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Nematode and Disease Problems of Pineapple

The pineapple (*Ananas comosus* (L.) Merr.) is grown worldwide for fresh fruit and processing. Pineapple for processing is generally grown as a plantation crop. Pineapple for the fresh fruit market may also be grown on a plantation scale, as in Hawaii, but frequently is grown by small farmers and sold at local fruit and vegetable markets typical of developing countries.

Hawaii was at one time the major commercial production area, but the planted hectarage has declined in recent years. Production has increased in the Philippines, Thailand, Kenya, Honduras, and Costa Rica to more than compensate for declines in Hawaii. Land areas planted to pineapple have remained constant or declined in South Africa, the Ivory Coast, Taiwan, Malaysia, and Australia.

The pineapple plant has three botanical characteristics that may contribute to its disease and nematode problems (7). First, roots originate adventitiously (Fig. 1) and do not regenerate if killed to the stem. As the stem grows, roots continue to originate in the leaf axils. Only roots that contact the soil at planting are functional for soil nutrients, moisture, and anchorage of the plant. Second, the fruit originates from 100–200 individual florets that develop acropetally. Thus, a single fruit has florets and fruitlets in markedly different stages of development (Fig. 2). Third, the plant is essentially a xerophyte and will survive extended periods of drought. Uniform moisture is required for good growth and economic production, however, and excess moisture can result in total loss of the root system if pathogens are present.

In commercial production, pineapple is generally grown as a monoculture crop because of the high capital investment in processing machinery, field equipment, and land. Cultural techniques are remarkably similar wherever pineapple is produced commercially. The crop is vegetatively propagated by crowns, slips, or suckers (seed material) (Fig. 3) inserted a few centimeters into the soil. Fertilizers and herbicides are applied before planting and over the developing plants. When temperature and moisture are favorable, the plants are induced (forced) to flower approximately 1 year after planting by applying a growth regulator such as ethylene or ethephon. The fruit matures 6–7 months later (plant crop). A second crop (first ratoon) and sometimes subsequent crops (additional ratoons) may be obtained at approximately yearly intervals. Since the pineapple plant is a perennial, multiple ratoons require a functional root system. When production becomes uneconomical, often because of loss of the root system, the remaining plant material is disked down and incorporated into the soil, allowed to decompose on the surface, or burned. Nematode, insect, and disease control practices are used only where needed and when economical.

Plant-Parasitic Nematodes

Plant-parasitic nematodes constitute a major limitation to worldwide pineapple production. Damage to pineapple roots is amplified by the nonregenerative nature of the roots. The plant crop yield may be significantly reduced when the root system is damaged, but the ratoon crop may be devastated, with either a drastically reduced yield or total crop failure. The number, size, and vigor of the suckers producing the ratoon crop depend primarily on the health of the initial soil roots produced by the mother plant.

The important nematode genera attacking pineapple on a worldwide basis are *Pratylenchus brachyurus* (Godfrey) Filipjev & Schuurmans Stekhoven (lesion), *Meloidogyne javanica* (Treub) Chitwood (root-knot), and *Rotylenchulus reniformis* Linford & Oliveira (reniform) (8). *P. brachyurus* is the most important nematode in Brazil and the Ivory Coast, *P. brachyurus* and *M. javanica* predominate in South Africa, *M. javanica* is the primary one in Australia (14), and *M. javanica* and *R. reniformis* predominate in Hawaii. Many other nematode genera have been found associated with pineapple roots, but either the degree of pathogenicity has not been demonstrated or the amount of damage has not been significant.

P. brachyurus. Although important in other pineapple-growing areas of the world, the lesion nematode is of limited significance in Hawaii and is found in relatively high numbers on only a small hectarage. *P. brachyurus* feed in the cortex parenchyma, and if the infection is serious and occurs on secondary roots, the roots may be destroyed.

M. javanica. In Hawaii, wherever found, the root-knot nematode is a serious problem on pineapple. Infection takes place at the tips of the primary roots soon after they emerge from the seed piece (a few millimeters to a few centimeters) and usually results in a terminal gall (Fig. 4A). Subsequent infection of lateral roots results in a similar type of gall. Severe infections may lead to an extremely abbreviated root system with limited ability to absorb water and nutrients and to anchor the plant. If such plants are grown under water stress, the growth and yield of the crop will be markedly reduced and the

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ratoon may fail. Without water stress, growth of infected plants may not be as restricted, and the greatest effect will be reduced number and size of suckers and a smaller ratoon yield. In Hawaii, root-knot nematodes are found in well-drained areas of pineapple fields and are seldom evenly distributed over a large hectarage. The nematode appears to be well adapted to the highly acid soils prevailing in Hawaiian culture.

R. reniformis. In 1935, a plant-parasitic nematode later described as *R. reniformis* was observed on the roots of cowpea growing in soil from a pineapple field on the island of Oahu (11). Whether it was endemic or introduced was not determined, but from that initial finding, the reniform nematode has become the most significant nematode pathogen in pineapple culture in Hawaii and is now found on all the major islands. *R. reniformis* feeds on the cortical tissue of the lateral roots and does not appear to seriously affect elongation of the primary roots (Fig. 4B). The soil anchorage of a reniform-infected plant is good compared with that of a root-knot-infected plant. The reniform nematode is frequently found very evenly distributed over a large hectarage.

The development of the reniform nematode problem can be attributed to a number of agricultural practices in the industry over the past 35–40 years. The following practices interacted to change an initial occurrence of reniform nematode into a major limiting factor in Hawaiian pineapple culture:

Monoculture. The reniform nematode readily adapted to pineapple as a host. The practice of monoculture and the use of the single cultivar Smooth Cayenne contributed significantly to the increase and spread of the nematode.

pH. In the early development of the pineapple industry, the soils were slightly acid to neutral. Over an extended period, the industry used ammonium sulfate as a fertilizer and significantly reduced soil pH to 3.5–5.0. Unpublished research at the Pineapple Research Institute of Hawaii shows that the nematode is favored by an acid environment. The optimal pH for reproduction of the reniform nematode in Hawaiian soils is 4.8–5.2. A 10-year liming study at the institute showed that increasing pH to above 6.0 significantly reduces the population of reniform nematodes.

Soil fumigation. In the early 1940s, Walter Carter, working at the Pineapple Research Institute, discovered the soil fumigant D-D (1,2-dichloropropane, 1,3-dichloropropene). The beneficial effect was originally considered to be plant growth stimulation but was eventually shown to be nematode control. Thereafter, ethylene dibromide (EDB), dibromochloropropane (DBCP), and dichloropropene became part of the nematode control program in Hawaii. Soil fumigation enabled successful culture of pineapple but also reduced the population of natural antagonists of nematodes to negligible levels. The nematodes that survive preplant fumigation rapidly increase to population levels higher than those in the preceding crop. After 40 years of soil fumigation in Hawaii, the nematode problem in pineapple soils is much greater than when fumigation was introduced.

Soil preparation. As the world market for pineapple increased, its culture intensified. Long plant cycles with fallow periods were replaced by short cycles with few or no fallow periods. Thus, new plantings were made on land with little natural reduction of nematode populations. Also, soil preparation was less efficient and soil fumigation less effective, resulting in increased nematode survival before planting.

Soil moisture. During the early years of cultivation, irrigation of pineapple was not considered economically beneficial. If available, irrigation water was applied by overhead sprays to set the seed pieces after planting; postplant irrigations were infrequent. Because rainfall in Hawaii is seasonal, the crop was usually grown under some degree of water stress during at least part of the cycle. Research at the University of Hawaii (1,18) has shown that the reniform nematode not only survives but flourishes under low moisture conditions. Thus, low soil moisture both places the pineapple plant under water stress and provides an environment suited to the pathogen.

Some of these factors also favorably influence the root-knot and lesion nematodes, specifically, monoculture with a single cultivar, reduction of natural antagonists by soil fumigation, and intensified land use with short-cycle operations. The root-knot nematode, however, has never spread throughout the pineapple hectarage and is limited to areas within fields or to fields of small hectarage within a plantation. The lesion nematode is basically confined to limited hectarage on one island.

Control measures. A nematode control program based on the use of a volatile soil fumigant evolved in the Hawaiian pineapple industry with the discovery of D-D. As the nematode problem became more severe, the entire industry adopted soil fumigation as a standard practice. The four fumigants—D-D, EDB, DBCP, and dichloropropene—became the principal products used. They were intensely researched for the most effective rates and methods of application by the Pineapple Research Institute and individual pineapple companies. Most of that research became moot when D-D, EDB, and DBCP were removed from the commercial market in the United States. Dichloropropene is currently being applied by chisel injection before planting at the rate of 224–336 L/ha. Plastic mulch laid over the bed at the time of application retains the fumigant and also serves as a planting guide, increases soil temperature, conserves moisture, and reduces weed growth.

Recent research conducted at the Pineapple Research Institute and the University of Hawaii has concentrated on developing practices suitable for non-volatile nematicides. The research has progressed from preplant application of granular formulations, through spray application of the systemic nematicides fenamiphos and oxamyl, to application of emulsifiable concentrates or water-

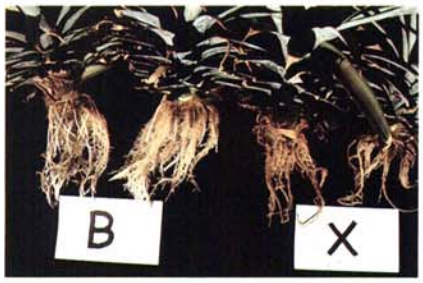

Fig. 1. Rooted pineapple crowns showing (B) adventitious nature of normal root system and (X) nonregenerative nature of root system in root rot caused by *Phytophthora cinnamomi*.

Fig. 2. Stages of floret development in pineapple inflorescence.

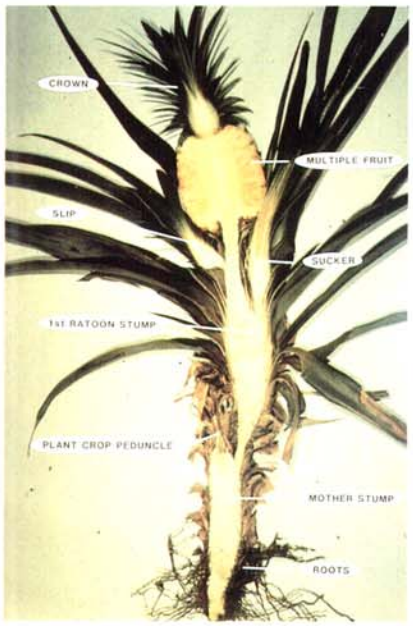

Fig. 3. Cross section of first ratoon pineapple plant.

soluble formulations by drip irrigation (2,3). Use patterns for several nonvolatile nematicides have been developed, but this discussion will be limited to products currently registered for use on pineapple in Hawaii.

Fenamiphos and oxamyl are cleared for use as foliar sprays and for direct application to the soil through a drip irrigation system. They may be applied in conjunction with a preplant fumigation treatment or used alone, in which case applications should begin when rooting occurs, usually 2–3 weeks after planting. Fenamiphos is most effective when applied as a spray or by drip irrigation at the rate of 0.56–3.36 kg a.i./ha at 1–3 month intervals up to 30 days before harvest. Oxamyl can be applied foliarly at the rate of 1.12–4.48 kg a.i./ha monthly or bimonthly up to 30 days before harvest; the rate for postplant application by drip irrigation is 0.56–4.48 kg a.i./ha biweekly, monthly, or bimonthly. For greatest effectiveness, soil moisture should be at optimal levels before and after applications of fenamiphos or oxamyl.

The total amount of fenamiphos approved is 44.7 kg a.i./ha for the plant crop and 22.5 kg a.i./ha for the ratoon crop. Oxamyl is limited to 53.8 kg a.i./ha for the plant crop and to 26.9 kg a.i./ha for the ratoon crop.

The pineapple industry in Hawaii has now returned to a long plant cycle that includes a fallow period of 6–12 months. This practice reduces nematode populations before nematicides are applied. The industry has also adopted drip irrigation to supply optimal amounts of water during the entire crop cycle, providing a soil environment unfavorable for the reniform nematode and favorable for root development.

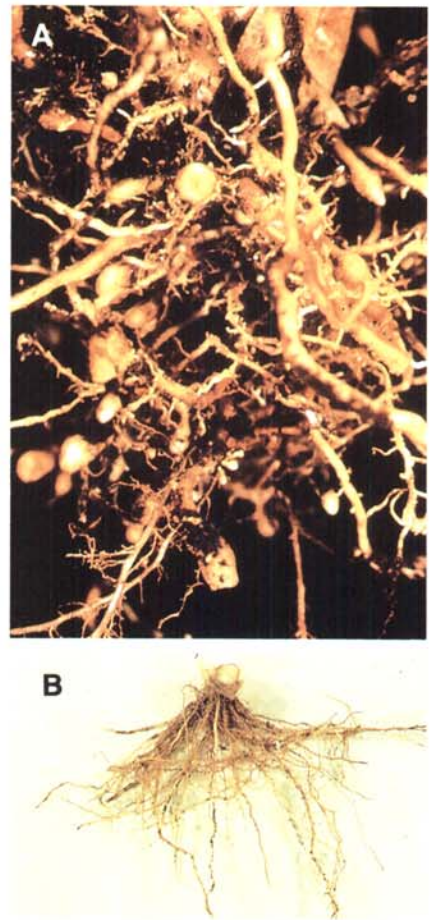

Fig. 4. Infection of pineapple by (A) root-knot nematode (*Meloidogyne javanica*) and (B) reniform nematode (*Rotylenchulus reniformis*).

Plant Diseases

Mealybug wilt. Wherever pineapple is grown, mealybug wilt (Fig. 5) can be a major problem. The disease is associated with the gray pineapple mealybug (*Dysmicoccus neobrevipes* Beardsley) and the pink pineapple mealybug (*D. brevipes* Cockerell) (4,5). Although the exact cause of the disease is not known, a recent report (12) identified virus particles in wilted plants.

Control in many countries is very poor. Once established in pineapple plants, mealybug wilt is difficult to control because of vegetative propagation and movement of infected symptomless seed to new plantings. In recent years, mealybug wilt has not been a problem in Hawaii because of excellent control of the field ants that attend the mealybugs and interfere with the mealybug's natural enemies. Three species of ants are important in Hawaii: the big-headed ant, *Pheidole megacephala* Fabricius; the Argentine ant, *Iridomyrmex humilis* Mayr (Fluker & Beardsley); and the fire ant, *Solenopsis geminata* Fabricius. Ants are controlled with mirex bait at the rate of 2.24 kg (0.3% a.i.)/ha and with broadcast sprays of heptachlor at the rate of 2.24 kg a.i./ha (4).

In Hawaiian plantation fields where mealybug wilt has been essentially eradicated, Beardsley et al (4) have suggested that control can be maintained by ant surveillance and application of control agents on field borders only, since ants are generally responsible for movement of mealybugs into the fields. In practice, however, broadcast sprays of heptachlor may be necessary.

Heart and root rots. Pineapple heart rot, like mealybug wilt, occurs universally. Heart rot (Fig. 6) can be caused by *Phytophthora parasitica* Dastur, *P. cinnamomi* Rands, or *P. palmivora* (Butler) Butler, whereas the root rot phase of the same disease (Fig. 1) is generally caused by *P. cinnamomi* or various *Pythium* species, most commonly *Pythium arrhenomanes* Drechs. (10). In Hawaii, *P. cinnamomi* is the predominant pathogen at the higher elevations, which tend to be cool with high rainfall. *P. parasitica* occurs at the lower elevations, which tend to be drier. Old reports indicate the presence of *P. palmivora* in Hawaii, but a survey by Klemmer and Nakano (10) did not identify it as a heart rot pathogen.

Fig. 5. Symptoms of mealybug wilt of pineapple include dieback of leaf tips and yellowing of the plant resulting from root system collapse.

Fig. 6. Mortality of pineapple plants at various stages of development caused by *Phytophthora parasitica*.

P. cinnamomi infects pineapple through the root tip, then follows the root into the stem, where heart rot can be induced. *P. parasitica*, and probably also *P. palmivora*, infect through the leaf axils. *P. cinnamomi* and *P. parasitica* differ distinctly in environmental requirements for infection (Table 1). *P. cinnamomi* occurs only where soil temperatures are cool and rainfall is high, whereas *P. parasitica* occurs under a wide range of temperature and moisture conditions. The incidence of both pathogens is increased in soil with a high pH, e.g., where excessive lime or coral has been applied; *P. cinnamomi* can also be severe in soil with a low pH.

Pineapple heart rot is controlled by dipping the seed material (crowns, slips, or suckers) in a fungicide suspension before planting. These fungicides include captan and captafol, which can also be applied to the leaves of developing plants to extend control; captafol is more effective. Currently, seed material is being dipped in fosetyl Al (Aliette), 2.24 kg a.i./935 L/ha. Control can be extended by foliar applications of fosetyl Al (not yet cleared by the Environmental Protection Agency) at the rate of 6.72 kg/ha in 2,805 L of water at intervals of 3–6 months. Fosetyl Al acts systemically and thus also provides excellent control of root rot (16).

Butt rot. This soft rot of the lower stem tissues of freshly removed seed material is caused by *Ceratocystis paradoxa* (de Seynes) Moreau (Fig. 7). Seed material

becomes completely resistant to infection when allowed to air-dry or "cure" for a few days after removal from the plant. Seed material placed on the mother plants and air-cured in the field does not require treatment. When mechanized handling makes curing impossible, however, a control method is needed. In Hawaii, the current method is preplant dipping of seed material in benomyl at the rate of 71 g a.i./935 L/ha (6). Benomyl alone is used when heart rot is not a problem; a mixture of benomyl and fosetyl Al is used for butt and heart rots.

C. paradoxa may also cause a leaf spot. Infection occurs through abrasions caused by wind. The symptom is unsightly, but the problem is rarely of economic significance.

Yellow spot. Pineapple yellow spot (Fig. 8) is caused by a strain of tomato spotted wilt virus transmitted from host weeds such as *Emilia fosberyii* Nicholson by the onion thrip, *Thrips tabaci* Lind. Infection always kills the plant, so the virus is not transmitted to subsequent plantings. Infection occurs most frequently on young crowns still on the fruit or during the first few months after planting. Control by maintaining weedfree plantings is relatively easy on large plantations with contiguous plantings. Where small plantings are intermixed with other crops and weed hosts, however, control can be very difficult or impossible.

Table 1. Influence of environmental factors on severity[a] of heart and root rot of pineapple

		Phytophthora cinnamomi		*Phytophthora parasitica*	*Phytophthora palmivora*	*Pythium arrhenomanes*
Factor	Level	Heart rot severity	Root rot severity	Heart rot severity	Heart rot severity	Root rot severity
Soil type	Heavy	3	3	1	3	3
	Light	1	1	1	1	1
Soil pH	>6.0	1	2	3	3	?
	<5.0	0	0	2	1	?
Temperature	High	1	1	3	3	?
	Low	3	3	1	1	?
Rainfall	High	3	3	2	3	3
	Low	0	0	2	1	1

[a] Disease incidence: 0 = none, 1 = <1%, 2 = 1–10%, 3 = >10%.

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Walter J. Apt

Dr. Apt is a professor of plant pathology at the University of Hawaii. He received his B.S. in horticulture and, in 1958, his Ph.D. in plant pathology from Washington State University. His research interest has been in the development and use of volatile and nonvolatile nematicides for pineapple nematode control and in the ecology of the reniform nematode. He previously spent 10 years with the section of nematology of the U.S. Department of Agriculture and many years with the Pineapple Research Institute of Hawaii.

Fruit Diseases

Fruit disease losses in Hawaii occur very sporadically. Total losses averaged over several years are very low and much less than occur in most foreign production areas, although occasional epidemics may result in losses as high as 40% in a single forcing. The sporadic nature of fruit diseases in Hawaii has seriously affected research on etiology and control measures because test conditions are unpredictable. For research purposes, the problem has been overcome in part by the use of susceptible cultivars, inoculation, and multiple forcings for each test.

The pineapple fruit develops from an aggregate of individual florets (Fig. 2). Each floret has three sepals, three petals, six stamens, and a single compound three-locule pistil. A bract subtends the floret and eventually covers the lower half of the developing fruitlet (13). Two parts of the floret, the stylar canal and the nectary duct, provide the primary entrance for fruit pathogens. At flowering, the stylar canals of each pistil form three openings, presumably for pollen tube growth during pollination. Three ducts at the base of the blossom cup lead to nectary glands between each pair of carpels. Because the florets are arranged in a spiral pattern around the central core, with the youngest on top, some flowers are open and susceptible to pathogen entrance for a period of 3–6 weeks. During flowering, nectar may be excreted and reabsorbed, depending on environmental conditions. Thus, plant stress presents conditions for pathogen entrance.

After flowering, the style withers and the stylar canals above the carpels are sealed with mucilaginous substances and ingrowth of the cells lining the canal. Enlargement of the sepals closes off the nectary ducts (13). Under moisture stress, the closure processes limiting the period for infection may not be completed.

When moisture is optimal during fruit development, the individual fruitlets mature as a unit. When maturation occurs under low moisture conditions followed by rainfall during the later stages of fruit enlargement, however, cracks in the tissues between fruitlets and in blossom cups may become entry points for pathogens.

Fruit diseases can be divided into three categories according to mode of infection: preflower, flower, and wound.

Preflower infections. As far as is known, *Penicillium funiculosum* Thom is the only pathogen that enters the developing floret before flowers open. Interfruitlet corking, leathery pocket, and fruitlet core rot (Fig. 9) were previously reported as separate diseases but actually are all symptoms of *P. funiculosum* infection. The pineapple fruit mite, *Steneotarsonemus ananas* Tyron, has been implicated in the pathogenesis of *P. funiculosum*, but not as a vector. Fruit mites are found at the base of the newly developing leaves in the plant heart (growing point), where they feed on the newly forming trichomes. Populations build up continuously as the plant grows and peak between forcing and the time of inflorescence emergence, 6–7 weeks after forcing (*unpublished data*). Young trichomes on the new leaves and the bracts and sepals of the emerging inflorescence are injured. Spores of *P. funiculosum* deposited in the plant heart 1–2 weeks after forcing germinate and apparently colonize the injured trichomes, resulting in the glossiness symptom (Fig. 9A). Sufficient inoculum potential builds up so that the developing floret is invaded by the fungus 2–3 weeks before flowering (7–9 weeks after forcing). Once inside the developing floret, *P. funiculosum* infects the anthers and style. The fungus continues down the stylar canal into the locule and frequently colonizes the placental tissue and the locular surface, producing the leathery pocket symptom (Fig. 9B). Extension of the fungus into the intercarpellary areas causes the fruitlet core rot symptom (Fig. 9C). The interfruitlet corking symptom (Fig. 9D) results from uneven development of infected fruitlets, presumably caused by a lack of hormone production by the destroyed placental tissue.

Environmental conditions conducive to infection by *P. funiculosum* are a maximum number of hours of cool temperatures (mean daily temperatures ranging between 16 and 20 C) from forcing to 5 weeks after forcing for buildup of inoculum potential and 10–15 weeks after forcing for infection (preflowering through early flowering). Temperatures warmer than 20 C inhibit disease development. Rainfall is important for buildup of inoculum potential but not for infection (17). Conditions for mite population buildup are similar.

P. funiculosum infection has been controlled with foliar sprays of endosulfan to reduce fruit mite populations. Timing of endosulfan application is critical because the mite population must be reduced during the 5-week postforcing period. With low to moderate disease levels, infection has been controlled by applying endosulfan (3.36 kg a.i./ha in 2,338 L of water) at forcing and 3 weeks

later. With high disease levels, especially under inoculated conditions, control has not been consistent, indicating that inoculation may eliminate the need for mite feeding.

The sporadic occurrence of the disease makes regular use of endosulfan uneconomical. Thus, mite threshold information must be developed to predict disease potential. Knowledge of the presence of *P. funiculosum* after forcing is of little value, since the information is acquired too late for mite control. Foliar fungicides have not given control in the field, although control has been obtained by physically applying the fungicide directly on the emerging inflorescence.

Flower infections. Three major groups of pathogens infect through the open flower. Pink disease, caused by *Erwinia herbicola* (Lohnis) Dye, *Gluconobacter oxydans* (Henneberg) Deley, and *Acetobacter aceti* (Pasteur) Beijennek, is characterized by brown discoloration of cooked fruit tissues (Fig. 10A). The disease occurs sporadically in Hawaii and appears to be limited to production areas where fruit develops under cool conditions. The causative bacteria cannot survive fruit temperaures >38 C, and thus the disease occurs only when flowering is initiated during cool weather or a rainy season (ambient temperatures around 18 C) and when fruit mature during periods when air temperatures do not exceed 29 C. Work by Hine (9) in the Philippines indicates that drought before flowering followed by rainfall during flowering (>25 cm per month) increases disease incidence.

Marbling disease, caused by *Acetobacter* species, *A. peroxydans* Visser 't Hooft, and *E. herbicola* var. *ananas* (Serrano) Dye, is characterized by a brown granular appearance and consistency of infected fruit tissue (Fig. 10B). In contrast to pink disease, marbling disease and fruitlet core rot (Fig. 10C), caused by *Fusarium moniliforme* Sheld. var. *subglutinans* Wollenw. & Reink., occur when fruit are initiated, flower, and mature under warm conditions (>21–27 C), such as in the lowland tropics. Although moisture does not appear to be critical for infection, disease is enhanced with rainfall during flowering and when fruit matures under dry, hot conditions followed by rainfall during the last 6–8 weeks of development.

The field source of inoculum of flower-infecting pathogens has not been clearly identified. These organisms may be a normal part of the epiflora of the pineapple plant and may be carried to the open flower by insects from deteriorating infected pineapple fruit or other fruit growing adjacent to pineapple fields. Insects are certainly vectors of pink disease bacteria, since insecticides such as methyl parathion and disulfoton have been used for control in the Philippines, the only area where the disease occurs frequently enough to justify their application. Effective controls for marbling and fruitlet core rot are not known.

Wound parasites. The most important wound pathogen of pineapple fruit is *C. paradoxa*, which produces a soft rot (Fig. 11). When the fruit is harvested, the broken peduncle end provides an ideal point of entry for *C. paradoxa*. Natural growth cracks and shell bruises also provide entry points. Although not a problem with commercially processed fruit (harvested fruit is processed within 24–48 hours), infection is a major problem with fruit held at ambient temperatures for longer than 3 days. Refrigeration at 8 C retards—but does not prevent—infection and development of *C. paradoxa*. Thus, fruit held at ambient temperatures at the retail market after refrigeration for 2 weeks or longer during shipment can still have severe rot problems.

Inoculum levels of *C. paradoxa* on harvested fruit vary considerably, with 0–100% of the fruit becoming infected. Without a prediction method, essentially all commercial fresh-market fruit must be treated. In Hawaii, fruit are dipped or sprayed with benomyl (1,200–2,400 ppm a.i.) before packing (6). Fruit must be treated within 6–12 hours of harvest to prevent infection.

The bacteria that cause marbling, *F. moniliforme* var. *subglutinans*, and yeasts also may infect maturing fruit through wounds or natural growth cracks. In Taiwan, marbling in fruit that has developed under dry conditions is thought to result from afternoon rainfall on hot fruit 6–8 weeks before harvest. The hypothesis is that rain rapidly cools the fruit, causing air inside to contract and draw marbling bacteria in through natural growth cracks or unsealed stylar canals or nectary ducts. Fruit maturing under dry conditions tends to be very

Fig. 7. Butt rot of pineapple crown caused by *Ceratocystis paradoxa*, with loss of basal stem tissue where adventitious roots originate.

Fig. 8. Pineapple yellow spot on developing crowns caused by a strain of tomato spotted wilt virus.

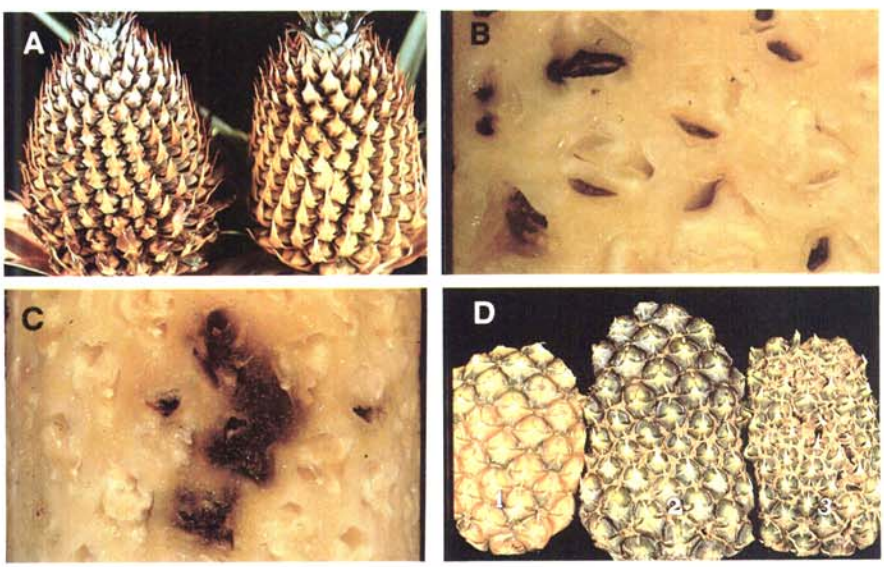

Fig. 9. Symptoms caused by infection of the developing floret by *Penicillium funiculosum*: (A) glossiness (loss of trichomes) of infected inflorescence on right compared with normal inflorescence on left, (B) leathery pocket, (C) fruitlet core rot, and (D) interfruitlet corking (1-3, increasing levels of severity).

porous, and some evidence indicates that the stylar canal and nectary ducts do not close normally (13). In Brazil, ovipositing and larval feeding sites of the pineapple caterpillar, *Thecla basilides* Geyer, provide wounds for *F. moniliforme* var. *subglutinans*. Control of *T. basilides*, however, does not completely eliminate fruitlet core rot induced by *F. moniliforme* var. *subglutinans* (15). In Hawaii, yeasts have been shown to enter fruit cracked by applications of gibberellic acid during flowering.

Physiological disorders. Endogenous browning (Fig. 12), also called internal browning, is the only physiological disorder of pineapple fruit. This disorder can occur in the field in developing fruit exposed to cold temperatures (5–10 C) but is predominantly a problem with refrigerated fresh fruit. The browning results from polyphenoloxidase activity, which yields brown phenolate pigments. The disorder can be controlled by planting resistant cultivars or dipping harvested fruit in a paraffin-polyethylene wax (FMC 705 or FMC 7051), at a wax-to-water ratio of 1:4–9.

Fig. 10. (A) Pink disease characterized by brown discoloration of cooked fruit tissue (cylinders on right of each pair are cooked). (B) Marbling disease characterized by brown granular appearance and consistency of fruit tissue. (C) Fruitlet core rot caused by *Fusarium moniliforme* var. *subglutinans*.

Outlook for the Industry

Pineapple production in Hawaii will probably remain at the current levels, with about 20% marketed as fresh fruit and the remainder processed. The nematode problem is severe, and loss of any more control measures would mean the demise of the industry. Although plant diseases are not in the same economic category as nematodes, their control is important from the standpoint of increased production efficiency. The industry's current use of fungicides for heart rot and butt rot attests to the economic viability of the agents. Because of the sporadic occurrence and the complexity of the fruit diseases, economic importance varies and development of control strategies is difficult. For controls to be economically viable, predictive systems need to be developed.

Fig. 11. Pineapple fruit rot caused by *Ceratocystis paradoxa*.

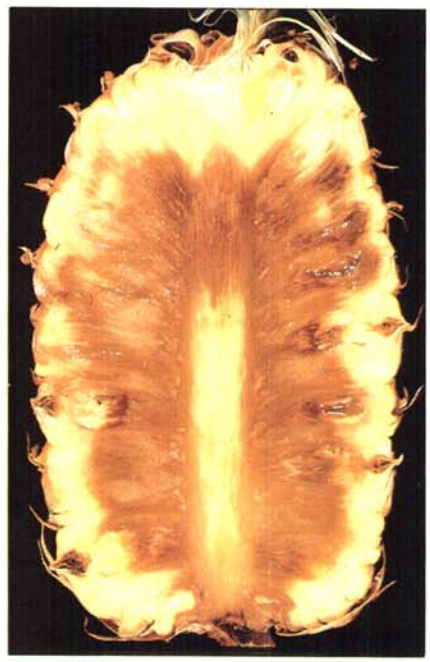

Fig. 12. Endogenous browning of pineapple fruit caused by chilling injury.

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