Susan Schenck
Hawaiian Sugar Planters' Association, Aiea

Oliver V. Holtzmann
University of Hawaii, Honolulu

Evaluation of Potential Problems in a Changing Agricultural System: Nematode Control in Hawaiian Crops

Tropical plantation agriculture is usually carried out on a large scale by companies whose production must remain profitable. The need for profit encourages efficient, cost-effective land use and practices that include long-term monocrops with heavy use of chemical pesticides and fertilizers and strict production schedules. As Hawaiian agricultural companies seek to become more diversified and avoid the threat of toxic chemical residues in the environment, there is increased interest in integrated pest management and alternative practices for nematode control. Implementation of these practices will require flexible management of agricultural operations, as well as understanding of nematode populations, plant susceptibility, effects of environmental conditions, and interactions among these factors. The eventual advantages should be well worth the effort.

Sugarcane (*Saccharum officinarum* L., *Saccharum* spp.) is the foremost agricultural crop in the state of Hawaii in total hectares planted and in cash value (9). Pineapple (*Ananas comosus* (L.) Merr.) is second in importance. Sugarcane production has been gradually decreasing in recent years, however, and Hawaii's agriculture is becoming increasingly diversified into alternative crops suited to Hawaii's subtropical climate. Plant-parasitic nematodes are associated with both sugarcane and pineapple and may limit alternative crops in the changing agricultural system. In this article we summarize the status of nematode problems pertaining to pineapple and sugarcane and potential problems that might threaten alternative crops. Strategies to control nematodes on these crops are discussed, as well as the principal plant-parasitic nematodes found on pineapple and sugarcane and their known associations with other crops (Table 1).

Nematode problems in tropical plantation crops can be especially severe because there are no low winter temperatures to reduce soil populations. Also, plantation crops are usually grown in cycles over several years, thus giving nematode populations time to increase to damaging numbers. Plantations usually remain in monoculture for many years, and the soil ecosystem becomes stable, with particular parasites predominating. When another crop is planted, the existing parasite populations may or may not be injurious, depending on the new crop's susceptibility. The state of Hawaii and its agricultural companies are committed to reducing production costs and increasing environmental safety through expanded use of cultural and biological control methods to manage diseases and nematodes. Reduced pesticide use during the early stages of a newly planted crop should result from a thorough understanding of nematode ecology and crop susceptibility.

Nematodes and Sugarcane

Sugarcane is grown under a wide range of climatic and agronomic conditions, and an unusually large number of plant-parasitic nematode species are associated with this crop (Fig. 1). *Meloidogyne* and *Pratylenchus* are most common (35). Many of the other species associated with sugarcane are not known to be parasitic and fewer yet are serious pathogens, but given the relatively high numbers of several plant-pathogenic species in sugarcane fields, their cumulative effect probably has a negative impact on plant vigor.

Root-knot nematodes (*Meloidogyne* spp.) have been reported frequently in sugarcane soils and is the genus most likely to cause economic damage. In Hawaii, *M. incognita* (Kofoid & White) Chitwood (= *M. incognita acrita*) is the predominant species, but *M. javanica* (Treub) Chitwood and *M. arenaria* (Neal) Chitwood may be present to a lesser degree. In random samples of root-knot-susceptible tomatoes after sugarcane, O. V. Holtzmann (*unpublished*) showed the distribution of *M. incognita, M. javanica*, and *M. arenaria* to be 67, 22, and 11%, respectively.

Pratylenchus zeae Graham and *P. brachyurus* (Godfrey) Filipjev & Schuurmans Stekhoven are the most common lesion nematode species reported in sugarcane-growing areas of the world (13, 17,30,34). At one time, *P. brachyurus* was thought to be one of the most economically important nematodes in sugarcane in Hawaii (18), but recently *P. zeae* has become the principal lesion nematode.

The reniform nematode (*Rotylenchulus reniformis* Linford & Oliveira) has a relatively wide host range and has been reported from sugarcane soils (14,30) and in association with *S. spontaneum* L., a wild relative of commercial sugarcane (34). Its presence in soil indicated to some observers that it multiplies on sugarcane roots, but mature females or egg masses on the roots have not been found (7,38). Birchfield (6) concluded that although found in sugarcane fields in several parts of the world, *R. reniformis* failed to reproduce on sugarcane. Gargantiel and Davide (14) observed slight damage to potted sugarcane seedlings, but there was no detectable nematode population increase after 3 months. In Hawaii and Puerto Rico, fields infested with *R. reniformis* rarely were found to be infested after several years in sugarcane (4,29; S. Schenck, *unpublished*). These researchers concluded that sugarcane was immune to the reniform nematode.

In the early 1900s, Cobb (11) first described *Radopholus similis* (Cobb) Thorne (= *Tylenchus biformis*), the burrowing nematode isolated from

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Table 1. Some nematodes associated with pineapple, sugarcane, and selected tropical and subtropical crops[a]

Nematode	Host plant							
	Pineapple	Sugarcane	Banana	Cacao	Arabica coffee	Corn	Edible ginger	Papaya
Helicotylenchus dihystera	+*[b]	+*	+*	+*	+*	+*	+*	+*
H. multicinctus	+*	–	+*	–	–	–	–	–
Meloidogyne arenaria	–	+*	–	–	–	+*	+*	–
M. incognita	–	+*	+*	+	+	+*	+*	+*
M. javanica	+*	+*	+*	+	+	+	+*	+
Pratylenchus branchyurus	+*	+*	+*	+	+	+*	–	+
P. coffeae	+	+	+*	+	+*	+	+	+
P. zeae	+	+*	–	–	–	+*	–	–
Radopholus similis	+*	+*	+*	–	+	+	+*	–
Rotylenchulus reniformis	+*	+	+*	+	+	+*	+*	+*

[a] According to W. J. Apt (*personal communication*), O. V. Holtzmann (*unpublished*), Peachey (24), Williams and Orton (40), and Goodey et al (Goodey, J. B., Franklin, M. T., and Hooper, D. J. 1965. The Nematode Parasites of Plants Catalogued Under Their Hosts. Commonwealth Agricultural Bureaux, Farnham Royal, England. 214 pp.).

[b] + = Reported from areas other than Hawaii, * = reported from Hawaii, – = not reported as associated with host.

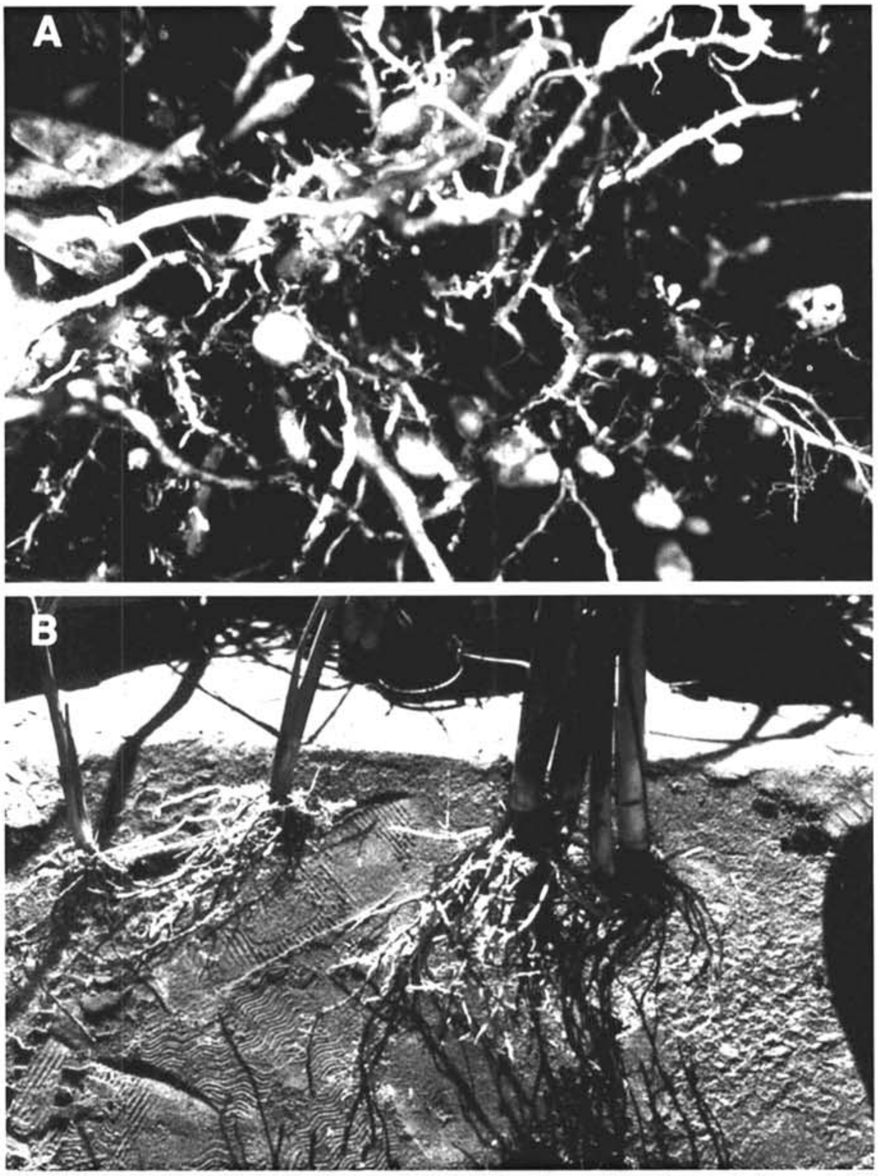


Fig. 1. Sugarcane roots (A) with severe infestation by root-knot nematodes and (B) damaged by unidentified nematodes.

sugarcane roots in Hawaii, and established its endoparasitism and pathogenicity. The importance of the burrowing nematode probably continued into the early 1940s, but in the late 1950s less than 10% of sugarcane samples were infected (18). By the mid-1960s, *R. similis* was difficult to find at all in sugarcane fields in Hawaii (O. V. Holtzmann, *unpublished*). The decline in the *R. similis* populations probably was the result of genes for resistance being bred unknowingly into the Hawaiian sugarcane cultivars.

The nematodes just described occur sporadically and do not often cause major economic loss in sugarcane, but some may be severe pathogens of alternative crops that follow sugarcane. In Hawaii, because sugarcane is not treated with nematicides, populations may build up to high numbers. The spatial distribution of nematodes in sugarcane is not well documented, but higher numbers and greater damage to sugarcane in sandy soil than in heavier soils have been reported (31,37). Differences also may be associated with elevation. Larger numbers of root-knot nematodes have been associated with higher elevations (600–1,200 m), which are cooler and wetter in Hawaii. The opposite was true for the burrowing nematode, *R. similis*, which was rare or absent above 600 m (37).

Population distribution also varies with sugarcane plant age and root system (8). Cane plants have an extensive fibrous root system near the soil surface; roots may extend radially 2 m from the plant. Production of new shoots and roots over the length of the crop cycle gives a continual supply of new root tips for infection sites (36). Also, buttress roots grow at an angle downward and very deep roots grow vertically downward as far as 4.5–6.0 m. With such deep penetration of root systems, nematode populations would be expected to occur even in the subsoil. When sampling sugarcane for nematodes in Hawaii, it was found that nematode numbers and species were evenly distributed throughout a 30-cm profile (*unpublished*). During trenching operations for irrigation installations in sugarcane fields in Hawaii, samples at various depths to 60 cm (S. Schenck, *unpublished*) contained a variety of nematode species in abundance. The residual populations following sugarcane may infect even a shallow-rooted crop because soil fumigants usually are not placed below 30 cm and nematodes, particularly *Meloidogyne* spp., are able to migrate upward to infect roots (1,25).

Nematodes and Pineapple

Although fewer nematode species are reported on pineapple than on sugarcane, these often cause severe root and plant stunting and result in significant crop loss (Fig. 2). In Hawaii, *R. reniformis* (Fig. 3), *M. javanica, P. brachyurus, Helicotylenchus dihystera* (Cobb) Sher (= *H. nannus*), and *Paratylenchus minutus* Linford, Oliveira & Ishii are known to parasitize pineapple (15,19,20, 28). The last two species have no apparent pathogenic effects.

The reniform nematode (*R. reniformis*) was first described as a new species in 1940 infecting cowpeas in pineapple plantation soil on Oahu (19). Failure of nematologists to identify *R. reniformis* in Hawaii before that time may indicate that it was introduced. It was not of economic importance on pineapple until the early 1960s (W. J. Apt, *personal communication*). The reniform nematode multiplies rapidly, can withstand desiccation, and remains viable in dry, fallow soil for months (2,26). Its wide host range makes most rotations and cover crops unsuitable as economic control measures. Since first reported, *R. reniformis* has become the most serious nematode pest of pineapple in Hawaii and cannot be controlled without chemical nematicides (28).

M. javanica is the only *Meloidogyne* species reported to be parasitic on pineapple in Hawaii (28). Root-knot nematodes may cause severe yield losses in pineapple. When root tips are attacked, root growth is arrested and, in severe cases, the root system may be almost completely destroyed and plant anchorage lost. Severe root-knot infestations sometimes occur when pineapple follows sugarcane. It seems curious that *M. incognita* does not occur on pineapple in Hawaii because it is reported to infect pineapple in Puerto Rico (24) and the Ivory Coast (31). Perhaps races pathogenic to pineapple occur elsewhere. More intensive study of Hawaiian *Meloidogyne* species might help to clarify the question.

As with most other crops, nematodes in pineapple are distributed mainly in the root zone (3,27). Drip irrigation systems in Hawaii wet the soil only to about 30 cm under polyethylene bedding mulch, and the root system develops in the irrigated soil volume. Nematodes multiply in the root zone, but not appreciably below it or in the dry interbed spaces. Pineapple is vegetatively propagated and produces an initial flush of roots that reaches maximum size approximately 12 months after planting. Thereafter, few additional roots develop, and the roots are gradually reduced in mass and activity over the next 3 years. Populations of *R. reniformis* follow the same trend, reaching maximum numbers 12 months after planting and then gradually declining.

When sugarcane fields are converted to pineapple, certain of the nematode species present may cause problems. Although sugarcane does not support reniform nematode populations, *M. javanica* or *P. brachyurus* may remain in the deeper soil layers even after fumigation. Damage to the young pineapple root system, which lacks the capacity for regeneration, can irrevocably reduce the yield of the planted crop and succeeding ratoon crops.

Nematode Problems on Selected Alternative Crops

Coffee. Commercially grown coffee (*Coffea* spp.) is usually of the arabica type (*C. arabica* L.) and, to a lesser extent, *C. canephora* Pierre & Froehner and *C. liberica* Bull & Hiern. Arabica coffee is, in general, the type most susceptible to attack by root-knot nematodes (10,23,24). Mature coffee trees can suffer significant root damage and defoliation from nematode attack, but they are generally more tolerant than seedlings and young trees. Coffee is a deep-rooted crop, although the root system development varies markedly with soil porosity (42). Vertical taproots may extend downward to 360 cm. The root system within the 200-cm radius of the tree is profusely branched to a depth of about 200 cm (42). Large nematode populations can develop on coffee roots because the root system is extensive, coffee is relatively tolerant, and plants may live up to 40 years.

Coffee has been extensively surveyed for nematode parasites around the world and is host to many species (22,24,31). The nematodes most widespread and damaging to coffee are *Meloidogyne exigua* Goeldi, *M. incognita, Pratylenchus coffeae* (Zimmerman) Filipjev &

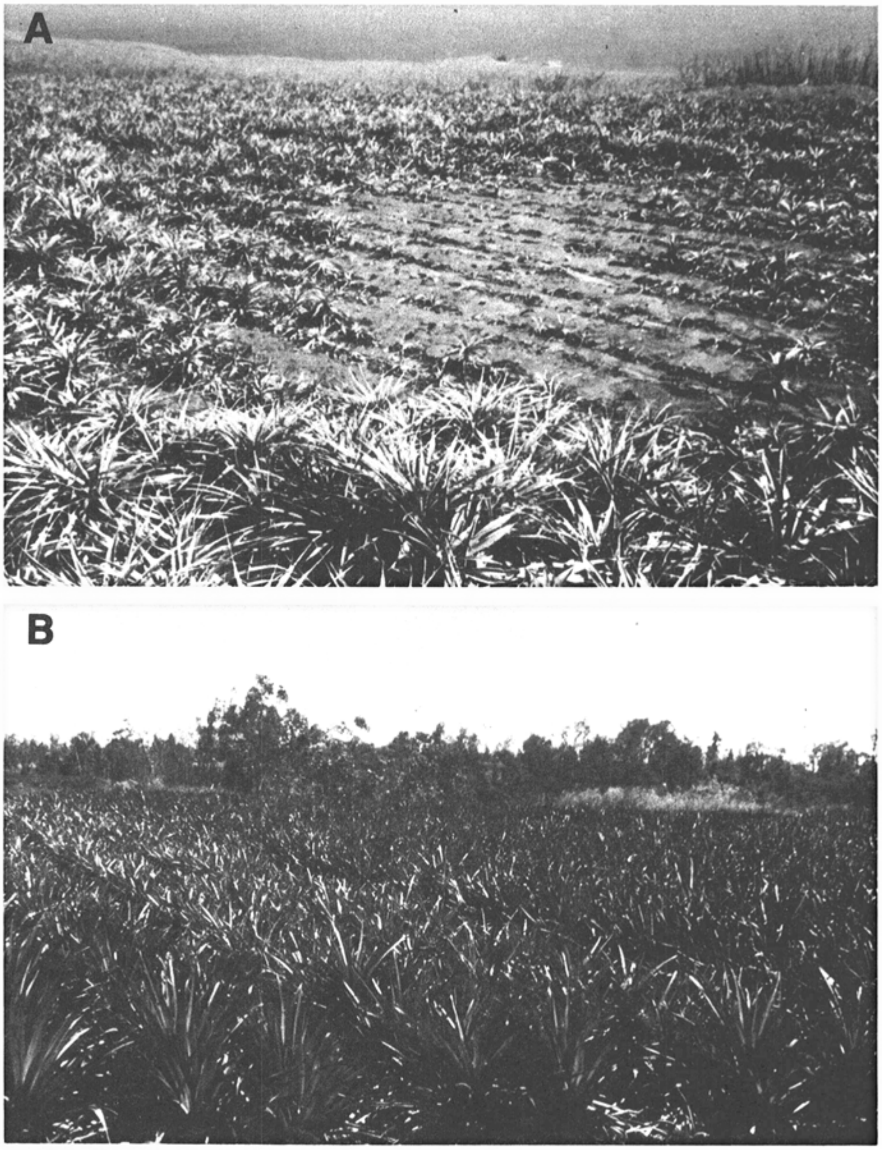


Fig. 2. (A) Pineapple field with destruction resulting from *Meloidogyne javanica*. (B) Pineapple field with damage from *Rotylenchulus reniformis*; stunted plants in four rows (center and right foreground) resulted from blocked fumigator shanks.

Schuurmans Stekhoven, *P. brachyurus*, *Radopholus similis*, and *R. reniformis*. Other species cited less often were in the genera *Helicotylenchus*, *Scutellonema*, *Xiphinema*, *Paratylenchus*, *Hemicriconemoides*, *Trichodorus*, and *Tylenchorhynchus*.

Compared with other coffee-growing areas of the world, little research has been done on the nematodes parasitic on coffee in Hawaii, probably because the area cultivated is relatively small. Coffee plantations are increasing, however, and the potential exists for serious nematode problems. Some of the most severe coffee pathogens are already present in high numbers in sugarcane, banana, and pineapple plantations (Table 1). In Hawaii, *Helicotylenchus* sp., *H. dihystera*, *Meloidogyne* sp., *P. brachyurus*, *P. coffeae*, and *R. reniformis* have been found associated with arabica coffee. Sporadically, coffee plants in the field have been found to be severely affected with root-knot nematodes.

M. incognita and *P. brachyurus* in sugarcane fields may damage coffee. *P. zeae* that occurs on sugarcane and on the Sudax (sorghum [*Sorghum vulgare* Pers.] × sudangrass [*S. vulgare* var. *sudanense* (Piper) Hitchc.]) hybrid planted as windbreaks in coffee nurseries is not known to parasitize coffee. *R. reniformis* may be damaging to coffee but does not multiply on sugarcane, so this pathogen would not be a threat when coffee follows sugarcane. However, potentially serious damage could occur if coffee is planted on land previously occupied by pineapple or by *R. reniformis*-susceptible members of the aroid, banana, and ginger families. *Radopholus similis* is considered to be one of the most damaging nematodes of coffee in Java and India—second in pathogenicity only to *P. coffeae* (22,24). The burrowing nematode is widely distributed in Hawaii on many crops but has not been found in sugarcane fields since the mid-1960s and does not occur in pineapple. Nonetheless, *R. similis* could be introduced into new Hawaiian coffee plantations.

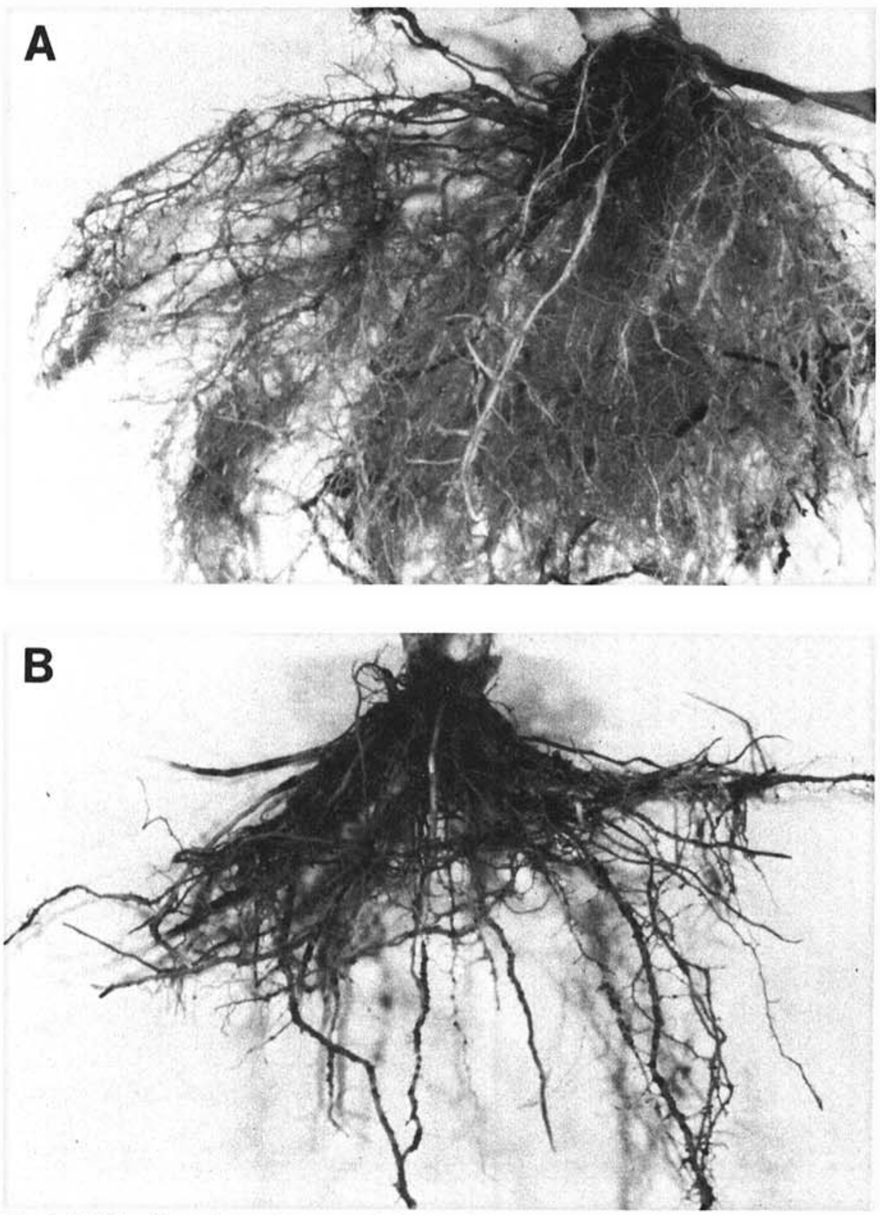


Fig. 3. (A) Healthy pineapple roots with abundant secondary branching and (B) roots damaged by *Rotylenchulus reniformis*. (Courtesy W. Apt)

Banana. The most serious root pest of banana is the burrowing nematode (*R. similis*), which is responsible for "blackhead" disease. Since *R. similis* is not found in pineapple and sugarcane fields of Hawaii, most banana infections result from previously infected planting materials or contaminations from plants of the families Araceae, Musaceae, and Zingiberaceae. Other endoparasitic nematodes, i.e., *P. coffeae* and *P. brachyurus*, can cause symptoms as severe as those induced by *R. similis*. *Helicotylenchus multicinctus*, a spiral nematode with an endoparasitic habit, is frequently found in and around banana roots. Pathogenicity in Hawaii is suspected, but not proved. *R. reniformis* is often found in high numbers in banana fields and is suspected of contributing to plant decline.

Cacao. To date, no serious nematode infestations of cacao have been found in Hawaii. In Samoa, both *P. coffee* and *R. reniformis* are associated with cacao, but pathogenicity requires further study (40). The root-knot nematodes infect cacao but cause only minimal damage.

Corn. Corn should not follow either sugarcane or pineapple, but especially sugarcane. Most nematodes that attack sugarcane can be damaging to corn.

Ginger. Edible ginger can be severely damaged by root-knot nematodes. Although the quantity of yield may not be greatly affected, light to moderate root-knot infestations severely reduce the quality and market value of the rhizomes. *Rotylenchulus reniformis* is not known to be a serious pathogen of ginger even in high numbers, although this association warrants further study. *Radopholus similis*, an endoparasite of edible ginger, causes yield loss at times.

Macadamia nut. Macadamia nuts are reported to be associated with a number of plant-parasitic nematodes. To date, no pathogenic relationships have been established.

Papaya. *Rotylenchulus reniformis* has been found to be the most important nematode pest of papaya in Hawaii. It generally is serious where the crop is grown in soil rather than in lava rock. Root galling by *M. incognita* also occurs and is most common and severe on papaya grown in sandy or very light textured soils as compared with the heavier clays.

Methods of Control

As agriculture in Hawaii becomes more diversified, new crops may be adopted for which pesticides have not been tested or registered. Because the time and expense needed for pesticide development and registration are burdensome, nematicides may not be available for some time, if ever. According to Caldwell et al (9): "The potential of an alternative crop may hinge on learning to control pests through cultural and biological methods." These methods sometimes are very effective. Often changes in cultural practice can be implemented easily and fit well into overall plantation operations and integrated pest management strategies.

Chemical nematicides are used routinely in some tropical plantations. Sometimes they may be the only effective means to maintain profitable yields. They should be used only at the minimum rate and frequency needed, in the most effective manner, and in combination with alternate control methods. One must have a thorough knowledge of the pest species present, the population distribution, and potential threat, as well as familiarity with the agricultural practices in each particular case. With this knowledge, the various control measures can be integrated effectively into the overall production program.

Crop rotation. A pineapple-sugarcane-pangola grass (*Digitaria decumbens* Stent.) rotation has been recommended in Puerto Rico (5,31). Pangola grass is resistant to both *M. incognita* and *R. reniformis* and is planted as pasture in Puerto Rico. The three-crop rotation apparently was practical for farmers to use in their agricultural system. Although a sugarcane-pineapple rotation has been suggested in Hawaii, differences in irrigation installations and the large-scale nature of commercial production make it impractical. Nonetheless, even with large commercial plantations, it has occasionally been possible to take advantage of differences in crop susceptibility in order to reduce the use of pesticides. *Meloidogyne* spp. are more easily controlled by chemical fumigants than is *R. reniformis*. Since the latter is absent in sugarcane plantations, less fumigant is needed when pineapple plantings follow sugarcane than when pineapple follows pineapple.

Cover crops. For large, commercial plantations, intercycle cover crops for nematode management generally have not been used (24), although nonhost crops may be feasible for small growers in some situations. Several are reported to be effective, but it is difficult to find one that will control more than one species in a mixed population.

Pangola grass has frequently been mentioned as a good cover crop and a nonhost of *M. arenaria, M. hapla, M. javanica, M. incognita,* and *R. reniformis* (5,16). It reduced nematode numbers enough to increase pineapple yields where these nematodes were limiting. However, when pangola grass was planted in pineapple soil heavily infested with *R. reniformis*, the nematode populations did not decline faster than in the weedfree fallow plots (S. Schenck, *unpublished*). *Pratylenchus* spp. and *P. brachyurus* were not controlled by pangola grass (5,31).

R. reniformis populations increased dramatically on broadleaf weeds, were maintained on maize and sorghum, and declined in fallow. *H. dihystera* increased under all strategies except fallow. Some *Crotalaria* spp. were reported to be nonhosts of *M. incognita, M. javanica,* and *P. brachyurus* (31) but supported reproduction of *R. reniformis* (21) and *H. dihystera* (31). Likewise, African marigold (*Tagetes erecta* L.) and French marigold (*T. patula* L.) have been reported to be nonhosts or poor hosts of *Meloidogyne* spp. and *Pratylenchus* spp. (12), but they are hosts of *R. reniformis* (21).

Cover crops may be useful when they are cost-effective and the cover crop has some commercial value, but as intercycle plantings between long-term monocropping systems, they are not advantageous when compared with fallow alone. They require additional field cultivations, planting, and pest control. The time and acreage taken to grow them and to plow them under all add to production costs.

Fallow and soil management. Fallowing is generally considered a practical and effective way to control nematodes between plantation crops, but often the intercrop period is insufficient to attain the desired effect. A weedfree fallow period long enough to allow complete plant residue degradation is necessary for control. Plantings of pineapple or coffee are expected to remain in that crop for many years so an extended fallow period may be cost-effective if significant reduction of pathogens is realized, especially since it is most important to protect the young plants until they develop sufficient root mass to tolerate infection.

Under dry field conditions in Hawaii, *M. javanica, H. dihystera,* and *Paratylenchus minutus* were reduced to undetectable levels within 4 months, but *R. reniformis* still remained viable in low numbers for up to 2 years (2,26; S. Schenck, *unpublished*). *P. brachyurus* also can survive for long periods in dry soil (15). Fallow control of nematodes that can withstand desiccation may be successful if soil remains wet and free of weeds. The nematodes remain active, eggs hatch, and the population begins to decline because of starvation. Although populations of *R. reniformis* were significantly reduced in moist fallow soil in 6–8 months, preplant fumigation still was needed for commercial pineapple production.

Biocontrol. Commercial control of nematodes of tropical crops by biocontrol agents has not been achieved, although many potentially useful agents exist. Production of a single crop such as orchard trees or coffee over a long period of time, or of repeated cycles of a plantation crop such as sugarcane, increases biocontrol agents in the soil, particularly if pesticides are not applied. Fields of a single, relatively tolerant crop in place for many years would be more likely to benefit from the introduction and establishment of a biocontrol organism. Stirling and White (33) detected *Bacillus penetrans* (Thorne) Mankau in vineyards over 10 years old and concluded that it reduced the population of *Meloidogyne* spp. A parasite found on root-knot females from sugarcane appeared to be similar or identical to *B. penetrans* (39). On the other hand, predatory nematodes in sugarcane fields, instead of controlling plant parasites, disappeared after a number of years (18).

Introduction of a biocontrol agent into a natural environment may or may not have more than an ephemeral effect. Such organisms, especially obligate parasites, are difficult to produce in quantity and form that can be delivered to the field. The production of *B. penetrans* on root-knot females in tomato roots and incorporation of the dried, powdered roots into soil was a creative and successful attempt at control on a small scale (32). The use of commercial preparations of *Paecilomyces lilacinus* (Thom) Samson, a fungal parasite of nematode eggs, has increased yields of several crops in the Philippines (13). The commercial success of any biocontrol agent will depend on its cost and effectiveness relative to currently available nematicides. Biocontrol has potential for nematode control but is not yet in common practice in plantation crops. In some cases, the incorporation of biocontrol agents into nematode control programs may prove to be useful and should be studied further.

Resistant cultivars. As high-yielding sugarcane was selected over the years in Hawaii, genes for nematode resistance were probably bred into commercial cultivars and may account for the unexplained shifts in plant-parasitic nematode populations that have occurred. The Hawaiian Sugar Planters' Association has been very successful in producing resistant cultivars.

Considerable variation in root-knot susceptibility was reported among pineapple and coffee cultivars (17,23). Under selection pressure of the past 50 years, some cultivars of the pineapple variety Smooth Cayenne are now recognized as having a higher nematode tolerance than the newer cultivars (17). In some coffee-growing areas of the world, susceptible arabica varieties are grafted to robusta selections, which are generally more resistant to *Meloidogyne* spp. (41).

Overview

The two major Hawaiian agricultural commodities traditionally have been sugarcane and pineapple. Each is host to a number of parasitic nematode species, but management strategies are very different. Sugarcane in Hawaii is not seriously damaged by nematodes, and control by resistance in commercial cultivars is effective. The resulting nematode community is diverse and probably contains a number of natural biocontrol agents.

Pineapple is severely damaged by *R. reniformis* and *M. javanica*. Despite the use of various cultural control practices, the industry relies extensively on chemical pesticides. Pineapple fields generally have only one to three species of parasitic nematode, but often in high numbers. Natural biocontrol agents may have been eliminated by the pesticides.

When an alternative crop to either sugarcane or pineapple is considered, the most effective nematode control strategy depends on its susceptibility and cultivation practices as well as those of the preceding crop. As an example, three potentially damaging nematodes of coffee—*R. reniformis, M. incognita*, and *P. brachyurus*—occur in Hawaiian pineapple and sugarcane fields. These could be especially serious during the first year of a coffee crop when the plants are most susceptible and intolerant of root injury.

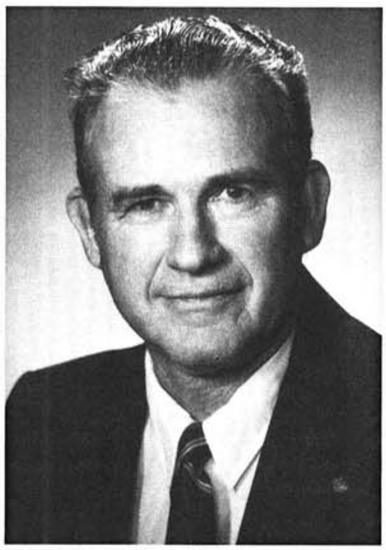
Following pineapple, *R. reniformis* and, to a lesser extent, *P. brachyurus* populations need to be reduced to low densities before coffee is planted. Long, weedfree fallow between crops is essential. Another useful strategy might be to plant an intercrop of sweet corn for sale on the local market. Corn is resistant to the reniform nematode and is susceptible to *Pratylenchus zeae*. Populations of *P. zeae* appear to compete against *P. brachyurus*, resulting in lower numbers of the latter species. If necessary, arabica coffee seedlings can be grafted to resistant rootstocks, but this is relatively expensive.

Coffee planted in previous sugarcane fields would be expected to become infested with *M. incognita* or *P. brachyurus*. Since these nematodes are not usually found in high numbers in sugarcane, long intercycle fallow is not as critical. The practice in Hawaii of germinating coffee seedlings in commercial potting mix before replanting in the field helps to ensure a good start for the plants. Another practice that has proved useful is the planting of Sudax windbreaks between rows of coffee seedlings. Sudax, like corn, favors the increase of *P. zeae* over that of *P. brachyurus*.

Surveys of young Hawaiian coffee plantations indicated that growers have so far avoided serious nematode damage without the use of nematicides. As more diverse crops are introduced, knowledge of the existing nematode problems in sugarcane and pineapple plantations and awareness of the susceptibility of the alternative crops will allow the development of integrated pest management strategies. By anticipating possible problems and making use of cultural control strategies, both heavy losses from uncontrolled nematodes and overuse of pesticides may be avoided.

Susan Schenck

Dr. Schenck is an associate plant pathologist with the Hawaiian Sugar Planters' Association. Since 1979 her career has been devoted to the investigation and control of nematodes and diseases of tropical plantation crops. Her research is centered mainly on applied, integrated control programs for pineapple, sugarcane, and coffee and covers a range of disease problems. She received her M.S. degree from the University of Wisconsin and her Ph.D. degree from New York University and did postgraduate research at the Station Nationale de Recherche Agronomique, Versailles, France, and at Rutgers University.



Oliver V. Holtzmann

Dr. Holtzmann is an emeritus professor at the University of Hawaii, where he worked for 30 years before retiring in 1986. He served as department chairman for 15 years and taught general plant pathology for 25. He also taught a graduate course in plant nematology. He received his B.S. and M.S. degrees from Colorado State University and, in 1955, his Ph.D. degree from Washington State University. His research interests were mainly in biology and control of plant-parasitic nematodes in tropical crops. In his retirement, he continues research in turfgrass diseases and teaches a short course in tropical plant pest quarantine.

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