, but all other fungal pathogens listed above are now known to occur in Hawaii.

The rapid growth of the orchid industry in Hawaii during the 1980s was accompanied by a proliferation of diseases with unknown etiologies. Little research-based information was available for the many pathogens associated with diseases of orchids. Our research efforts were focused on diseases of *Dendrobium*, with support for studies coming from commercial growers and state agencies, and findings have aided local and international growers. These studies also serve as a foundation for investigations of problems in other genera, such as *Cattleya, Cymbidium, Epidendrum*, and *Vanda*. This article describes important diseases of orchids in Hawaii, with emphasis on fungal diseases associated with *Dendrobium*.

Botrytis Blossom Blight

Botrytis cinerea causes floral spots, petal blights, and soft rots of many plant genera. In 1952, blossom rot of *Vanda* occurring in shipments to the continental United States was attributed to unidentified species of *Botrytis, Gloeosporium*, and *Alternaria* (6). Today, most commercial cultivars of *Dendrobium* and *Vanda* are known to be susceptible to *B. cinerea*, whereas flowers from *Cattleya, Cymbidium, Epidendrum*, and *Phalaenopsis* are more tolerant of this fungus. Flower blights on *Dendrobium* begin as small flecks or

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spots that rapidly expand into flaccid, translucent blights and soft rots (Fig. 1A) (10). Infections from single spores produce flecks that may expand and eventually destroy flowers, although many flecks initiated from single spores remain localized. After a few weeks, the pathogen cannot be reisolated. As inoculum levels increase, the frequency of multiple spores per lesion and the number of lesions increase. *B. cinerea* readily produces conidia on rotted flowers in *Dendrobium* and *Vanda* fields, and many spores develop on decomposing flowers (Fig. 1B). Epidemics caused by *Botrytis* are common during the cool, moist winter months. The economic impact is magnified because many *Dendrobium* and *Vanda* cultivars produce fewer flowers during the winter and market demand is high.

At least one other pathogenic *Botrytis* sp., characterized by large ellipsoidal conidia, occurs on blighted orchids (10). Isolates of this second species have also been found in *Vanda* fields.

Field sanitation is critical to disease control because conidia are produced in large numbers and are readily windborne. Several fungicides, including triadimefon, vinclozolin, and mancozeb, are available for control of Botrytis blossom blights (3).

Floral and Foliar Diseases Caused by *Colletotrichum* sp.

Floral symptoms caused by *Colletotrichum* species are similar to those of Botrytis blossom blight (20). Elliptical to round, tan to dark brown spots (Fig. 2A) expand into soft rots at rates slightly slower than those caused by *Botrytis*. Lesions may also be off-white, pink, or various shades of purple, depending on orchid type and flower color. Concentric rings of salmon-colored conidial masses are frequently produced on older lesions. Diagnosis can be confounded by growth of saprophytic fungi that produce similar rings on colonized *Phytophthora* lesions or other damaged tissue, such as sunburn spots. Diagnosis should not be based on symptomatology alone, and *Colletotrichum* should be confirmed by microscopic examination or isolation on agar media.

Floral spikes, young leaves, and leaf sheaths are susceptible to *Colletotrichum*. Dark, oval lesions occur on floral spikes, frequently girdling and killing young spikes. Spots and blights develop on young foliar shoots.

Cool winter months in Hawaii are conducive to diseases caused by *Colletotrichum*. Flower losses and defoliation are particularly severe during prolonged wet periods. Foliar disease (Fig. 2B) was readily reproduced at greenhouse temperatures of 20–25 C. In contrast, young shoots inoculated during the summer months (28–34 C) developed small, restricted, black, sunken lesions on leaves, especially at the leaf base. As inoculated canes matured, a few diseased leaves were lost but the plants, maintained in a glasshouse, recovered without treatment.

Isolates of *Colletotrichum* collected from diseased orchids were identified as *C. gloeosporioides* and, tentatively, as *C. coccodes* (Wallr.) S.J. Hughes. None of the *C. gloeosporioides* isolates caused significant spotting or blighting of *Dendrobium* flowers after inoculation. In contrast, all *C. coccodes* isolates were pathogenic and shared three major characteristics: 1) narrow conidia, 2) growth inhibition at temperatures of 31 C and higher, and 3) high tolerance to benomyl.

Conidia of seven isolates of *C. coccodes* averaged 15.6 μm in length and 3.5 μm in width and those of seven isolates of *C. gloeosporioides* averaged 15.9 and 5.4 μm, respectively. At 31 C, *C. gloeosporioides* grows and sporulates, whereas orchid isolates of *C. coccodes* are greatly inhibited and produce small, black stromata. *C. gloeosporioides* is highly sensitive to benomyl, and fungicides will prevent diseases caused by this pathogen. Radial growth of *C. coccodes* on benomyl-incorporated agar is comparable to that of benomyl-resistant isolates of *C. gloeosporioides*, and field applications of benomyl do not control disease. The tolerance of orchid isolates of *C. coccodes* to benomyl is consistent with a report of similar tolerance among tomato isolates of this fungus (4). *C. coccodes* has also been isolated from *Arundina, Ascocentrum, Spathoglottis, Vanda*, and *Vanilla*.

Diseases Caused by *Phytophthora* spp.

Several major diseases of orchids are caused by *Phytophthora* species, primarily *P. palmivora*. Isolates identified as *P. palmivora* have all been morphological form I. Thirty years ago, Hine (7) demonstrated the pathogenicity of this fungus to *Vanda* and *Epidendrum*. *P. nicotianae* Breda de Haan is another important species in Hawaii, whereas *P. cactorum* and *P. cinnamomi* Rands are of lesser importance. These four *Phytophthora* species collectively affect a large number of orchid genera, viz., *Brassia, Cattleya, Cymbidium, Dendrobium, Epidendrum, Oncidium, Paphiopedilum*, and *Vanda*.

The major diseases are seedling damping-off, bud and flower blights (Fig. 3), leaf and pseudobulb rots, stem rot, root rot, and slow decline followed in many cases by plant death (21). Seedling losses are especially high because young plants are planted in densely packed community pots. After several months, the plants are individually transplanted into 5-cm-diameter pots arranged tightly in trays to prevent toppling and to economize on space. These cultural conditions favor fungal sporulation (Fig. 4A) and rapid disease spread, although increased humidity also enhances plant growth. Leaf lesions on young *Dendrobium* plants are generally irregular in shape, are olive-green to brown with dark green, water-soaked borders, and may appear blistered (Fig. 4B). Infected leaves eventually become yellow and abscise. Under dry conditions, lesions are sunken and often dark, ranging from brown to black. Similar symptoms occur on young shoots of older plants. Foliar lesions on *Vanda* are water-soaked when moist and brown to brownish black, becoming yellow with age. Pseudobulbs and canes are readily rotted through leaf or root infections or occasionally directly. In many genera, rots of older pseudobulbs and canes are generally dry and brown or black and the advancing lesion is usually irregular. In contrast, young succulent canes and pseudobulbs may have wet, black necrosis resembling that caused by bacteria (Fig. 4C).

Mild to severe root rots are common, although these epiphytic plants survive long periods with only a few functional roots. When the root system is infected, the normally white velamen becomes brown or is absent and the total root mass is greatly reduced (Fig. 4D).

Production of sporangia on diseased tissue is common in the tropics, and species such as *P. palmivora* produce sporangia in abundance. Spores are dispersed primarily by splashing water or through the reuse of contaminated potting media. Chlamydospores are common in infected host tissue. Oospores of *P. palmivora* have not been observed in nature in Hawaii, probably because compatibility type A2 is rare. Of 104 isolates of *P. palmivora* collected from orchids, papaya, macadamia, and other ornamental hosts in Hawaii, 98 were compatibility type A1. In contrast, all 12 isolates of *P. palmivora* collected from diseased cacao, introduced into Hawaii during 1986–1987, were type A2.

The common occurrence of *P. palmivora* on papaya, orchids, ornamental hosts, and cacao raised important questions about the cross-pathogenicity among these isolates. Inoculations of *Dendrobium*, papaya, and cacao plants with 81 representative isolates revealed a high level of host specialization within the population of isolates identified as *P. palmivora* (19). Exceptions included one cacao isolate that caused an occasional stem rot in *Dendrobium*. Several isolates collected from macadamia, ivy, and *Chamaedorea* were very aggressive on *Dendrobium*. *P. palmivora* occurring on ornamental plants may serve as sources of inoculum for orchids.

Fungicides such as metalaxyl and etridiazole effectively reduce the incidence of disease. Sanitation, control of

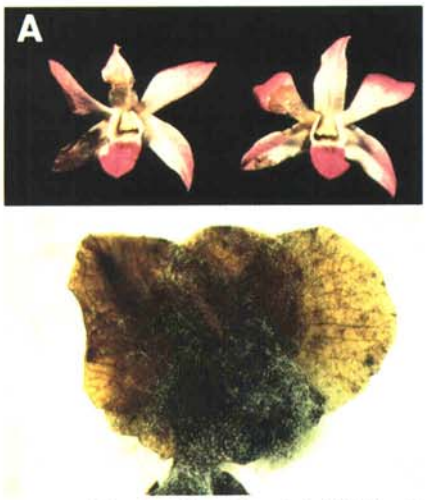

Fig. 1. (A) Sepal and petal blight of *Dendrobium* flowers caused by *Botrytis cinerea*. (B) Abundant conidia of *B. cinerea* on rotted *Vanda* flower.

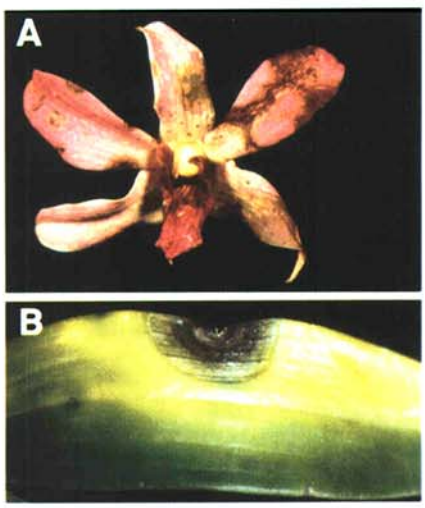

Fig. 2. (A) Advanced blight of *Dendrobium* flower caused by *Colletotrichum coccodes*. (B) Leaf spot and general yellowing of *Dendrobium* 11 days after inoculation with *C. coccodes*.

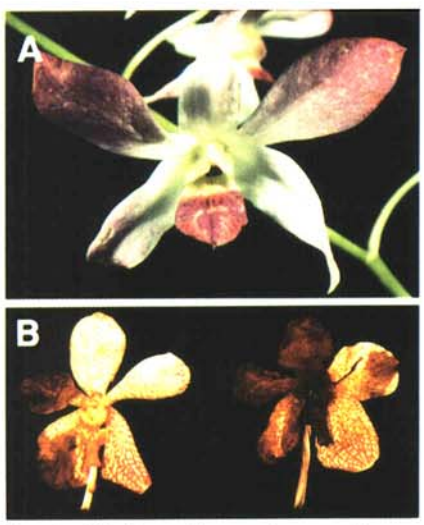

Fig. 3. (A) Irregular sunken spots on *Dendrobium* flower 4 days after inoculation with *Phytophthora palmivora*. (B) Severe blight of *Vanda* flowers caused by *P. palmivora*.

insects and slugs, and destruction of badly diseased potted plants are recommended.

Phyllosticta Leaf Spot

Phyllosticta capitalensis (= *Phyllostictina pyriformis* Cash & A.M. Watson) is common in commercial *Dendrobium* fields and on potted blooming plants (18). This and/or other species of *Phyllosticta* are also present on *D. infundibulum* Lindl., *D. nobile* Lindl., *Vanda*, and *Ascocentrum*.

Leaf lesions on *Dendrobium* caused by *P. capitalensis* begin as small (2–3 mm) chlorotic circular spots (Fig. 5). A few spots become blackened and necrotic as the leaf matures, but most remain small and chlorotic.

These spots were long thought to have a viral etiology because spot development was unrelated to recent rainfall or high moisture patterns and because healthy plants became spotted without apparent exposure to diseased plants. Furthermore, spots were uniformly common in large fields, persisted without change for long periods, and did not respond to chemical treatment. Yellow spots produced by *Phyllosticta* typically do not expand for many months or even years. As the cane ages, fungal growth accelerates and yellow spots enlarge and become tan. Mycelia spread throughout the internal leaf tissue, and the leaf is eventually blighted. Formation and dissemination of conidia complete the disease cycle. Symptomless but infected plants may develop leaf spots months later, frequently after being sold, thereby spreading the fungus to many nurseries and private collections. Transplanting young, symptomless plants into fields for cut flower production also results in large populations of diseased plants.

As a field problem in nurseries producing flower heads or floral sprays, Phyllosticta leaf spot reduces yield and shortens the productive life of a field. Vigorous plants with yellow spots apparently produce enough photosynthates to limit disease development to the yellow spot phase. In the field, canes with yellow spots defoliate after 3–4 years, whereas uninfected healthy canes retain leaves for longer than 5 years. In contrast, potted plant producers suffer heavy losses, as leaf spots rapidly expand in retail centers or in transit to markets in the continental United States. In both situations, spot expansion and rapid defoliation are the consequences of holding plants in reduced lighting or in extended periods of darkness.

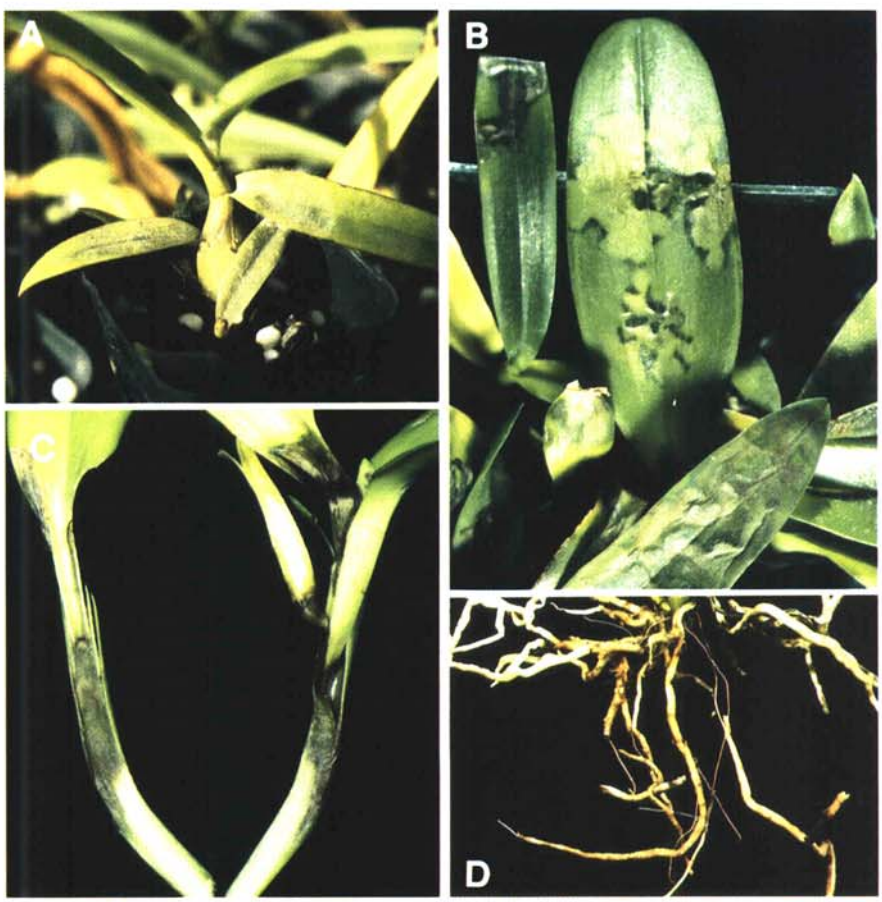

Fig. 4. (A) Sporangia of *Phytophthora nicotianae* formed on *Dendrobium* seedling. (B) *Dendrobium* leaf with typical irregular, water-soaked lesions caused by *P. palmivora*. (C) Young *Dendrobium* cane with typical wet, black necrosis caused by *P. palmivora*. (D) Root rot of *Dendrobium* caused by *P. palmivora*.

In a few localities in Hawaii, wet winter months conducive to *Colletotrichum* epidemics have also resulted in high levels of *Phyllosticta* disease. Leaf blights caused by *C. coccodes* are rapidly followed by expansion of *Phyllosticta* yellow spots on the same leaf.

Thiram provides excellent protection from infection by *Phyllosticta*, but as yet, no chemical treatment has been found to eradicate the yellow spot stage. Since levels of Phyllosticta leaf spot are greatly reduced under solid covered greenhouses, modifications in cultural practices and sanitation are recommended to growers in areas of high rainfall.

Blossom Flecks

Blossom flecks and small spots are common during the summer in *Dendrobium* and *Vanda* grown in open fields or under shade cloth. The incidence of blossom flecks increases markedly after frequent rains, and intense flecking renders flowers unmarketable. Flower flecks are also a problem on potted plants of *Phalaenopsis, Cattleya*, and many other orchids. Flecks are light to dark brown, sunken, and 1 mm or less in diameter, rarely expanding beyond 3–5 mm. These spots essentially represent aborted infections and have little or no damaging effect on the plant.

The major organisms involved in blossom flecks are *Exserohilum rostratum* (Drechs.) K.J. Leonard & E.G. Suggs, *Alternaria alternata* (Fr.:Fr.) Keissl., *Bipolaris setariae* (Sawada) Shoemaker, *B. sorokiniana* (Sacc.) Shoemaker, and other *Bipolaris* species (17). *A. alternata* lesions occur most frequently and require 2 weeks or longer to develop after inoculation (Fig. 6A). In contrast, *Bipolaris* causes larger lesions in less than a week (Fig. 6B).

Because all these pathogens produce inocula on dead flowers and leaves, sanitation practices greatly reduce inoculum in the field. Unfortunately, many *Dendrobium* and *Vanda* fields are subjected to a continuous supply of inoculum produced on surrounding weeds, commonly grasses (17). Weed control and occasional fungicide application to flowers reduce the problem, and solid covered greenhouses virtually eliminate disease.

Bacterial Diseases

Bacterial diseases are common on orchids and have been especially troublesome in wet areas of Hawaii. The most serious are rots of *Dendrobium, Oncidium*, and *Phalaenopsis* plants, blights of *Vanda* flowers, and postharvest losses of *Dendrobium* sprays. Infected plants have leaf spots, blights, and soft rots, which progress into canes or stems and kill the plants (Fig. 7). Roots of *Dendrobium* are not usually affected, and dead plants frequently have large root masses.

Erwinia chrysanthemi Burkholder, McFadden, and Dimock and *Pseudomonas gladioli* Severini pv. *gladioli* have been identified as pathogens in *Dendrobium* fields. Disease progresses rapidly after inoculation and kills young shoots within 2 weeks. Wounding is not needed for disease initiation, and young tissue is the most susceptible.

Viral Diseases

Viral infections are common on orchids in Hawaii and are primarily caused by Cymbidium mosaic virus (CyMV) and Odontoglossum ringspot virus (ORSV) (9). Most commercial cultivars of *Vanda* grown for lei flower production are infected with CyMV (9), even though flowers appear symptomless. Infections on some *Dendrobium* and *Cattleya*, however, cause dark tan to brown streaks on petals (Fig. 8) and leaf pitting. Reduced yield is also

Fig. 5. *Dendrobium* with typical yellow and black leaf spots caused by *Phyllosticta capitalensis*.

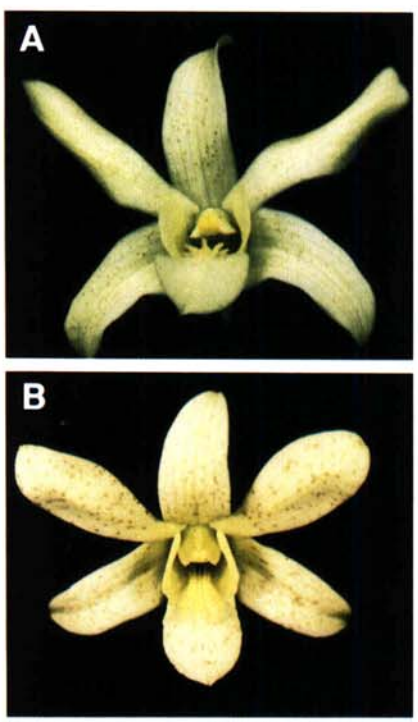

Fig. 6. Dark flecks on *Dendrobium* flowers (A) 2 weeks after inoculation with *Alternaria alternata* and (B) 6 days after inoculation with *Bipolaris sorokiniana*.

Fig. 7. Necrosis of young *Dendrobium* leaves and shoots caused by *Erwinia chrysanthemi*.

Fig. 8. Brown petal streaks and necrosis on *Dendrobium* associated with Cymbidium mosaic virus infection.

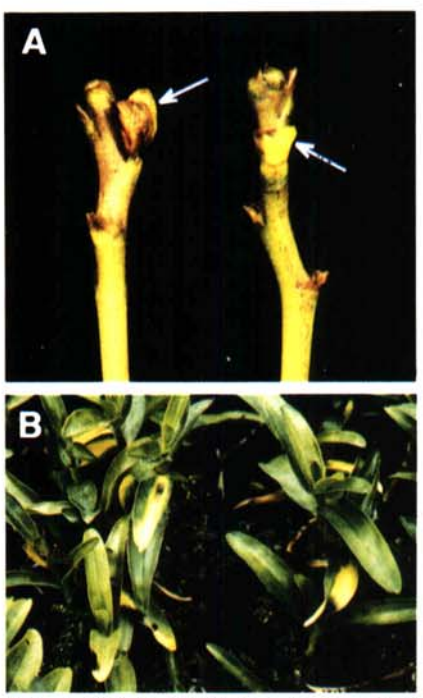

Fig. 9. (A) Necrotic and yellow bud symptoms (arrows) on *Vanda* and (B) leaf blotch on *Dendrobium nobile* caused by *Aphelenchoides besseyi*.

probable (14). Color break (9) and deformity have been associated with ORSV infections on several types of orchids, including *Cattleya*. Symptomless plants such as those found within the cultivar Uniwai Supreme also occur (14) and hinder control efforts.

Prevalence of CyMV in Hawaii is attributed to several factors, including a wide host range within the Orchidaceae for CyMV, vegetative propagation of orchids, the large numbers of symptomless orchids serving as viral reservoirs, the fairly high titers of CyMV in host tissue, easy mechanical transmission of the virus, and unwillingness of growers to confront, rogue, and commit to virus-free orchid culture.

Tomato spotted wilt virus was recently identified on leaves of *Oncidium*, with chlorotic to necrotic ring spots 1–2 cm in diameter (8). Symptoms on flowers were not observed.

Today, seed-propagated cultivars of *Dendrobium* (23) and accurate assays afforded by ELISA make virus-free *Dendrobium* plantings possible.

Diseases Caused by Nematodes

Certain nematodes cause rots of flowers, leaves, and pseudobulbs. The nematode causing yellow-bud blight of *Vanda*, characterized by yellow buds and bud rot (Fig. 9A) and spike necrosis, was originally identified as *Aphelenchoides ritzemabosi* (Schwartz) Steinder & Buhrer (W. A. Feder, *unpublished*), then subsequently reidentified as *A. besseyi* Christie (15). This nematode also causes leaf blotch of *D. nobile* (13) (Fig. 9B) and a dry leaf rot of other *Dendrobium* cultivars, as well as a leaf and pseudobulb rot of *Cattleya* (*unpublished*). *A. fragariae* (Ritzema Bos) Christie is associated with rotted leaf sheaths of *Vanda* (15).

Outlook

Research on fungal disease of orchids continues in our laboratory. Species of *Calonectria, Fusarium, Mycoleptodiscus, Phytophthora, Pseudocercospora, Pythium, Rhizoctonia*, and other pathogens reported to be associated with orchid diseases are being investigated. The culture, identification, and proof of pathogenicity for many of these organisms are continuing and will expand our knowledge about disease problems facing commercial growers throughout the world.

In Hawaii, commercial production of *Dendrobium* and other genera will require integrated disease control methods. The few chemicals available for fungal disease control have been diminished with the recent removal of ornamental crops from the Benlate label, the expiration of the Special Local Needs registration for Spotrete, and the generally low priority given by chemical companies to register new chemicals on minor crops. Greater reliance on disease prevention and management through cultural methods is recommended to growers. Variations in cultivar susceptibility to *Phytophthora* and *Colletotrichum* are being documented for use in breeding programs.

The modest orchid industry in Hawaii has provided limited funds for urgently needed research on diseases of this exotic, diverse, popular, and valuable plant family.

Acknowledgments

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