630 US ISSN 0271-9916 April, 1995 RESEARCH EXTENSION SERIES 159

Diseases of Heliconia in Hawaii

Kelvin T. Sewake and Janice Y. Uchida

HITAHR · COLLEGE OF TROPICAL AGRICULTURE AND HUMAN RESOURCES · UNIVERSITY OF HAWAII

The Library of Congress has catalogued this serial publication
as follows:

Research extension series / Hawaii Institute of Tropical
Agriculture and Human Resources. — 001-
— [Honolulu, Hawaii] : The Institute,
[1980-
v. : ill. ; 22 cm.
Irregular.
Title from cover.
Separately catalogued and classified in LC before and including no. 044.
ISSN 0271-9916 = Research extension series - Hawaii Institute of Tropical Agriculture and Human Resources.
1. Agriculture—Hawaii—Collected works. 2. Agriculture—Research—Hawaii—Collected works. I. Hawaii Institute of Tropical Agriculture and Human Resources. II. Title: Research extension series - Hawaii Institute of Tropical Agriculture and Human Resources.
S52.5R47 85-645281
630'.5—dc19
AACR 2

The Authors

Kelvin T. Sewake is associate county extension agent, Cooperative Extension Service, College of Tropical Agriculture and Human Resources (CTAHR), University of Hawaii at Manoa.

Janice Y. Uchida is associate professor of plant pathology, Department of Plant Pathology, CTAHR.

Acknowledgments

The authors thank Dr. Minoru Aragaki, emeritus plant pathologist in the Department of Plant Pathology, CTAHR, for manuscript review; Mr. Desmond Ogata and Mr. Brian Bushe, research associates in the CTAHR Agricultural Diagnostic Service Center, for their assistance in disease diagnoses; Dr. Stephen Ferreira, associate extension specialist in the Department of Plant Pathology, CTAHR, for photographic slides of bacterial diseases; Dr. Brent Sipes, assistant plant pathologist in the Department of Plant Pathology, CTAHR, for photographic slides of nematodes; Mr. Chris Kadooka and Ms. Pat Yahata, research associates in the Department of Plant Pathology, CTAHR, for technical assistance; Mr. Daniel Schuster for field and laboratory assistance; and Ms. Doreen Koizumi for typing assistance.

Funding for research and this publication was made possible by USDA Floriculture Research Grant No. 89-34199-4420 and by a grant from the County of Hawaii Department of Research and Development. This work was supported by the Hawaii Tropical Flowers and Foliage Association—Big Island Chapter, and participating members as cooperators in conducting this research.

Cover photo: *Heliconia rostrata.*

Contents

Figures

Diseases of Heliconia in Hawaii

Kelvin T. Sewake and Janice Y. Uchida

The Hawaii heliconia industry is fairly new. Crop production and value of grower sales data have been recorded only since 1985 by the Hawaii Agricultural Statistics Service (HASS 1992). Sales figures rose rapidly from a statewide value of $125,000 in 1985 to almost $1.4 million in 1988. Value of sales remained greater than $1 million through 1991. Changes in HASS reporting methods in 1992 make it difficult to compare values of sales since that year with previous years.

There is excellent potential to expand heliconia production in Hawaii because of its low start-up cost, the relative ease of plant culture, and the ideal growing environment in Hawaii. Another opportunity that has arisen recently for existing and new heliconia farmers is the availability of affordable land on the Hamakua Coast of the Big Island of Hawaii. The demise of the Hawaii sugar industry has made available vast acreages of land at relatively low prices. These sugarcane lands have deep soil profiles, which are ideal for heliconia production.

However, with the many advantages and opportunities for heliconia production, the Hawaii Tropical Flowers and Foliage Association—Big Island Chapter recognizes severe disease-related problems associated with the production of heliconias. Because of the high rainfall in East Hawaii, the major heliconia-producing area of the state, many disease problems occur that have not been thoroughly studied and are not well understood. Little information is available to farmers to help them identify and control heliconia diseases in the field.

Heliconia farmers often cannot effectively apply disease management strategies or implement measures to prevent, control, or eliminate diseases when they lack accurate identification of the disease-causing agents and readily available information to understand the biology of the pathogens. Therefore, significant production losses can occur, resulting in financial losses. Although not well documented, production losses from disease-related problems may be extremely high, especially in severe cases of bacterial wilt caused by *Pseudomonas solanacearum* or fungal root rot caused by *Calonectria spathiphylli*.

This publication is designed as a guide for quick identification of heliconia diseases found in Hawaii for heliconia farmers and other agricultural professionals. Some general control recommendations are included in this publication, but farmers are advised to seek professional assistance from the Cooperative Extension Service or other sources for more specific diagnostic services and control recommendations.

Nomenclature of Heliconia Plants

Identification of the many of heliconia plants cultivated or found in the wild has been difficult and confusing for professional agriculturists and hobbyists alike. Although there may be legitimate arguments among heliconia enthusiasts regarding plant nomenclature, heliconia names in this paper will follow *Heliconia: An Identification Guide* by Fred Berry and W. John Kress (1991), which contains a list of 200 names along with color illustrations and plant descriptions that make heliconias easily identifiable. The book is useful to heliconia hobbyists, growers, and researchers for the references and nomenclatural origins it contains, and taxonomic changes can be proposed using it as a reference point.

Nomenclature of Plant Parts

Heliconia belongs to the family Heliconiaceae and contains 200 to 250 species of herbaceous plants that are primarily native to tropical America. Its vividly colored flowers are nearly always terminal and may be either erect (Figure 1) or pendant.

Plant parts are identified and labelled in Figure 2. Familiarity with the names of plant parts is important because they are used throughout this publication in disease descriptions, as well as in the trade.

Overview of Heliconia Diseases

A survey of records of heliconia diseases in Hawaii at the Department of Plant Pathology, University of Hawaii at Manoa, and the Agricultural Diagnostic Service Center (UH Manoa and Komohana Agricultural Complex, Hilo) revealed that most of the destructive pathogens have been recovered from roots and rhizomes. These included several root-rotting fungi, a bacterium, and several nematodes. Root-rotting organisms seem to play a greater role in the decline of heliconia stands than organisms infecting leaves and floral bracts, although some fungi isolated from foliage cause massive leaf destruction.

Few pathogens were recovered from floral bracts. Of those recovered, most are believed to be opportunistic or secondary pathogens causing problems only on weakened plants or damaged tissue.

Most of the organisms described in detail below are believed to be primary pathogens of heliconia. Others listed as "associated" with heliconia diseases need to be studied further and may represent host-pathogen interactions that are not yet well understood.

Foliage Diseases Caused by Fungi

Calonectria spathiphylli

Disease and symptoms. The most pronounced foliar symptoms on heliconia caused by *Calonectria spathiphylli* are leaf yellowing, "firing" or drying of leaf margins, sheath spots (Figure 3), and petiole blights. Rots of the sheath and petiole interfere with water movement to the leaf, causing water stress and producing dry leaf edges. As rots of the sheath expand, less water moves up to the leaf blade, and leaves become yellow. Eventually the leaves die, resulting in premature loss of older leaves (Figure 4). Less frequently, the fungus causes brown, oval spots of varying sizes up to 9.5 by 19 mm (3/8 by 3/4 inch) (Figures 5, 6). The photosynthetic or food-producing capacity of the diseased plants is reduced by multiple sheath and petiole infections followed by leaf loss. Foliage loss and root rots (discussed below) cause large, vigorous plants with high productivity to decline in a few years and become small, weak plants with poor flower production. Severely diseased plants of susceptible cultivars are killed.

Biology and spread. *Calonectria spathiphylli* has been isolated from diseased heliconia throughout the state. This common pathogen attacks *Heliconia* species and cultivars such as *H. angusta* cv. Holiday (formerly 'Red Christmas'), *H. bihai* cv. Kamehameha and cv. Lobster Claw One (formerly *H. jacquinii*), *H. caribaea* cv. Purpurea (formerly 'Red Caribaea' or 'Red Caribe'), *H. indica* cv. Spectabilis (formerly *H. illustris* var. *rubricaulis*), *H. mutisiana, H. psittacorum* cv. Parakeet, *H. psittacorum* x *H. spathocircinata* cv. Golden Torch (known as 'Parrot' in Hawaii), *H. stricta* cv. Dwarf Jamaican and cv. Fire Bird, and *H. wagneriana* (known in Hawaii as 'Rainbow', 'Avenue', 'Elongata', 'Easter', and 'Easter Egg Flower').

In Hawaii, *Calonectria spathiphylli* is also a highly destructive pathogen of many cultivars of spathiphyllum. In Florida, besides heliconia and spathiphyllum, this pathogen has been found on *Strelitzia nicolai* (white bird-of-paradise tree) and *Ludwigia palustris* (water purslane) (El-Gholl et al. 1992).

Calonectria also produces microsclerotia which are compact aggregates of fungal cells. These aggregates are survival structures that allow the fungus to persist in the soil for many months to years without the host.

Nomenclature. In its life cycle, *Calonectria* has an asexual stage that produces spores or conidia (Figure 7). This asexual stage is referred to as *Cylindrocladium*. A pathogenic (disease causing) fungus was discovered in Hawaii on rotting heliconia in the late 1980s (Uchida et al. 1989). Based on the characteristics of the asexual stage, the fungus was identified as *Cylindrocladium spathiphylli*. The shape and size of the asexual spores were similar to *C. spathiphylli* discovered on spathiphyllum in Hawaii during the early 1980s (Uchida 1989; Uchida and Aragaki 1992). Subsequently, mating studies showed that *Cylindrocladium* from spathiphyllum and heliconia would produce the sexual stage when certain pairs were grown together (El-Gholl et al. 1992). The fruiting bodies and spores of the sexual stage (ascospores) are characteristic of the genus *Calonectria*. Thus, *Calonectria spathiphylli* is now recognized as the fungus from heliconia and spathiphyllum.

Bipolaris incurvata and other *Bipolaris* species

Disease and symptoms. *Bipolaris* causes leaf spots (Figure 8) and large rots (Figure 9) of the leaf (referred to as blights). The disease begins as small, water-soaked flecks and spots. The fungus continues to grow in the leaf tissue, and the spots enlarge. After two weeks, many spots are 9.5 to 35 mm (3/8 to1 3/8 inch) in diameter, oval or irregular in shape, and are yellowed around the spot. The spots are light brown with a darker edge. Holes form on the leaf as diseased tissue falls out (Figure 10). Leaf blisters, an unusual symptom, also are formed on the under-surface of the leaf in wet weather. The petiole, sheath (Figure 11), and floral bracts (Figure 12) also are spotted with faint brown to purplish-red spots. Spotting of floral bracts makes flowers unmarketable.

Infections of young leaves result in deformed, blighted mature leaves. In advanced stages of the disease, leaves become tattered and brown.

Biology and spread. *Bipolaris incurvata* has been the most commonly encountered species on diseased heliconia. Other species such as *B. cynodontis, B.*

salviniae, and *B. setariae* have been isolated also (Uchida and Aragaki, unpublished).

Heliconia stricta cv. Dwarf Jamaican, *H. orthotricha, H. chartacea*, and *H. mutisiana* are susceptible to *Bipolaris* species (Uchida and Aragaki, unpublished). With further testing, many other susceptible cultivars are likely to be identified. Various *Bipolaris* species commonly occur on grasses, causing severe diseases of corn, rice, wheat, oats, and sorghum. In Hawaii, *Bipolaris* species cause significant diseases of corn, turf, and palms. *Bipolaris setariae* and *B. incurvata* are frequently found on grasses surrounding heliconia fields (Uchida and Aragaki, unpublished). In addition, they have been isolated from diseased orchids, bromeliads, proteas, and other plants.

With continuous moisture for at least 24 hours, spores of these fungi (Figure 13) are produced on the surface of diseased tissue. Wind and splashing water move spores to healthy leaf surfaces. Movement of foliage and contact with diseased leaves during field operations also agitate plants, causing spore dispersal. Given moisture, the spores germinate, penetrate the leaf surface, and initiate new spots. *Bipolaris* spores are dark colored and frequently have thickened walls, two characteristics that aid fungal survival.

Exserohilum rostratum

Disease and symptoms. Leaf spots caused by *Exserohilum rostratum* are similar to those caused by *Bipolaris*. Typical spots are oval and brown with slightly yellow borders. The spots expand into larger blights that kill parts of the leaves.

Biology and spread. *Exserohilum* has been isolated from diseased 'Dwarf Jamaican' and other diseased plants such as *Chrysalidocarpus lutescens* (the common areca palm), orchids (Uchida and Aragaki 1979), and grasses (Uchida and Aragaki, unpublished). *Exserohilum rostratum* is distributed world-wide and is common on the grass family. As with *Bipolaris, Exserohilum* spores are produced in moist environments on the surface of diseased leaves and are spread by wind and splashing water. Its biology is similar to *Bipolaris*.

Pyriculariopsis sp.

Disease and symptoms. Leaf spots caused by *Pyriculariopsis* begin as very small yellow areas with brown centers (Figure 14) and are concentrated on and along the midrib. A few to several hundred may occur along the midrib, enlarging to large brown spots (Figure 15) and killing adjacent leaf tissue (Figure 16). Large apical sections of leaves are killed (Figure 17), and leaf loss occurs with heavy infections. One-half or more of the leaf blade is commonly killed by these fungal invasions of the midrib. Less commonly, brown leaf spots develop on the leaf blade and induce chlorotic streaking.

Biology and spread. This is the first record of this fungus in Hawaii and the first record of this fungus as a pathogen of heliconia (Uchida and Kadooka 1994). The pathogen was isolated from *Heliconia angusta* cv. Yellow Christmas and also causes spots on *H. mutisiana.* Elsewhere, another *Pyriculariopsis* species has been found on banana.

Many fungal spores are produced on diseased leaves (Figure 18). Water or wind movements spread spores to other leaves, especially when the disease occurs high in the canopy of mature plants.

Mahabalella sp.

This fungus was isolated from leaf spots of *H. orthotricha* on the island of Hawaii. A rare fungus, it has been collected from bamboo in India. This is the first record of this fungus in Hawaii (Aragaki and Bushe, unpublished).

Cercospora and Pseudocercospora sp.

Disease and symptoms. These fungi are characteristically slow growing and cause diseases that develop over a long period of time. Initially, spots are pinpoint-size and then gradually become raised. These tiny spots can occur in very large numbers or in clusters, giving the appearance of physiological damage or a nutritional problem. Individual spots are olive-green to brown (Figure 19), and wide bands of yellow surround large groups of spots. Spots are frequently clustered along the midrib or on the larger lateral veins. Yellow bands extend from the midrib toward the leaf edge (Figure 20).

After many months, larger brown spots or blight develop (Figure 21). Fungal conidia or spores are formed on these older lesions.

Biology and Spread. Species of *Cercospora* and *Pseudocercospora* are known to infect almost every plant family. *Cercospora* and *Pseudocercospora* species have been isolated from leaf spots of *H. psittacorum* cv. Andromeda, *H. collinsiana, H. farinosa, H. bihai* cv. Lobster Claw Two, and *H. wagneriana* (Aragaki, Bushe, and Uchida, unpublished). These pathogens also occur on foliage plants such as schefflera, dracaena, and

Figure 1. *Heliconia bihai* cv. Lobster Claw One. Type of flower or inflorescence is erect and distichous in arrangement (bracts are upright and in two vertical rows).

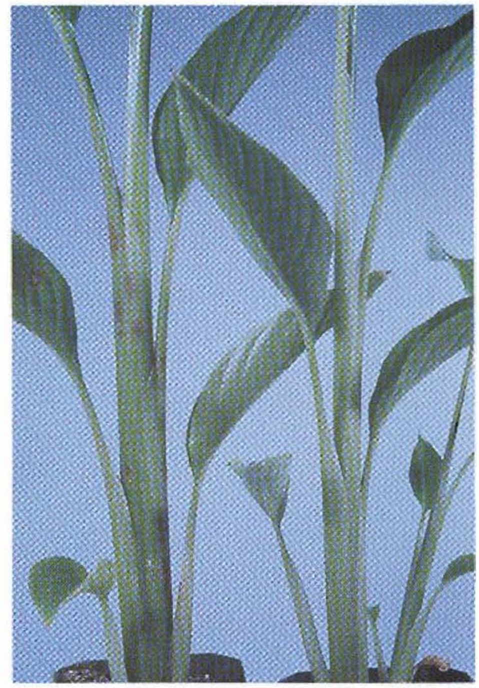

Figure 3. Sheath spots on *Heliconia caribaea* inoculated with *Calonectria spathiphylli* (left); healthy control plant (right).

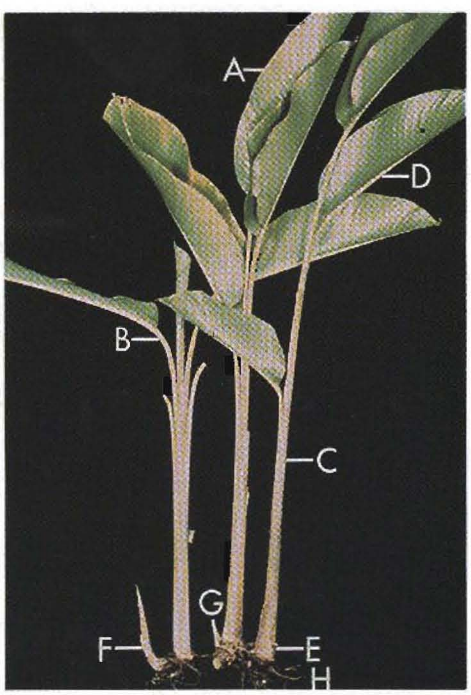

Figure 2. Heliconia habit: A. leaf blade; B. leaf petiole; C. leaf sheath; D. leaf midrib; E. "stem"; F. "eye" or new shoot; G. rhizome; H. roots.

Figure 4. Premature loss of *Heliconia mutisiana* leaves from leaf and petiole blights caused by *Calonectria spathiphylli*.

Figure 5. Small leaf spots caused by *Calonectria spathiphylli* on *Heliconia mutisiana*.

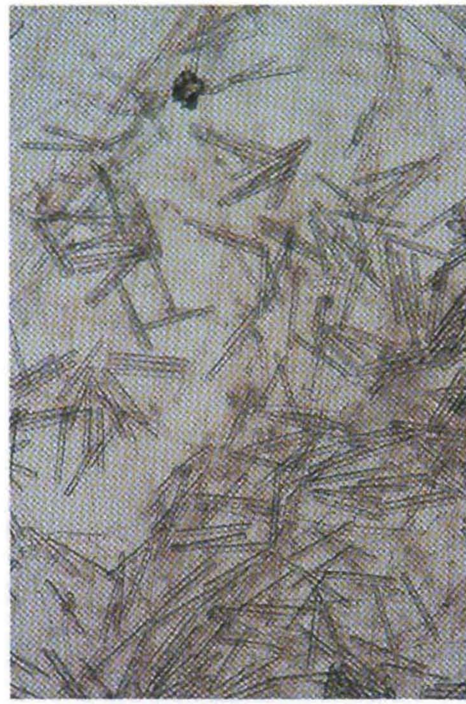

Figure 7. Photomicrograph of conidia or asexual spores of *Calonectria spathiphylli*. The conidial state is referred to as *Cylindrocladium spathiphylli*.

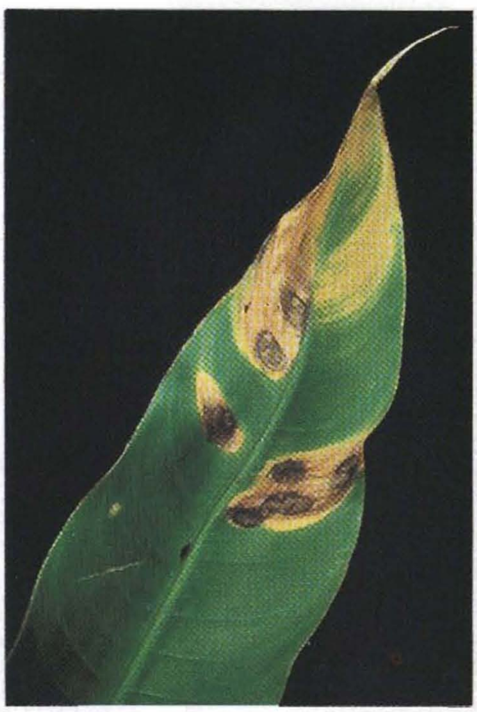

Figure 6. Large leaf spots caused by *Calonectria spathiphylli* on *Heliconia mutisiana*.

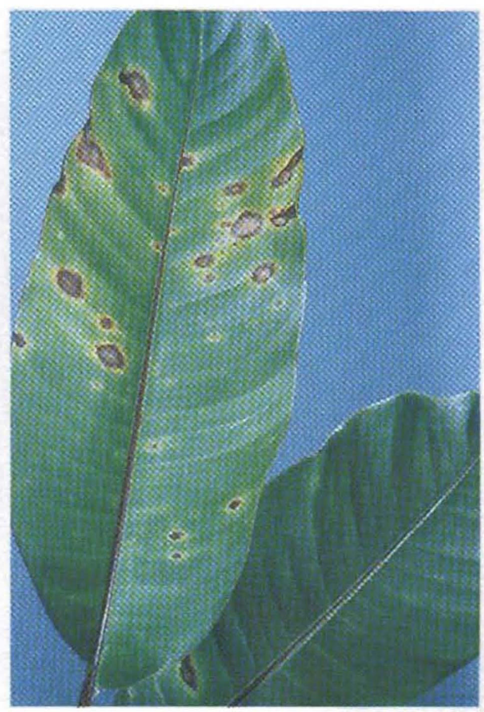

Figure 8. Leaf spots caused by *Bipolaris incurvata* on 'Dwarf Jamaican'.

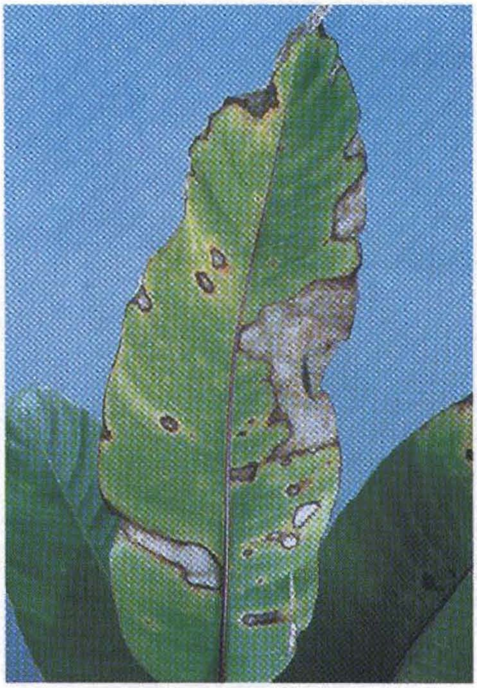

Figure 9. Leaf blight and spots caused by *Bipolaris incurvata* on 'Dwarf Jamaican'.

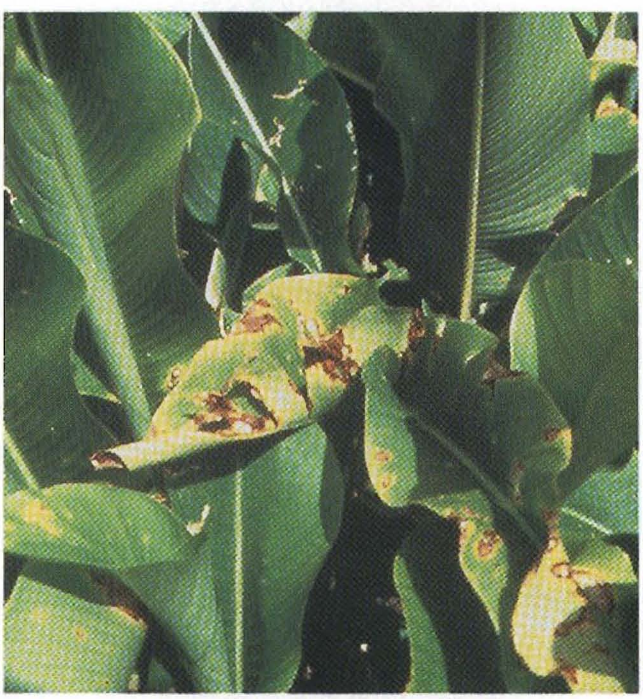

Figure 10. Leaf holes caused by the loss of diseased tissue, formed following infection by *Bipolaris incurvata*.

Figure 11. Sheath spots caused by *Bipolaris incurvata* on 'Dwarf Jamaican'.

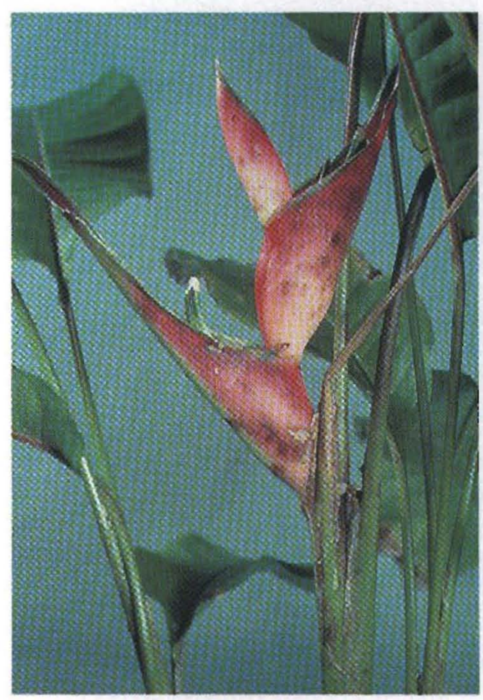

Figure 12. Spots on floral bracts of 'Dwarf Jamaican' caused by *Bipolaris incurvata*.

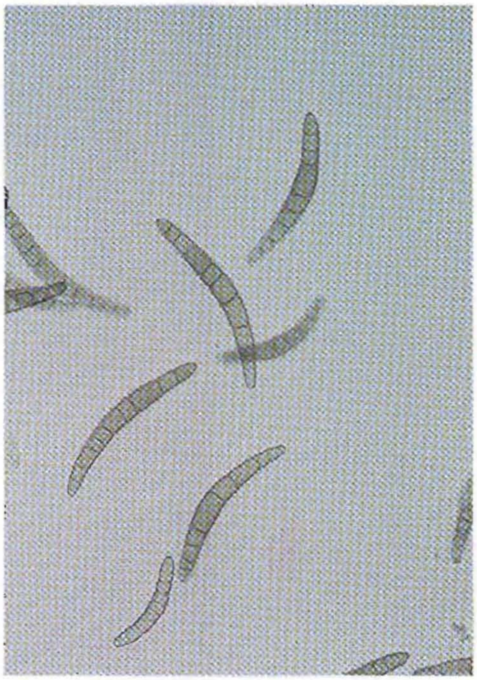

Figure 13. Photomicrograph of conidia (spores) of *Bipolaris incurvata*.

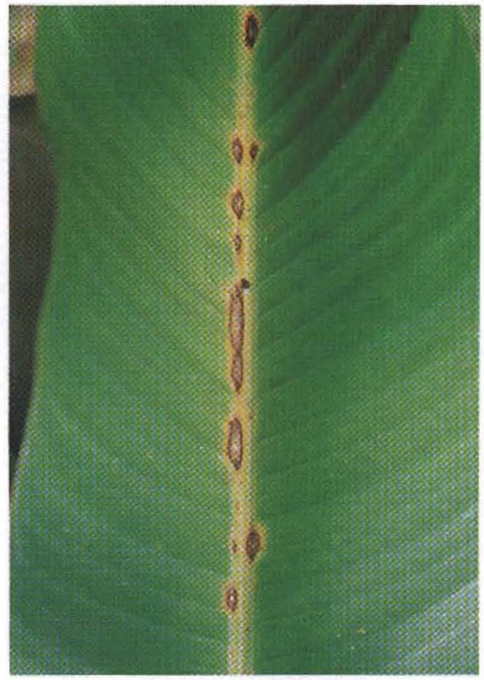

Figure 15. Brown lesions on the midrib of *Heliconia flava* leaf caused by *Pyriculariopsis*.

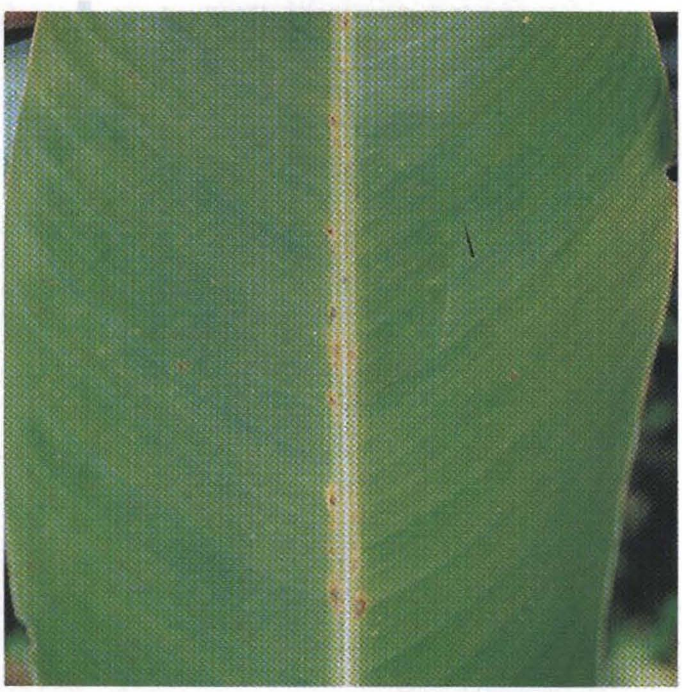

Figure 14. Small leaf spots and faint yellowing caused by *Pyriculariopsis* on *Heliconia flava*.

Figure 16. Severe *Pyriculariopsis* infection of the midrib and loss of the apical tip of this *Heliconia flava* leaf.

Figure 17. Typical *Pyriculariopsis* symptoms on *Heliconia flava* in the field.

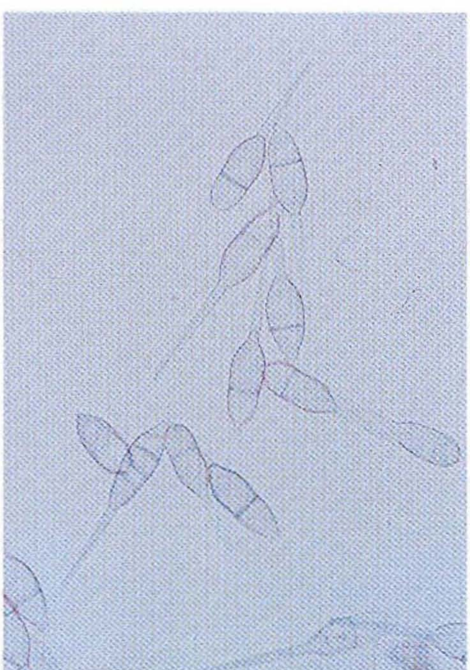

Figure 18. Photomicrograph of conidia (spores) of *Pyriculariopsis*.

Figure 19. Early stage of *Cercospora* leaf blight on *Heliconia psittacorum* cv. Andromeda.

Figure 20. Clusters of *Cercospora* spots surrounded by yellow (chlorotic) tissue on cv. Andromeda leaves.

Figure 21. Yellow to reddish brown blights of cv. 'Andromeda' leaf caused by *Cercospora*.

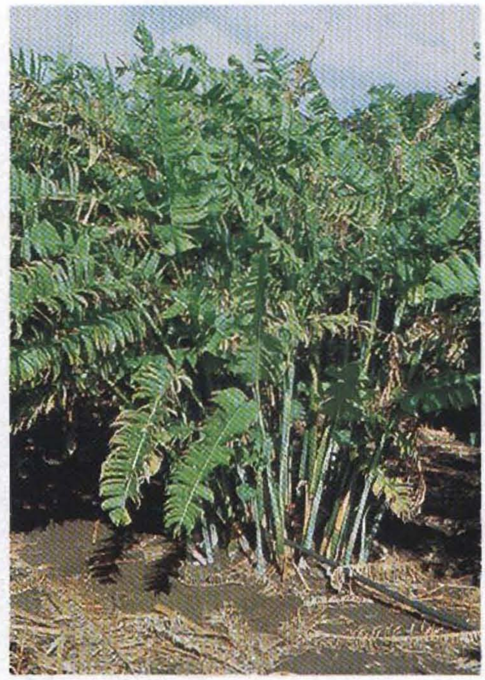

Figure 23. Healthy stand of *Heliconia chartacea* grown at low elevation.

Figure 22. Severe root loss and death of heliconia shoots caused bv *Calonectria*.

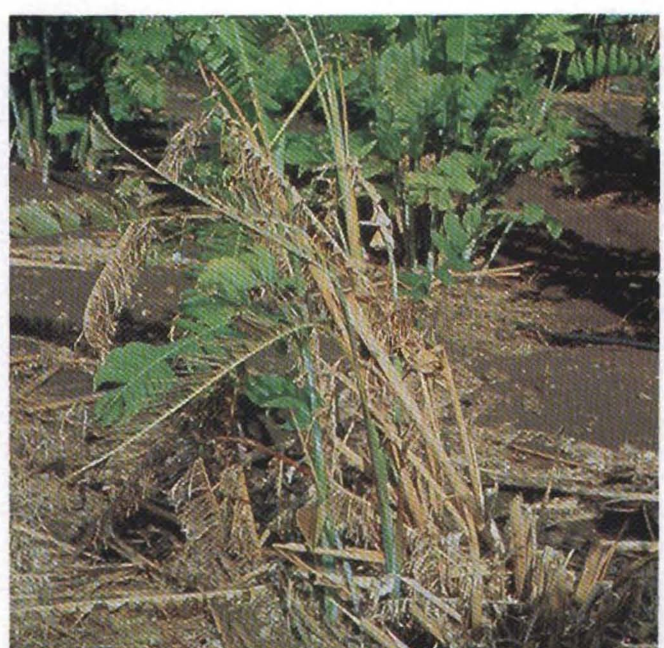

Figure 24. *Heliconia chartacea* plants destroyed by *Phytophthora* root and rhizome rots.

Figure 25. Stem and rhizome rot caused by *Phytophthora*.

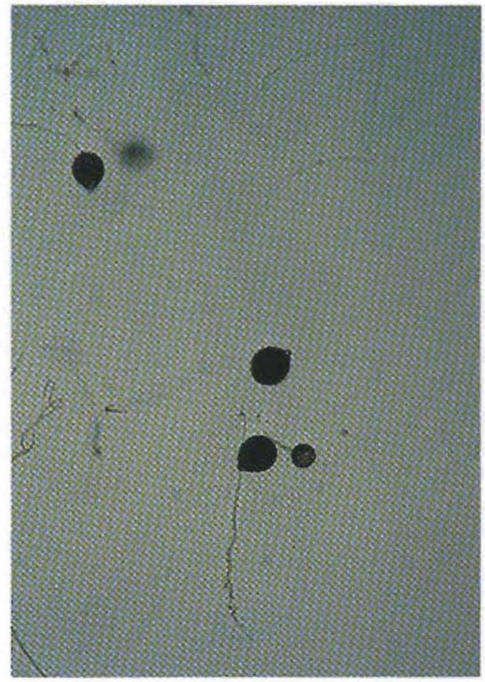

Figure 27. Photomicrograph of sporangia of *Phytophthora nicotianae*.

Figure 26. Internal stem section of heliconia shoots infected with *Phytophthora*.

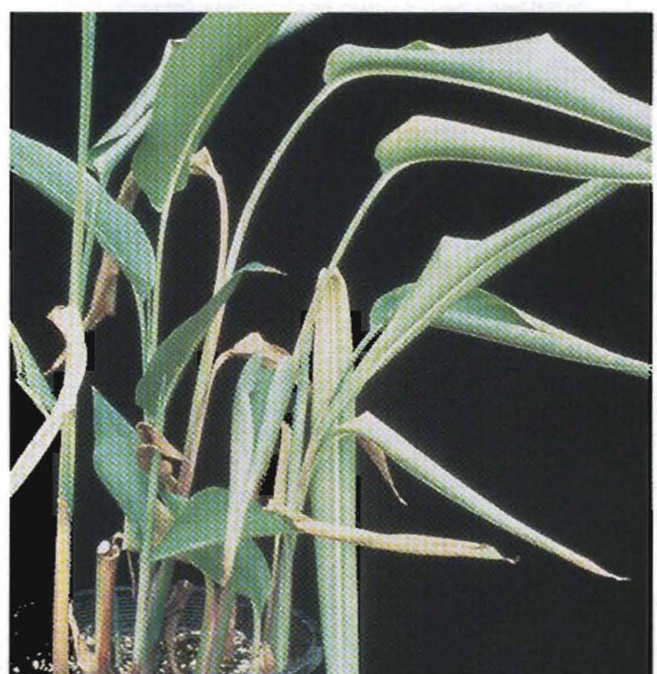

Figure 28. *Heliconia psittacorum* plants infected with *Pseudomonas solanacearum* exhibiting leaf rolling and wilting.

Figure 29. ***Heliconia psittacorum*** **plants infected with** ***Pseudomonas solanacearum*** **exhibiting leaf margin firing (browning of edges).**

Figure 31. ***Heliconia psittacorum*** **with dark brown vascular tissue in the center of a longitudinally cut rhizome infected with** ***Pseudomonas solanacearum.***

Figure 30. Brown leaf symptoms and shoot dieback on ***Heliconia psittacorum*** **caused by** ***Pseudomonas solanacearum.***

Figure 32. Lodging (falling over) caused by ***Calonectria*** **and nematode root rots.**

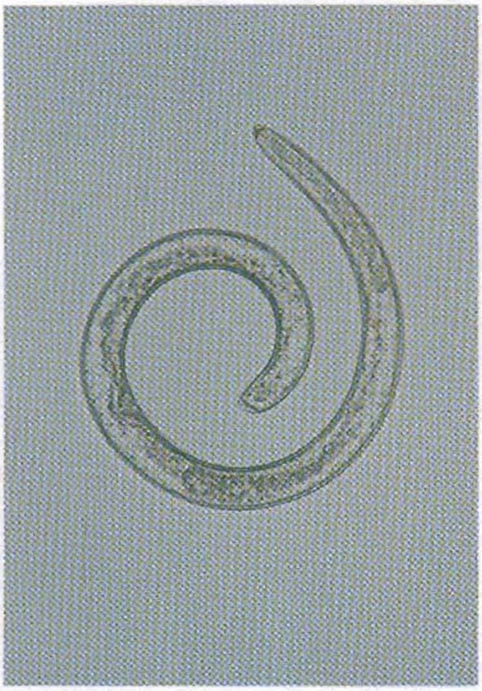

Figure 33. Photomicrograph of the spiral nematode, *Helicotylenchus* sp.

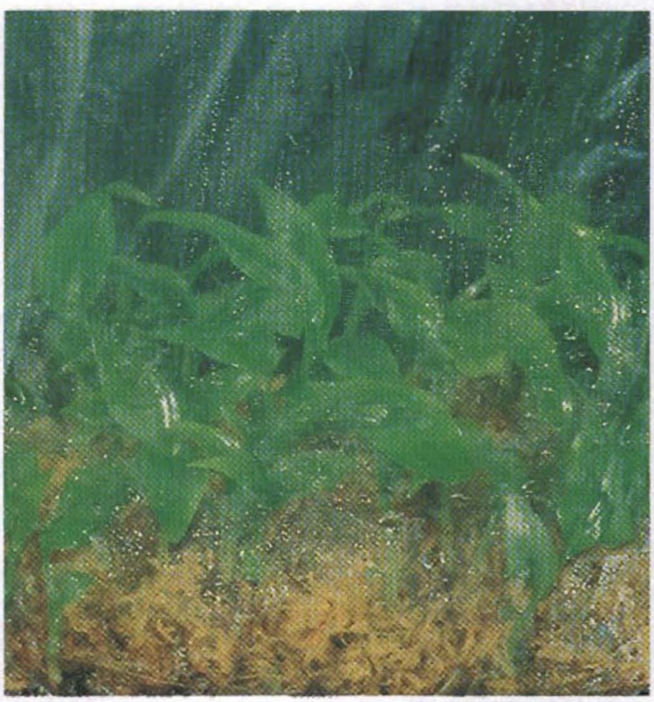

Figure 34. Seedlings of *Heliconia mutisiana* grown from seeds collected on Oahu.

Figure 35. Heliconia planting material (left) and trimmed, clean rhizome (right).

Figure 36. Plant growth stages (left to right): rooted, clean rhizome with new shoot; healthy growth continuing 3 months after planting; well established, clean plants formed about 8–9 months after planting.

Figure 37. Rat-feeding damage on the floral bracts of heliconia.

Figure 39. Pig-feeding damage to heliconia "stem" just above soil line.

Figure 38. Extensive pig damage to a heliconia stand.

Figure 40. Heliconia rhizome that has been trimmed and scrubbed, with discolored areas removed before hot water treatment for nematode control.

philodendron; on palms such as *Rhapis, Howeia* (sentry palm), and coconut; on food crops such as beans, beets, carrots, celery, eggplant, peanut, pepper, potato, tomato, and yam; on fruits such as papaya, banana, and citrus; and on forage crops such as alfalfa.

Small, needle-shaped spores of these pathogens are spread by wind and may be carried by insects. Prolonged periods of wet weather favor pathogen sporulation and disease spread. Similar to other diseases caused by these slow-growing pathogens, several weeks to months may pass before newly infected leaves develop symptoms.

Rhizome and Root Diseases Caused by Fungi

Calonectria spathiphylli

Disease and symptoms. This fungus is presently the most widely spread pathogen attacking roots and rhizomes of heliconia in Hawaii. Severe root and rhizome rots (Figure 22) kill plants or cause rapid plant decline. Root and rhizome rots of field heliconia start at the center of clumps with old diseased stalks, which are dry and collapsed, and develop outward. New growth is the healthiest, and diseased clumps of heliconia have empty circles within the older diseased growth. Root rots prevent proper anchorage, and taller diseased heliconia cultivars are prone to toppling.

Biology and spread. *Calonectria* infects roots and rhizomes of heliconia and can be found deep within the rhizomes in infected root traces that originate from severe root rots.

Fungal spores and microsclerotia move into a field with water (e.g., run-off). The pathogen also moves in infested or contaminated soil, especially in mud adhering to trucks, plows, other field equipment, tools, boots, etc. The fungus is also transported when infected rhizomes are moved to new fields.

Phytophthora nicotianae

Disease and symptoms. *Phytophthora nicotianae* has been isolated from rotted roots and rhizomes of *H. caribaea* (Ogata and Uchida, unpublished). Healthy, vigorous plants gradually decline over one to three years and then produce few flowers (Figures 23, 24). The disease has been found on Kauai and Oahu. *Heliconia mutisiana* appears to be highly tolerant of *P. nicotianae* (Aragaki and Uchida, unpublished).

Diseased stems have brown rots at the collar and are surrounded by rotted roots (Figure 25). Within the stem, the rot is blackish-brown (Figure 26).

Biology and spread. In Hawaii, *P. nicotianae* causes diseases of numerous crops. These include papaya, orchid, vegetables (tomato, pepper, eggplant, etc.), herbs (parsley, thyme, sage, rosemary, etc.), ornamentals (spathiphyllum, hibiscus, African violet, poinsettia, gerbera, etc.), palms, pineapple, and many other plants. This pathogen is generally nonspecific, and cross infection can occur between different hosts.

Phytophthora species produce specialized spores called sporangia (Figure 27) which release 20 or more swimming spores when water is abundant. These motile spores aid pathogen movement from one part of the plant to another or over longer distances through irrigation ditches, run-off, and streams. Spherical chlamydospores with thickened walls are formed in diseased tissue. These specialized spores allow the fungus to survive without the host for many months. Contact with spores on diseased plants or movement of infected tissues also transport the pathogen.

Pythium species

Disease and Symptoms. Several *Pythium* species have been isolated from diseased heliconia roots and rhizomes. These include *P. splendens, P. aphanidermatum, P. myriotylum,* and others. The role of these organisms needs to be investigated further. To date, *P. splendens* appears to be pathogenic, with disease developing slowly over a three- to four-month period (Aragaki and Uchida, unpublished). Root rot and slow decline of the plants are primary symptoms.

Biology and spread. *Pythium* species have been found on the cultivars 'Bengal', *Heliconia indica* cv. Spectabilis, and *H. psittacorum*. *Pythium* species have been isolated from many agricultural and landscape plants around the world. In Hawaii, important diseases caused by *Pythium* are root rots of taro, macadamia, papaya, orchids, vegetables, dracaena and other foliage plants, alfalfa and other legumes, turf, and more.

Moisture and poor drainage greatly favor diseases caused by *Pythium*. Like *Phytophthora*, most *Pythium* species produce motile spores which distribute the fungi over greater distances. Other spores, such as oospores, have thickened walls which enable the fungus to survive long periods within the dead plant tissue or in the soil. The pathogen is transported to new locations by the movement of contaminated soil and water or infected plants.

Rhizoctonia solani*-like fungi and *Rhizoctonia solani

Disease and symptoms. *Rhizoctonia solani*-like fungi have been recovered from rotting roots of *H. bihai* cv. Lobster Claw One and *H. caribaea* (Uchida, unpublished). Although frequently associated with diseased plants, these fungi are generally considered weak pathogens, and pathogenicity tests are needed to determine the role of these organisms on heliconia.

Rhizoctonia solani is one of the most common pathogens occurring throughout the world. Almost every crop is affected by *R. solani* or other *Rhizoctonia* species. In Hawaii, *R. solani* causes root rots of many legumes, papaya, alfalfa, and foliage plants; fruit and root rots of tomato, bean, and cucumber; and web blights (massive rots) of poinsettia cuttings, ornamentals, and herbs. World-wide, *R. solani* causes major losses in potato, vegetables, cereals, and numerous ornamentals.

Other Fungi Associated with Heliconias

Other fungi have been recovered from heliconia in addition to those described above. The ability of these fungi to cause disease on heliconia is not known, and continued research is needed. These fungi are listed here for documentation purposes and include *Colletotrichum* spp., *Pestalotiopsis* sp., *Phyllosticta* sp., *Phomopsis* sp., *Acremonium* sp., and *Fusarium* spp.

Disease Caused by Bacteria

Pseudomonas solanacearum

Disease and symptoms. The bacterial wilt pathogen *Pseudomonas solanacearum* causes foliar symptoms that include leaf rolling and wilting (Figure 28), leaf margin firing (browning of edges) (Figure 29), and eventual dieback of the shoot (Figure 30). Leaves curl initially due to water stress caused by vascular plugging following infection of roots and rhizomes. As the disease advances in the rhizome, drying and browning of leaf edges occurs, followed by formation of large patches of necrotic tissue towards the midrib. Usually, these symptoms are more pronounced on older leaves. Eventually, the entire leaf turns dark brown with an oily appearance, resulting in leaf loss. Within the rhizome, a dark brown discoloration of the vascular tissue runs longitudinally down the center (Figure 31). Often, a milky ooze is associated with this brown vascular discoloration.

Biology and spread. *Pseudomonas solanacearum* survives in plant parts and many weed hosts. As diseased plants die and decompose, bacteria are released into the soil, where they can then spread by the movement of infested soil and water through fields. The bacteria can spread rapidly, especially in high-rainfall areas where surface run-off is common. It can spread quickly within the crop rows because of high-density planting practices. Field-to-field spread also occurs by transplanting infected rhizomes into clean fields. Infection occurs through plant wounds or natural openings.

In Hawaii, *Pseudomonas solanacearum* has been identified on *H. psittacorum* and *H. rostrata* (Ferreira et al. 1991).

Root Diseases Caused by Nematodes

Nematodes are microscopic roundworms that inhabit the soil and feed on plants and animals. Nematodes differ from segmented worms (such as earthworms) in morphology, anatomy, and life cycle. Plant-parasitic nematodes cause diseases such as leaf rots, root or rhizome rots, flower or bulb rots, and seed damage.

Disease and symptoms. The major disease symptoms are brown, rotted roots, swollen roots or root knots, and root lesions. Nematode infections of roots may occur alone but sometimes are accompanied by pathogenic fungi such as *Calonectria spathiphylli, Rhizoctonia* spp., and *Pythium* spp. Although the relationship between nematodes and fungi on heliconia roots is not well understood, nematode-fungus relationships are known to cause diseases in other crops.

Plants with roots infected by nematodes exhibit symptoms similar to those caused by water stress and nutrient deficiency. These symptoms include yellow leaves, excessive leaf curling and wilting, and poor growth rate. With severe nematode infections accompanied by *Calonectria spathiphylli*, plants will topple over or fall with minor wind movement because of insufficient anchorage (Figure 32).

Biology and spread. Nematodes recovered from heliconias include the burrowing nematode (*Radopholus similis*), a root-knot nematode (*Meloidogyne* sp.), a lesion nematode (*Pratylenchus* sp.), the reniform nematode *Rotylenchus reniformis*, and a spiral nematode (*Helicotylenchus* sp.) (Figure 33). The burrowing, root-knot, and lesion nematodes are endoparasites that enter the host plant and feed within the roots. In the case of the root-knot nematode, the female becomes stationary in the plant and initiates gall formation. Other species move more freely within the plant or move about in the soil, feeding on roots without becoming attached to them.

Nematodes have been recovered from roots of *H. angusta* cv. Yellow Christmas; *H. farinosa* cv. Rio; *H. chartacea* cv. Sexy Pink; *H. stricta* cv. Bucky; *H. caribaea* cv. Purpurea; *H. psittacorum* cv. Andromeda; *H. rostrata*; and more (Sewake and Ogata, unpublished).

Most nematodes complete their life cycle from egg to larvae to adult in about three to four weeks given proper soil temperature, moisture, and aeration. If environmental conditions are not suitable for development, eggs can remain dormant for years, and larvae of some species can remain quiescent for long periods.

Nematodes are not very mobile in soil and move slowly within the soil solution that surrounds soil particles. They are spread greater distances by movement of soil on farm equipment and tools, surface water runoff, and infected plant propagation materials.

Fungal Disease Cycles and Control

In a typical fungal disease cycle, the pathogen produces spores or other propagules that are spread by various means to healthy plants. These spores germinate, producing fungal hyphae (strands or threads) which then infect the plant. In a susceptible plant, the fungus grows and feeds on the plant by releasing enzymes and absorbing nutrients released from damaged plant cells. The growth of the fungus and the plant damage it causes by its metabolic processes are seen as disease symptoms, i.e., spots, rots, etc. The pathogen continues to grow and produce new spores which repeat this cycle. This may occur as soon as a few weeks after infection or many months later. The sexual stage frequently increases the range of disease spread, since ascospores are forcibly discharged into the air, becoming wind-borne. Asexual spores formed early in the disease cycle may also be wind-borne but are primarily spread by splashing water.

All effective disease control methods interfere with one or more elements of this disease cycle. Some of the objectives of disease control are to prevent infection, to prevent pathogen growth after infection, to reduce pathogen movement in the plant, to reduce or eliminate sporulation, and to reduce pathogen level in the environment. These control measures are discussed below.

1. Prevention. Clean seed and clean rhizomes will prevent the introduction of pathogens to commercial nurseries. Few heliconias are propagated by seed, but for those for which seed is available, even in very small quantities, a unique opportunity exists for the establishment of clean stock (Figure 34). Seeds collected fresh from the field are generally free of pathogens. The fruits should be washed, rinsed, and dipped in a dilute household bleach solution (10–20 percent bleach in water) for one minute. Set aside all blemished or rotted fruit. Inspect the seeds for signs of rot, and keep only healthy seeds. Remove the pulp from clean fruits, rinse the seeds, and plant them in moist pasteurized sphagnum moss.

Procedures for producing clean rhizomes are as follows: Wash rhizomes well, remove all brown sheath tissue and all roots, and trim the outer layer of the rhizome (Figures 35). Dip in 10–20 percent household bleach for one minute. Plant the cleaned rhizome in clean media (Figure 36).

2. Moisture control. In general, moisture is needed for fungal sporulation, spore dispersal, spore germination, and penetration of the fungus into the leaf. For most tropical diseases, the rate at which the fungus grows in the plant (or the rate at which the disease develops) depends on moisture. In general, high moisture favors pathogen growth, especially for those diseases caused by *Pythium, Phytophthora, Bipolaris*, and some *Cercospora* species. Because moisture is so critical to the establishment and progress of disease, controlling moisture will decrease disease levels. Some moisture control suggestions are as follows:

A. Grow seedlings and clean rhizomes under solid cover (polyethylene film, fiberglass, solid plastic, etc.).

B. Increase air movement within the field. Adjust row direction to produce the best air flow based on wind direction and terrain. Remove dead plants and old leaves to eliminate damp areas. Keep weeds low.

C. Prepare the field along contour lines that will provide good drainage, avoiding patterns which pond or pool water. Areas with poor drainage are highly conducive to *Pythium* or *Phytophthora* rots.

3. Sanitation. Keeping the greenhouse or field free of diseased plants will reduce or eliminate pathogens. Severely diseased leaves in the field harbor pathogens and are a source of pathogen spores. Fungi survive in diseased plant tissue and persist in the environment for many months. Removal of pathogen sources will reduce possibilities of continuing the disease cycle.

Soil from fields with diseased heliconia may contain pathogen spores or plant tissue containing the pathogen. All field equipment should be washed before moving to a clean field to minimize transporting of pathogens through soil movement. This includes bulldozers, jeeps, and trucks and all tools such as shovels, hoes, picks, and sickles.

4. Organic matter. Adding organic matter to the field generally reduces the severity of root rots. Organic matter provides nutrients and aeration, promotes good drainage, and increases microbial competition. All of these factors can reduce pathogen growth. In some cases, microorganisms inhibit each other, either by micro-parasitism or through competition for nutrients. Incorporating organic matter before the field is first planted or adding organic matter to established fields may reduce root rots in heliconia, especially if the established field is declining severely from root and rhizome rots.

5. Host resistance. Host resistance uses the ability of the host plant to prevent disease. It is therefore the most economical and best method to control disease, but it usally takes a long time to develop. For many commercially important crops that have been in cultivation for a long time, researchers have identified sources of disease resistance and have added these genes to the plants. Today, biotechnological techniques that allow the transfer of genes from one plant species to another may hasten the development of new crops resistant to serious diseases.

6. Chemical control. Many chemical pesticides that inhibit or reduce the growth of fungal pathogens have been developed for agricultural crops. Broad-spectrum fungicides such as mancozeb are effective against *Bipolaris, Pseudocercospora, Exserohilum, Phytophthora,* and others. Metalaxyl is effective against *Phytophthora* and *Pythium.* Check with your local Cooperative Extension Service office for new fungicides available for use on heliconia and follow the pesticide label directions.

7. Insect and pest control. Snails, slugs, insects, rodents (Figure 37), and other animals such as pigs (Figures 38, 39) will transport spores of fungal pathogens. Large animals such as pigs easily track soil-borne spores from diseased to clean fields. Insects and slugs also carry pathogens because of the microscopic size of fungal spores. Thus, populations of these pests in fields and on plants should be kept to a minimum.

Bacterial Disease Control

Control measures described in the fungal disease control section also pertain to control of bacterial diseases, with the exception of chemical control. Unlike fungal diseases, bacterial diseases are seldom adequately controlled by chemicals. Prevention and sanitation are the keys to controlling bacterial diseases.

Although heliconia is affected by the bacterium *Pseudomonas solanacearum*, it is helpful to understand the specific bacterial control procedures used for anthurium blight caused by *Xanthomonas campestris* pv. *dieffenbachiae.* The general prevention and sanitation control procedures are similar for both heliconia and anthurium, regardless of the bacterial organism. Anthurium blight control recommendations are published in the *Proceedings of the Second Anthurium Blight Conference* (Nishijima 1989) and in *Common Mistakes in Anthurium Blight Control Practices* (Sewake et al. 1990). These publications discuss anthurium propagation and establishment for the production of disease-free plants, preparation of beds for planting, prevention of disease establishment in fields, and prevention of intra-field spread. These procedures can be adapted to control bacteria in heliconias.

Of foremost importance is the ability of *Pseudomonas solanacearum* to survive for long periods in soil and in many weed hosts. The bacterium moves with soil or water movement. Therefore, control measures should include immediate rogueing of infected plants or killing them with herbicide and keeping that area undisturbed. The adjacent areas should also be plant-free for several months. Water run-off should be prevented by covering the ground with a tarp and diverting water flow away from contaminated areas. Heliconias can probably be replanted using disease-free plants following 6 to 12 months or more of weed-free fallow.

Nematode Control

In native, endemic vegetation, serious pathogens such as the burrowing nematode are not likely to be present. Thus, the establishment of new heliconia fields with clean rhizomes is crucial. Some guidelines for heat treatment of diseased heliconia rhizomes can be adapted from those for the control of burrowing nematode in banana. For banana, corms are trimmed and all discolored areas are removed. These cleaned corms are placed in hot water held at 50°C (122°F) for 10–15 minutes (Trujillo 1964). For untrimmed heliconia rhizomes, hot water treatment at 50°C (122°F) for 15–30 minutes and immediate dipping into cold water to stop the treatment has been suggested (Criley 1988). The cleaning process used for banana corms may be used for heliconia rhizomes prior to hot water treatment (Figure 40). In certain tropical countries, some banana fields are flooded for five to six months to destroy nematodes and other pathogens. This procedure would have little applicability in volcanic soils but may help in heavy clay soils.

Traditionally, soil fumigation has been used to control many types of nematode diseases. These chemicals are becoming increasingly difficult to register for use and many are now unavailable for agricultural uses. Development of biocontrol strategies is being intensely pursued. Parasites that attack the eggs, larvae, or adults of pathogenic nematodes are being tested in many laboratories, along with new technologies developed to manipulate the complex host-pathogen relationships in ways that reduce susceptibility to disease.

Literature Cited

Berry, F., and W.J. Kress. 1991. *Heliconia*: An identification guide. Smithsonian Institution Press, Washington, D.C..

Criley, R.A. 1988. Propagation methods for gingers and heliconias. Bulletin, Heliconia Society International 3(2):6–7.

El-Gholl, N.E., J.Y. Uchida, A.C. Alfenas, T.S. Schubert, S.A. Alfiere, Jr., and A.R. Chase. 1992. Induction and description of perithecia of *Calonectria spathiphylli* sp. nov. Mycotaxon 45:285–300.

Ferreira, S., K. Pitz, and A. Alvarez. 1991. *Heliconia* wilt in Hawaii. Phytopathology 81:1159.

Hawaii Agricultural Statistics Service. 1992. Hawaii flowers and nursery products annual summary (July).

Nishijima, W.T. 1989. Current anthurium blight control recommendations. In: Proceedings of the Second Anthurium Blight Conference, 1989, Hilo, Hawaii, 7-9. Univ. of Hawaii, HITAHR 03.10.89.

Sewake, K.T., A.F. Kawabata, W.T. Nishijima, and T. Higaki. 1990. Common mistakes in anthurium blight control practices. Univ. of Hawaii, HITAHR Brief No. 091.

Trujillo, E.E. 1964. Clean banana rhizome certification. Hawaii Farm Science 13(4):8-9.

Uchida, J.Y. 1989. *Cylindrocladium* rot of *Spathipyllum*. Univ. of Hawaii, HITAHR Brief No. 078.

Uchida, J.Y., and M. Aragaki. 1979 Etiology of necrotic flecks on *Dendrobium* blossoms. Phytopathology 69:1115–1117.

Uchida, J.Y., and M. Aragaki. 1992. Further characterization of *Cylindrocladium spathiphylli* from *Spathiphyllum* in Hawaii. Mycologia 84:810–814.

Uchida, J.Y., M. Aragaki, and P.S. Yahata. 1989. *Heliconia* root rot and foliar blight caused by *Cylindrocladium*. Univ. of Hawaii, HITAHR Brief No. 085.

Uchida, J.Y., and C.Y. Kadooka. 1994. A new disease of *Heliconia* caused by *Pyriculariopsis*. Phytopathology 84.

Pesticides must be used in accordance with label instructions. Consult the product label to ensure that the desired crop use is included, and comply with state and federal pesticide laws. Mention of a trade or proprietary name does not constitute a guarantee or warranty of the product by the University of Hawaii or its employees and does not imply its approval for use in Hawaii or recommendation of its use to the exclusion of other unmentioned products.

Hawaii residents may order single copies of this publication free of charge from county Cooperative Extension Service offices. Bulk orders or out-of-state inquiries should be sent to the Agricultural Publications Distribution Office, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, 2500 Dole Street, Krauss A-19, Honolulu, Hawaii 96822. Price per copy to bulk users, $2.45 plus postage.

Issued in furtherance of Cooperative Extension Work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Noel P. Kefford, Director and Dean, Cooperative Extension Service, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, Honolulu, Hawaii 96822. An Equal Opportunity / Affirmative Action Institution providing programs and services to the people of Hawaii without regard to race, sex, age, religion, color, national origin, ancestry, disability, marital status, arrest and court record, sexual orientation, or veteran status.

RESEARCH EXTENSION SERIES 159—4/95 (2.5M)