College of Tropical Agriculture and Human Resources
University of Hawai'i at Mānoa

Plant Disease
April 2012
PD-84

Root-Knot Nematodes on Cucurbits in Hawai'i

Miriam Dorman and Scot Nelson
Department of Plant and Environmental Protection Sciences

Devastating diseases of cucurbit crops in Hawai'i include those caused by plant-parasitic nematodes. These soil-borne pests can cause major yield losses and be difficult to control. Here we discuss the symptoms and cause of root-knot disease of cucurbits in Hawai'i and suggest integrated management practices to limit crop loss and damage.

Pathogen

Root-knot nematodes (*Meloidogyne* spp.) are microscopic roundworms found in a wide range of habitats and agroecosystems. These parasites infect cucurbit plant roots, wherein they feed and complete their life cycles. When left uncontrolled, these pathogens can cause severe plant damage and yield loss to cucurbits and other common vegetables in Hawai'i and throughout the Pacific. Two species of nematodes infect cucurbits in Hawai'i: *Meloidogyne incognita* and *M. javanica* (Westerdahl and Becker 2011). Quantitative studies on cantaloupe in California have determined that a root-knot population density of 40 second-stage juveniles per 100 cm^3 of soil before planting can cause a minimum of 30% yield loss (Westerdahl and Becker 2011).

Host: Cucurbits

Cucurbits are a plant group that includes a variety of squashes, gourds, and melons. Plants within the Cucurbitaceae grow throughout tropical regions, including Hawai'i. Both vegetable and melon cucurbits are popular components of recipes in Hawai'i's regional cuisines.

Cucurbits are economically important crops to the state of Hawai'i. Between the years 2007 and 2008, cucumbers (*Cucurbita* spp.) were Hawai'i's most-produced cucurbit at 9.8 million lbs. (4,445 metric tons). Their farm value was over US$5.2 million. Italian squash, oriental squash, and pumpkin (all of the *Cucurbita* spp.) followed at 2.68 million lbs. (1215 metric tons), 850,000 lbs. (385 metric tons), and 560,000 lbs. (254 metric tons), respectively. Their farm values were worth US$1.7 million, US$437,000, and US$303,000, respectively. Hawai'i's farmers also produced 300,000 lbs. (136 metric tons) of bittermelon (*Momordica charantia)* with a farm value of US$249,000 (USDA 2010).

Galled roots (left) infected by *Meloidogyne* sp. In this early stage of infection, the bodies of adult females may protrude from roots and appear as small pearls (right) (Photograph: James L. Starr, Texas A&M University).

Published by the College of Tropical Agriculture and Human Resources (CTAHR) and issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, under the Director/Dean, Cooperative Extension Service/CTAHR, University of Hawai'i at Mānoa, Honolulu, Hawai'i 96822.

The head of a root-knot nematode, magnified, showing the spear-shaped, tube-like stylet used to penetrate the roots of host plants and extract food.

Life Cycle of the Pathogen

Root-knot nematodes complete most of their life cycle within the roots of their host plant, although they can survive in the soil as eggs or as second-stage juveniles. The wide host range of these pathogens makes them almost impossible to eradicate once they infest a soil.

Mature females can produce more than 1,000 eggs each during their relatively short lives. These are encased in a gelatinous sac that protects them from dehydration. This egg mass can sometimes be seen attached to the posterior end of the female.

First-stage juveniles develop within the eggs. Second-stage juveniles hatch from the eggs and infect the roots of the host plant. They establish a permanent feeding site of "giant cells" within the root and become immobile. This lifestyle is called *sedentary endoparasitism* (Westerdahl and Becker 2011). The juveniles progress through three molting stages while continuing to receive nutrients from the cells of their host plants. When mature, the adult females lay eggs to complete the life cycle.

The optimum soil temperature for root-knot nematode development is 25–28°C (77–82°F). Within this range, the nematodes require 3–4 weeks to complete their life cycle. Although they may develop at lower temperatures, the development will take more time (Westerdahl and Becker 2011).

Disease Cycle

Several plant cells adjacent to the head of sedentary females become enlarged, hypertrophic "giant cells" and serve as food factories for these pests. In addition, the number of plant cells around the feeding site greatly increases in number to form enlarged, hyperplastic galls. These are the "knots" typically seen on infected roots. Each gall can grow to more than 2.5 cm (1 inch) in diameter if it contains numerous actively feeding nematodes. The presence of galls inhibits the uptake of water and nutrients through the roots to the aboveground portions of the plant.

Plants stressed by inadequate nutrition or moisture may be more susceptible to damage by root-knot nematodes. Nematode-damaged plants may then be more vulnerable to infection by other pathogens.

Disease Signs and Symptoms

The most recognizable symptom of root-knot nematode infection is the presence of swellings, called galls or knots, on the roots.

Foliar symptoms may include flagging and chlorosis of the leaves, defoliation, stunting, and wilting. The plants may be slow to recover when soil moisture conditions are improved and are easily uprooted due to poorly developed root systems. Nematode-infected plants may have smaller leaves and fewer flowers than nematode-free plants, contributing to decreased yields and poor fruit quality. Nematode damage may cause some members of the cucurbit family to produce large amounts of ethylene gas. This can contribute to premature ripening of fruit (Noling 2009). The unhealthy plants may be distributed in a patchy or irregular pattern in the field.

It is difficult to diagnose a nematode infection solely by observing foliar symptoms. In many cases, they are similar to symptoms resulting from both biotic and abiotic factors such as insect pests, fungi and bacteria, drought, and nutrient deficiencies (Westerdahl and Becker 2011). To determine if soil is infested with root-knot nematodes, soil samples should be taken prior to planting. For a small fee, samples may be sent to CTAHR's Agricultural Diagnostic Service Center at the University of Hawai'i at Mānoa for nematode identification and to determine the severity of the problem. For instructions on how to sample soils, please see http://www.ctahr.hawaii.edu/oc/freepubs/pdf/SCM-9.pdf. For additional information regarding the preservation

of samples until analysis, please see http://www.ctahr.hawaii.edu/oc/freepubs/pdf/SCM-14.pdf.

Disease Epidemiology

Root-knot nematodes are most active in warm, moist soil conditions. In areas with especially low temperatures during the winter, root-knot nematode activity is suppressed. However, because warm temperatures are maintained during Hawai'i's very mild winters, there is year-round root-knot damage to cucurbits.

Disease Management

Although plant infection by root-knot nematodes is unavoidable in infested soils, the damage may be decreased with the appropriate cultural and/or chemical practices. These practices include crop rotation, fallowing, soil nematicides, and solarization, which is the process of covering soil with plastic to trap the sun's heat underneath to kill weeds and soil-borne pathogens such as nematodes.

It is best to prevent an infestation before it occurs, as once a growing area has become infested with root-knot nematodes, complete eradication is almost impossible. If a growing area does become infested, several methods can be used to keep the population in check and the damage to cucurbits to a minimum. These practices are most effective when used together rather than alone. This integrated approach will have the greatest effect in terms of prevention and control. Most of these methods are practical for home gardeners, landscapers, and organic or non-organic farmers. When an infestation is severe, more intensive measures may be necessary. In some cases, such as when applying a soil fumigant, a certified pesticide applicator's license is required. Examinations for this license are given by the Hawaii Department of Agriculture and must be renewed every 5 years.

Prevention

- Ensure that all planting material is free of nematodes before bringing it into the growing area. Seedlings can be obtained from nematode-free nurseries, or plants can be germinated directly from seed since root-knot nematodes are not seed-borne (Noling 2009).
- Ensure that all soil amendments are from nematode-free areas (Noling 2009).
- Grow grafted cucurbits; scions of desirable varieties can be grafted onto rootstocks resistant to root-knot nematodes (Thies et al. 2010).
- When available, grow cucurbit varieties resistant to root-knot nematodes (Sikora 1997). Such resistance is usually specific to single *Meloidogyne* species and may not hold up in all cases. A grower should first obtain a *Meloidogyne* species identification by submitting a soil and/or infested root sample to UH-CTAHR. Thereafter, the grower may contact the UH-CTAHR Cooperative Extension Service for suggestions regarding varieties of the desired cucurbit resistant to that *Meloidogyne* sp.

Galls enlarge over time as more nematodes hatch from eggs and re-infect the root system.

Management

- Rotate crops between growing seasons with non-hosts of root-knot nematodes (i.e., plants the nematode will not infect) (Westerdahl and Becker 2011). For example, cowpea (*Vigna unguiculata*) is well adapted to cultivation as a cover crop in the tropics, and many cowpea cultivars are poor hosts to root-knot nematodes (for a list of resistant cultivars, refer to Wang and McSorely 2004). Sunn hemp (*Crotolaria juncea*, 'Tropic Sun') is another excellent cover crop for nematode suppression. Growers may also plant nematicidal crops of African or French marigolds between

cucurbit cropping cycles or between plants within a cropping cycle. The roots of these marigolds exude chemicals that kill root-knot nematodes (Wang, Hooks, and Ploeg 2007).

- Plow deeply (Westerdahl and Becker 2011), allow a period of dry fallowing during the warmer months (Noling 2009), and then solarize the soil (this is particularly good for small vegetable gardens) (Westerdahl and Becker 2011). All of these methods will lower root-knot nematode populations and temporarily reduce the amount of damage to plants.
- Control the growth of weeds in and around the growing area. Many weeds are hosts of root-knot nematode (e.g., hairy and black nightshade, pigweed, purple and yellow nutsedge, etc.). Weeding can be conducted manually, or with organic or other approved herbicides (Westerdahl and Becker 2011).
- Add organic material to the soil (e.g., chicken manure, compost, etc.). Organic material improves soil characteristics and plant nutrition. It also stimulates the growth of various soil microorganisms that compete with nematodes (Noling 2009).
- Irrigate adequately; the less stress to which a plant is exposed, the less damage root-knot nematodes will cause (Westerdahl and Becker 2011).
- In extreme cases, the use of post-plant nematicides may be necessary. The following is a list of nematicides that are currently registered for use on cucurbits in the state of Hawai'i: Amazin® Plus; Azaguard®; DiTera® ES; Ecozin® Plus; and Molt-X™. See Table 1 for more information. Please note that our mention of these nematicides does not constitute an endorsement of them. In fact, some may have little measurable impact on nematode populations. Pre-plant nematicides such as Telone® soil fumigants and Vapam® HL soil fumigant can provide a relatively higher level of nematode control but may require certain specialized application technologies or equipment and a pesticide applicator's license. Always consult pesticide labels for safety information and for appropriate application rates and methods.
- Regular monitoring or scouting of the growing area for nematode damage is necessary, particularly during the early stages of plant growth (Noling 2009).

Table 1. Post-plant nematicides registered in Hawai'i for control of root-knot nematodes of cucurbits.*

Product Name	Active Ingredient(s)	Product Formulation	Product Label
Amazin® Plus	1.2% Azadirachtin	Emulsifiable concentrate	http://hawaii.gov/hdoa/labels/9521.80_2014.pdf
Azaguard®	3% Azadirachtin	Emulsifiable concentrate	http://hawaii.gov/hdoa/labels/8048.16_2012.pdf
DiTera® ES	27.5% ABG-9008, strain AARC-0255	Emulsifiable concentrate	http://hawaii.gov/hdoa/labels/8187.1_2012.pdf
Ecozin® Plus	1.2%	Emulsifiable concentrate	http://hawaii.gov/hdoa/labels/9521.79_2013.pdf
Molt-X™	3% Azadirachtin	Emulsifiable concentrate	http://hawaii.gov/hdoa/labels/9055.15_2012.pdf

*Source: Hawaii Pesticide Information Retrieval System. The products in the above table are examples of nematicides registered and approved for use against root-knot nematodes on cucurbits as of February 2012. Please note that some or all may be restricted-use pesticides and require an applicator's license.

These severely infected cucumber roots are heavily galled. Nematodes within the galls intercept nutrients intended for the foliage, causing poor plant growth and yield losses. Heavily diseased plants wilt during hot, sunny days and can develop secondary root rots.

Acknowledgements

The authors thank Fred Brooks and Brent Sipes of UH-CTAHR for their thoughtful reviews of this manuscript.

References

Noling, JW. 2009. Nematode management in cucurbits (cucumbers, melons, squash). http://edis.ifas.ufl.edu/ng025 (accessed 22 February 2012).

Olson, MW. 2011. Root-knot nematode. http://ag.arizona.edu/pubs/diseases/az1187 (accessed 22 February 2012).

Sikora, E.J. 1997. Common diseases of cucurbits. http://www.aces.edu/pubs/docs/A/ANR-0809/ (accessed 22 February 2012).

Thies, JA, Ariss, JJ, Hassell, RL, Olson, S, Kousik, CS, and Levi, A. 2010. Grafting for management of southern root-knot nematode, *Meloidogyne incognita*, in watermelon. *Plant Disease*. 94(10):1195–1199.

Hawaii Pesticide Information Retrieval System. http://state.ceris.purdue.edu/doc/hi/statehi.html (accessed 22 February 2012).

USDA. 2010. Annual Hawaii vegetables. http://www.nass.usda.gov/Statistics_by_State/Hawaii/Publications/Archive/xveg08.pdf (accessed 22 February 2012).

Wang, K-H, and McSorely, R. 2004. Management of nematodes with cowpea cover crops. University of Florida IFAS Extension, ENY-712. http://edis.ifas.ufl.edu/pdffiles/IN/IN51600.pdf (accessed 22 March 2012).

Wang, K-H, Hooks, CR2, and Ploeg, A. 2007. Protecting crops from nematode pests: using marigold as an alternative to chemical nematicides. Cooperative Extension Service, College of Tropical Agriculture and Human Resources, University of Hawai'i at Mānoa, PD-35. http://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-35.pdf (accessed 22 March 2012).

Westerdahl, BB, and Becker, JO. 2011. UC IPM pest management guidelines: cucurbits. http://www.ipm.ucdavis.edu/PMG/r116200111.html (accessed 22 February 2012).