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Survey of Nematodes on Banana in Hawai'i, and Methods Used for Their Control

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Plant-parasitic nematodes are microscopic roundworms that feed on plants. Most species feed on roots, but some feed on plants' foliar tissues. Among those nematodes infecting plant roots, some are *ecto*parasitic and others are *endo*parasitic. They differ in that ectoparasitic nematodes feed on plant tissues from outside of the plant, whereas endoparasitic nematodes feed on plant tissues from within the plant. Nematodes can be further broken down into *migratory* and *sedentary* types. If the adult female moves freely through the soil or plant tissues, the nematode is said to be migratory. An adult female that is immobile and remains at one area of the root is termed sedentary.

Three migratory endoparasitic nematodes that feed on the root cortex of banana plants are the burrowing (*Radopholus similis*), spiral (*Helicotylenchus multicinctus*), and lesion (*Pratylenchus* spp.) nematodes (Fig. 1). Their feeding results in dead root cells, or lesions (Fig. 2). Sedentary endoparasitic nematodes that feed on banana include the root-knot (*Meloidogyne* spp.) and reniform (*Rotylenchulus reniformis*) nematodes (Fig. 1). These nematodes penetrate banana roots, migrate and settle at a feeding site, and then start injecting growth-regulating substances into the root. This causes the surrounding cells, which now serve as their feeding site, to enlarge. Ectoparasitic nematodes commonly found in Hawai'i include the ring (*Mesocriconema* spp.) and another species of spiral (*Helicotylenchus dihystera*) nematodes. These ectoparasitic nematodes usually do not cause significant damage to most crops.

This mixed population of plant-parasitic nematodes, including root-knot, reniform, and lesion nematodes, was extracted from a banana rhizosphere.

Nematodes infecting banana in Hawai'i

Unfortunately, all the nematodes mentioned above are commonly associated with banana roots in Hawai'i. A survey of root-parasitic nematodes associated with banana plantings in Hawai'i was conducted between 2007 and 2008 in 27 banana fields distributed throughout the six major Hawaiian Islands (O'ahu, Hawai'i, Maui, Lāna'i, Moloka'i, and Kaua'i). During the survey, five major genera of nematodes associated with banana roots were found: spiral, burrowing, root-knot, reniform, and lesion (*Pratylenchus coffeae*) nematodes (Fig. 3).

Migratory endoparasitic nematodes

Among the many species of nematodes associated with banana, burrowing and spiral nematodes (*H. multicinctus* in particular) are of greatest concern. They have been reported to cause banana yield losses of 30–60% in different parts of the world. Burrowing nematode feeding causes necrotic cavities to develop in the root tissues (Fig. 2). Spiral nematodes

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Figure 1. Photomicrographs of nematodes extracted from banana roots (images are not to uniform scale)

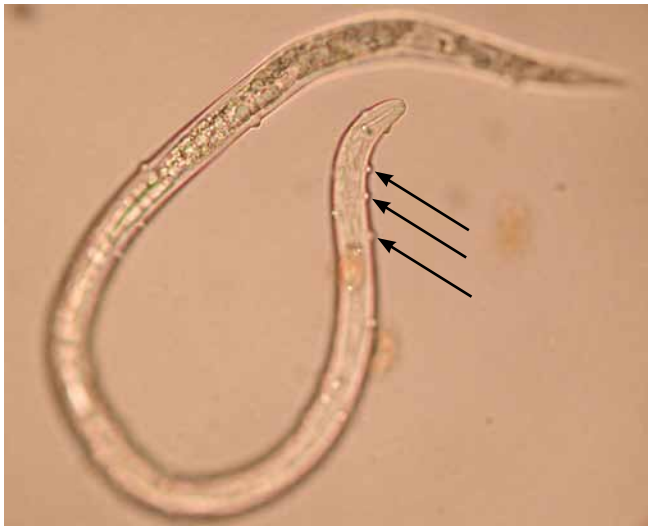
***Helicotylenchus multicinctus* male**

Tail end of a *Helicotylenchus multicinctus* female

***Radopholus similis* female**

***Radopholus similis* male**

***Pratylenchus coffeae* female**



A juvenile *Meloidogyne* sp. with *Pasteuria penetrans* spores attached (arrows)

Figure 2. (A) root lesions (darkened areas) caused by endoparasitic nematodes on banana; (B) root galls (swollen areas) caused by root-knot nematodes on banana.

mainly only attack the outer cells of the root and produce smaller and shallower necrotic lesions that develop more slowly than those caused by burrowing nematodes.

Lesion nematode, *Pratylenchus* spp., is another migratory endoparasitic nematode that damages banana. *Pratylenchus coffeae* and *P. goodeyi* are two of the most common lesion nematodes found attacking banana. Symptoms of infection are similar to those of the burrowing nematode, and some lesion nematodes can infect corm tissues, which impairs the plant's abilities to uptake water and nutrients. All migratory endoparasitic nematodes can reduce banana bunch size and prolong the vegetative growth cycle. Root injury caused by nematodes affects plant anchorage, and thus uprooting or toppling of plants may occur.

The 2007–2008 survey of nematodes in Hawai'i banana plantings revealed that the spiral nematode, *Helicotylenchus multicinctus*, was present in great abundance and at many sites (Fig. 3). The survey revealed that 64 percent of the banana plantings are infested with this nematode, compared to only 43 percent infested with burrowing nematodes. These results are similar to findings from a survey conducted in American Samoa. In that survey, population densities of spiral nematodes were five times higher than those of burrowing nematodes. Although a damage threshold for burrowing nematodes on banana has not been established, it has been proposed that 2000 burrowing nematodes per 100 g of fresh roots will cause a yield loss in most commercial cultivars worldwide. In a greenhouse experiment conducted in Hawai'i, infection by spiral nematodes was shown to reduce banana plant height.

Sedentary endoparasitic nematodes

Although root-knot nematodes were found on all banana farms in the survey, *Pasteuria penetrans*, a natural enemy of root-knot nematode, was associated with that nematode in 26 percent of the farms. *Pasteuria penetrans* is a bacterial parasite of the root-knot nematode that attaches to the surface of juvenile root-knot nematodes, penetrates into the body, and interferes with the nematode's reproduction system. It has been proved to be an effective biological control agent against root-knot nematodes and will keep the numbers of root-knot nematodes under control.

Economic impacts of reniform nematodes on banana have not been reported.

The overall conclusion drawn from this survey was that greater attention should be given to the spiral nematode, which is a known contributor to yield loss in banana. It was typically found in high numbers on farms where banana plants had toppled. When plants within a mat (a cluster of banana plants and suckers) start toppling, the chance that this mat will produce a harvestable bunch in the following cycle is reduced.

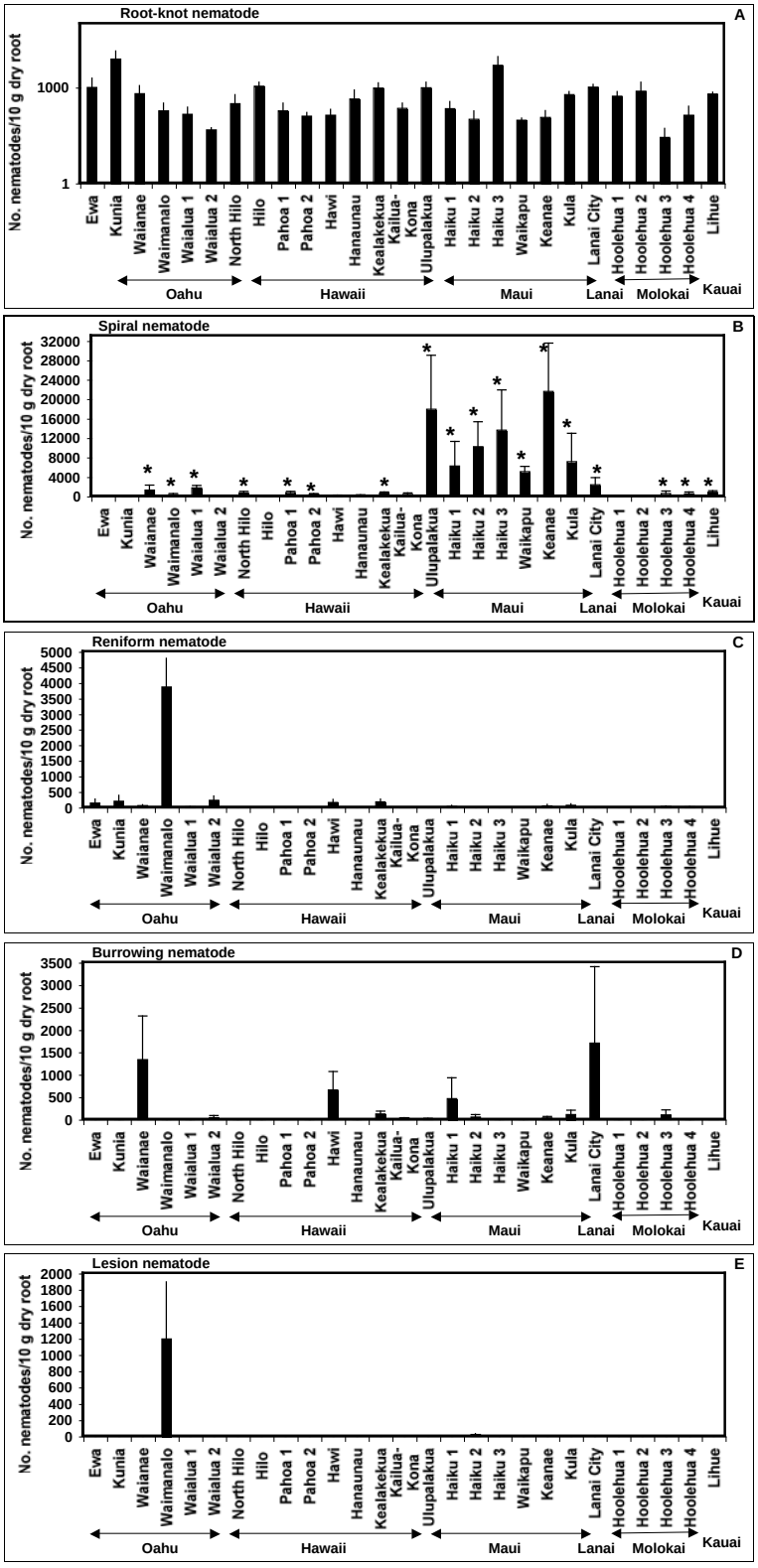


Figure 3. Numbers of plant-parasitic nematodes extracted from fresh banana roots (equivalent to 10 g dry root weight) sampled from 27 banana farms distributed among five Hawaiian islands; (A) root-knot, (B) spiral, (C) reniform, (D) burrowing, and (E) lesion nematodes. An asterisk over a column in B indicates the presence of *Helicotylenchus multicinctus* (Wang and Hooks 2009).

Control measures for banana nematodes

Banana is a long-lived perennial crop, which makes nematode management more challenging than for annual crops. Although soil fumigation as a pre-plant treatment, such as with Telone II® (1,3-dicloropropene), is very effective in suppressing nematode populations, it is short lived compared to the life of a banana crop. Plant-parasitic nematodes tend to repopulate an area fairly quickly after fumigation. Telone potentially contaminates groundwater, is a restricted-use pesticide, and is also rather costly.

Because banana is usually cultivated as a perennial crop, post-planting treatment is essential for nematode management. In terms of post-plant nematicides, fenamiphos (Nemacur®) is environmentally harsh and hazardous to applicators. Its Special Local Needs label for Hawai'i has expired. Although erthoprop (Mocap®) and *Myrothecium verrucaria* (DiTera®) are also effective post-plant nematicides, they are difficult to handle. In 2003, CTAHR and the Hawaii Banana Industry Association developed an integrated pest management program for banana production in Hawai'i. This includes selecting banana cultivars resistant to or tolerant of plant-parasitic nematodes. Two banana hybrids from the Fundacion Hondurena de Investigacion Agricola (FHIA) breeding program with resistance to black leaf streak disease were tested for their resistance to plant-parasitic nematodes of banana in American Samoa. The FHIA-01 hybrid was relatively resistant to burrowing nematodes, whereas FHIA-25 was relatively resistant to all plant-parasitic nematodes commonly feeding on banana in American Samoa.

Most banana growers, however, choose banana varieties based on their market value, or their susceptibility to key pest organisms, and they avoid using nematicides. Propping fruiting plants to prevent toppling (Fig. 4), managing keiki (suckers), mulching, and fertilizer applications to increase plant vigor are preferred by growers over using nematicides. The unintentional planting of keiki already infected with nematodes is the principal means of nematode dispersal to uninfested sites. Therefore, obtaining nematode-free planting material is the first step in limiting nematode spread. Several strategies are listed here to reduce initial nematode infection of banana planting materials.

Figure 4. An old banana farm with plants propped up by sticks to avoid toppling due to heavy bunch weight and nematode-damaged root systems.

Banana tissue culture

Preventing the spread of pests and diseases is one of several advantages for using tissue-cultured plantlets. Using known nematode-free banana plantlets for planting material is one mechanism to ensure that nematodes are not being spread around an infected field or introduced to a new field. A banana micro-propagation facility that can provide a reliable source of banana bunchy top virus–free and nematode-free planting material has been developed at the University of Hawai'i at Mānoa. For more information, see http://www.ctahr.hawaii.edu/oc/freepubs/pdf/BIO-8.pdf.

Hot-water treatment

A hot-water dip has been successfully used to control burrowing nematodes in anthurium and root-knot nematodes in ginger. Although treatment recommendations by researchers from different parts of the world vary from 5 minutes at 50°C to 25 minutes at 55°C, CTAHR researchers recommend disinfesting banana suckers by soaking them for 10 minutes at 50°C. Our experiment with keiki collected from a farm heavily infested with spiral nematodes with low numbers of burrowing nematode showed that hot water treatment at 50°C for 10 minutes was sufficient to kill all nematodes in roots, regardless of the size of the corm (which ranged from 2 to 6 inches in diameter). All of the heat-treated keiki grew well when planted in the field. One drawback of this method is that it requires the use of a hot water tank with temperature-control capability (Fig. 5).

Figure 5. Banana keiki soaking in a hot-water tank with the temperature kept at 50°C for 10 minutes to kill plant-parasitic nematodes.

Figure 6. Banana keiki covered in clear plastic and left in direct sunlight to absorb solar heat to kill off plant-parasitic nematodes. A control treatment (left) is wrapped in black plastic.

Sodium hypochlorite dip

Currently, some banana growers in Hawai'i concerned with nematode damage treat their suckers with a dip in a diluted household bleach solution, consisting of one part bleach (6.0% sodium hypochlorite content, unscented and without other additives) and nine parts water, for 10 minutes prior to planting. Results indicated that sodium hypochlorite dip reduced 85 percent of spiral nematodes in the roots as compared to those untreated (Wang, unpublished). Bleach dipping might reduce plant vigor but it is an easily accessible method for most farmers.

Modified solarization—A layman's approach

Soil solarization involves heating the soil beneath a clear (transparent) plastic sheet to reach temperatures lethal to soilborne pests. The method has been successfully used against plant-parasitic nematodes and other soilborne diseases in several crops and regions around the world, especially in hot climates. In addition to investigating the use of soil solarization to manage nematodes in the soil before planting, we are experimenting with a modified solarization technique that involves directly heating nematode-infected banana keiki (Fig. 6). This solarization method might provide an effective alternative to hot-water tanks for heat treatment. We hope to determine the specific time interval required for this solarization technique to successfully rid banana keiki of nematode infection.

Cover cropping

Planting 'Single Gold' French marigold (*Tagetes patula*) or 'Tropic Sun' sunn hemp (*Crotalaria juncea*) (Fig. 7A, B) can help reduce initial levels of spiral and root-knot nematodes when planting banana in nematode-infested soils. There is also a potential to continuously reduce nematode damage during the banana growth cycle by planting low-growing cover crops, such as marigold, around the banana plants (Fig 7C). Some studies have shown that certain species or cultivars of marigold that are toxic to plant-parasitic nematodes are as effective as soil fumigants in suppressing some nematode pests. It is believed that chemical fumigation only kill nematodes in top soil layer.

Summary

Plant-parasitic nematodes can cause significant yield loss to banana production and should not be ignored. Banana growers should consider replanting and practice the nematode management tactics listed above if their fields are heavily infested with damaging nematodes.

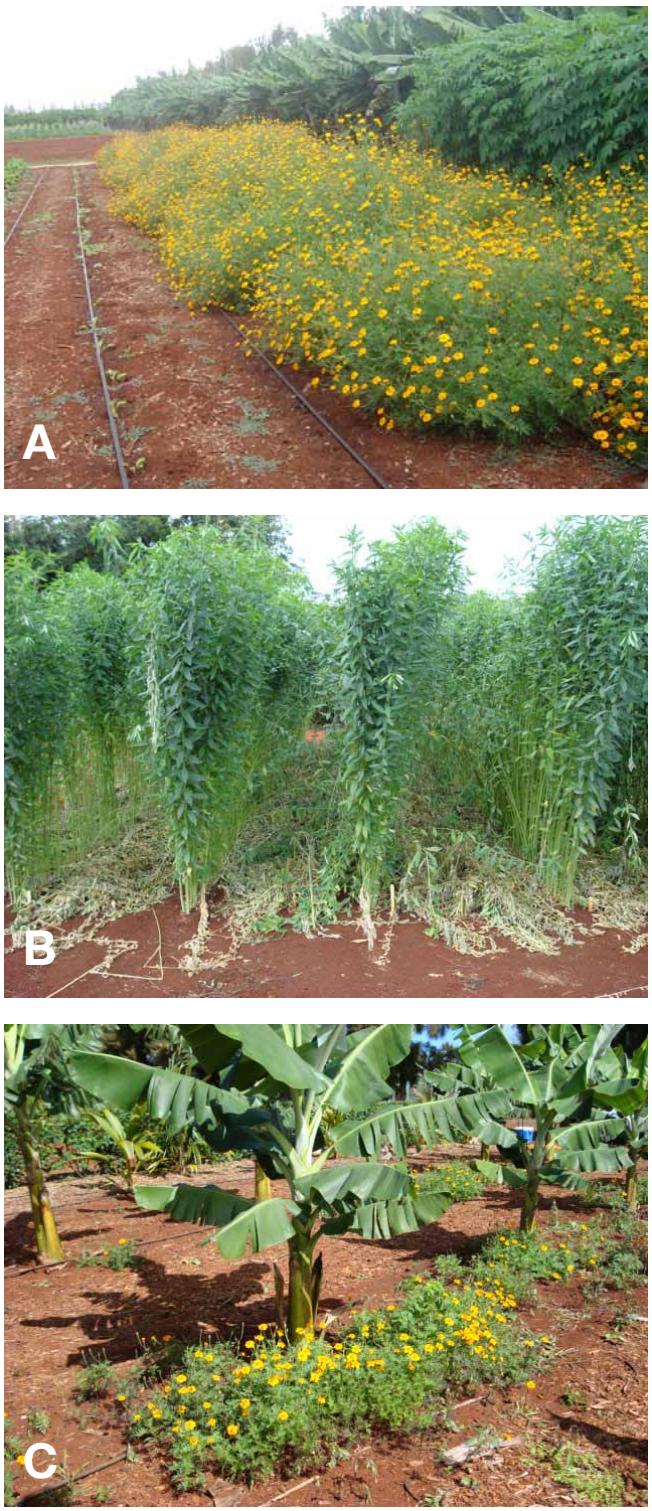


Figure 7. (A) 'Single Gold' marigold and (B) 'Tropic Sun' sunn hemp used as cover crops before planting banana. (C) Banana interplanted after establishment with marigold to suppress spiral nematodes (*Helicotylenchus multicinctus*).

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