MANAGING ROOT-KNOT NEMATODES

in Georgia Watermelons

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Watermelon (*Citrullus lanatus* var. *lanatus*; Cucurbitaceae) is one of the most popular fruiting vegetables in the world. In 2017, the total production of watermelon was 118 million tons. The U.S. is the seventh largest watermelon producer in the world, and approximately 50% of the total national production of watermelon is produced in the Southeast, including Georgia, Florida, South Carolina, and North Carolina farms. With approximately 20,000 acres of cultivated area and a farm gate value of $135 million (2018 Georgia Farm Gate Value Report), Georgia is ranked as the fourth largest watermelon producing state. The principal challenge in watermelon cultivation is disease, as watermelon is susceptible to several soilborne pathogens throughout the crop cycle. Intensive cultivation in limited land resources has significantly increased some soilborne pathogens and pests in recent years. A major constraint to watermelon production is root-knot nematode (*Meloidogyne* spp.).

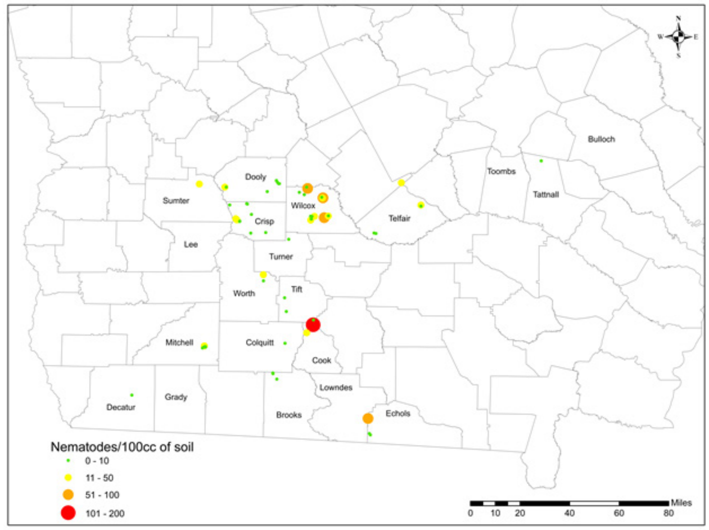

Figure 1. The distribution of root-knot nematodes in 66 southern Georgia watermelon fields in 2018. Circles with different colors signify the nematode abundance (nematode numbers per 100 cubic centimeters of soil). Note: The damage threshold (minimum number of nematodes at which the crop is at some damage risk) of root-knot nematode on vegetable crops in Georgia where conditions are conducive (e.g., sandy soils, hot weather, and ample rainfall) is one nematode per 100 cubic centimeters of soil.

Detection and prevalence of root-knot nematodes in Georgia watermelon systems

Root-knot nematodes are highly adaptable, obligate plant parasites (parasites that cannot reach adulthood without a host) that attack plant roots and establish a prolonged relationship with their hosts. There are three common species of root-knot nematodes known to parasitize watermelon in the U.S.: the southern root-knot, *M. incognita*, the peanut root-knot, *M. arenaria*, and the Javanese root-knot, *M. javanica*. The southern root-knot nematode is ranked first in terms of negative impact on watermelon production, particularly in warm temperate climates. Many watermelon fields in Georgia are infested with one or more species of root-knot nematodes. A University of Georgia Cooperative Extension survey in southern Georgia consisting of 66 soil samples collected in 2018 found root-knot nematodes in 50% of the fields planted to watermelon. The average number of root-knot nematodes per 100-cubbic-centimeter soil sample was 27.3, in the range of two to 162 nematodes (Figure 1). Furthermore, molecular detection assays conducted by UGA's vegetable nematology laboratory showed that *M. incognita* (88%) followed by *M. arenaria* (38%) were the most widespread root-knot nematode species found in watermelon producing systems with 22% of the fields infested with both nematode species. In contrast, *M. javanica* had a very limited distribution in the fields surveyed (Figure 2).

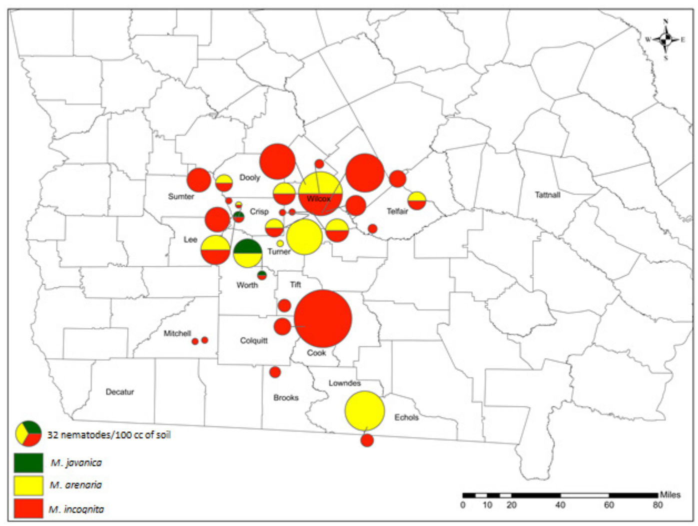

Figure 2. The distribution of three species of root-knot nematodes (*Meloidogyne incognita*, *M. arenaria*, and *M. javanica*) in watermelon fields in southern Georgia. Circles with different colors signify the nematode abundance (nematode numbers per 100 cubic centimeters of soil).

Biology and damage symptoms

Root-knot nematodes have been reported to cause up to 20-30% yield losses in watermelon. Watermelon plants infected by root-knot nematodes may show foliar symptoms such as slight stunting to severely suppressed growth, which often occurs in elliptical patterns in the field. Chlorosis or yellowing of the foliage may also occur (Figure 3A), and root galling is a classical symptom of root-knot nematode infections (Figure 3B). The galls disrupt the vascular system of plants, making them grow poorly, and sometimes leads to severe stunting of crops under

Figure 3. Foliar yellowing (A) and root galling (B) caused by root-knot nematodes on watermelon.

heavy infestation. Root galls vary in size and number, depending on the plant cultivars, the density of the nematode population, and the root-knot nematode species present in soil.

The life cycle of root-knot nematode is completed in three basic steps: egg, juvenile (J), and adult stages. Eggs are deposited in a gelatinous mass that protects eggs from environmental extremes (e.g., temperature) and microbes. The egg masses can be found on the surface of galled roots or embedded within the gall tissue and can contain up to 1000 eggs per mass. Under favorable conditions, egg development takes place and the first stage juvenile (J1) is formed. The J1 molts into second-stage juveniles (J2s) that hatch from eggs. The infective J2s invade plant roots and migrate toward the vascular system of the root tissues, where they develop permanent feeding sites. The feeding sites serve as a nutrient source for the J2 growth. The J2 molts to J3, which molts again to become the fourth-stage juvenile before become a mature female. The nematode completes its life cycle within three to four weeks, when mature females begin to reproduce eggs. However, the length of the life cycle and reproductive mode is dependent on root-knot nematode species, host crops, and environmental conditions. In southern Georgia, where the majority of watermelon is produced in the state, moderate to high temperatures and abundant rainfall will cause an increase in nematode development and reproduction. The nematode may complete two to three generations in watermelon, which requires 90 to 100 days to mature, resulting in higher nematode numbers in the soil and lower crop yields.

Root galling and watermelon growth

In most vegetable crops, including watermelon, the degree of root-knot nematode damage is associated with the number of nematodes present in the soil at planting. In fact, the crop yield loss is commonly associated with pre-plant infestation levels in the soil, as well as the loss of root function due to population increase and nematode reinfection of plants. Nematode populations in the soil are favored by environmental conditions such as high temperatures, moderate moisture, and sandy soils that promote the early appearance of symptoms and increase the severity of damage.

Using a greenhouse pot experiment, we have examined the reaction of 'Sugar Baby' watermelon to different population densities of *M. incognita*. The plants were infected with 500, 1,000, 2,000, 4,000, 8,000, and 16,000 nematodes per plant and grown for 35 days, after which the plants were examined for root galling and growth performance. Results showed that increasing the initial population densities of *M. incognita* significantly reduced several growth parameters of watermelon (Figures 4 and 5) including plant height, root dry weight, and shoot dry weight compared with the untreated control. In addition, root galling caused by the nematode increased with increasing nematode population densities (Figures 4 and 5). In general, this study indicates that higher nematode numbers will result in greater yield loss. Knowing about nematode pressure in the soil before planting a crop may help growers consider an appropriate management option for nematode control. These include pre- or post-plant applications of nematicides for short-term management. Having a soil sample analyzed for the presence and numbers of nematodes is one of the best approaches to determine whether a crop is at the risk of infection by root-knot nematodes. In Georgia, the best times to check soil samples are before planting in the spring (March to April) and after harvest in the summer (June to July), when the nematode population is likely at the highest.

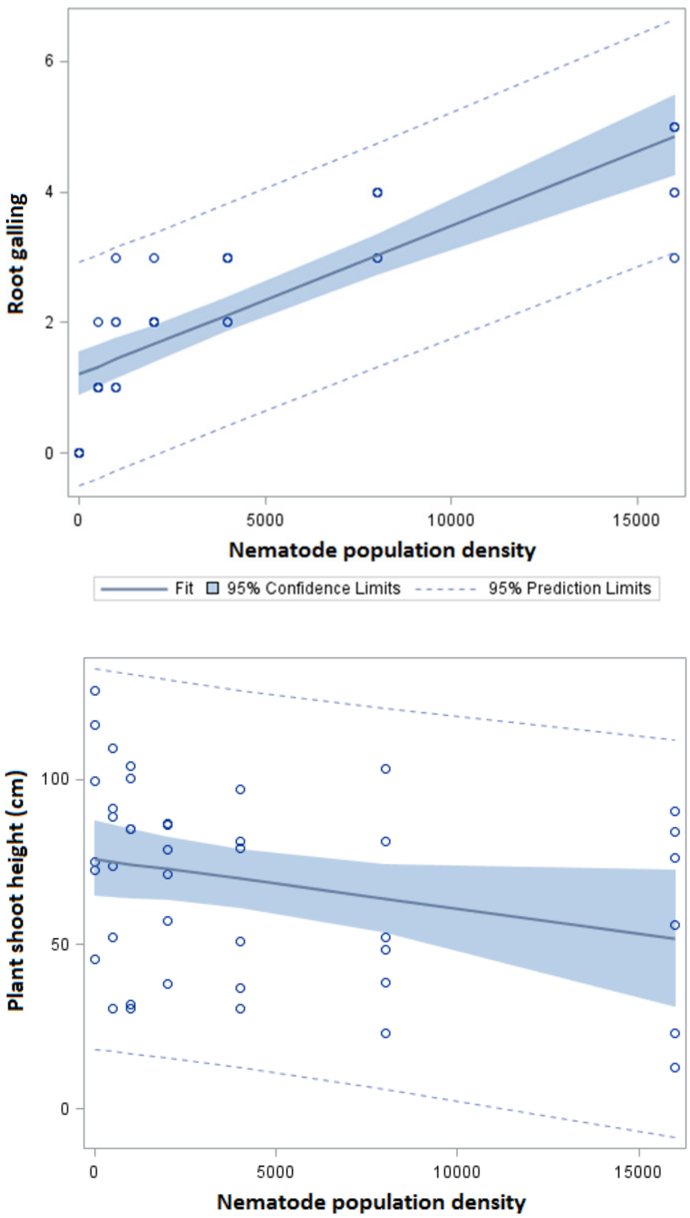

Figure 4. Relationships between the at-plant population density of root-knot nematode (*Meloidogyne incognita*) and root gall severity (A) and watermelon growth (B). Note: With the increase of population density of nematode in soil, root galling increased and watermelon growth (i.e., plant height) decreased.

Figure 5. The damage symptoms on the foliage (A) and roots (B) of 'Sugar Baby' watermelons infected with different population densities of southern root-knot nematode, *Meloidogyne incognita*.

Co-infection and watermelon growth

Root-knot nematodes, if present alone in soil, do not generally cause complete crop failure in mature watermelon plants. However, if the nematode and soilborne fungal diseases such as Fusarium wilt (caused by the fungus *Fusarium oxysporum* f. sp. *niveum*) are present in a complex, they could produce more severe damage (or the death of a crop) than when only one or the other pathogen is present. Co-infection of watermelon by root-knot nematodes and Fusarium wilt may lead to greater wilt severity in soil naturally infested with both pathogens than with only Fusarium wilt. Recent research in South Carolina revealed that *M. incognita*-susceptible rootstocks such as interspecific hybrid squash ('Strong Tosa') and bottle gourd ('Macis') as well as nematode-resistant rootstocks, such as hybrid citron ('Carolina Strongback'), retain resistance to Fusarium wilt when they are co-infected with both pathogens. However, when interspecific hybrid squash rootstocks are used to graft watermelon, producers should control root-knot nematodes because there is a risk of yield loss.

Managing root-knot nematodes in watermelon

Cultural control

At the farm level, cleaning all agricultural machines and equipment helps to avoid transporting nematodes to uninfested fields. Avoiding the introduction of nematodes will remove the need to manage it. Once present in a field, root-knot nematodes are difficult to eradicate and management is required. Removing residual roots in the soil has been reported to reduce nematode populations by 90% compared with leaving them in the soil, but removing roots is labor intensive. High temperatures (greater than 100 °F) are considered lethal for plant-parasitic nematodes. Soil temperatures can be increased by soil solarization, that is, by using clear plastic mulch to trap solar energy at the soil surface. Although this method controls nematodes effectively, the soil microbial populations and their activities can be negatively affected with repeated treatments. Crop rotation is also effective in reducing nematode populations, but knowing the specific nematode species is important when deciding on the crop for rotation. Planting a rotational crop that is resistant to one root-knot nematode species may not be effective against another species. Nematode sampling is important for growers to understand the population levels of different species present in a field. In the Southern U.S., a number of non-host crops such as *Mucuna pruriens* (velvet bean), *Aeschynomene americana* (joint vetch), *Tagetes* spp. (marigold), *Crotalaria juncea* (sunn hemp), and some cultivars of sorghum-sudangrass (*Sorghum bicolor* × *S. arundinaceum*) have been successfully used as cover crops for root-knot control. Multiple cropping sequences are possible, including summer and winter cover crops for managing nematodes.

Biological control

Biological control employs bacterial or fungal agents that antagonize nematodes by infecting eggs, juveniles, or adults or by producing toxic compounds that suppress their populations in soil. Different commercial formulations of biocontrol agents (bionematicides) have been marketed for controlling nematodes. For instance, commercial formulations of MeloCon WG (a.i. *Purpureocillium lilacinum* strain 251) and Majestene (*Burkholderia rinojensis* strain A396) are available with the potential of controlling plant nematodes in vegetable systems. These products have become increasingly important in integrated pest management programs.

Host resistance

The most important, and often most economical, management method is using root-knot nematode resistant or tolerant cultivars whenever they are available. Resistance to nematodes is characterized as the ability of a plant species to prevent nematode development or reproduction. Examining a core collection of *Citrullus* spp. from the U.S. Plant Introduction Station revealed that several accessions of *C. lanatus* var. *citroides* (citron melon) had moderate resistance against *M. incognita* and *M. arenaria*. Resistance sources to these nematode species have been identified in germplasm accessions of *Citrullus* spp., but they are not widely used by breeding programs. No commercial watermelon cultivar with resistance to root-knot nematodes is currently available.

Grafting

In the U.S., a growing root-knot nematode management practice in watermelon is grafting susceptible, high-yielding cultivars onto nematode-resistant rootstocks. This practice has been mostly used for control of Fusarium wilt of watermelon. For example, interspecific hybrid squash (*Citrullus maxima* × *C. moschata*) and bottle gourd (*Lagenaria siceraria*) rootstocks have been used as Fusarium-resistant rootstocks for grafting watermelon, but these rootstocks are susceptible to *Meloidogyne* spp. Moderate to high levels of resistance to different species of root-knot nematodes have been identified in *Citrullus* spp. accessions in both greenhouse and field studies. No rootstock or cultivar that has resistance to both pathogens was commercially available until recently. Research conducted in the southern U.S. has recently (2019) shown that a few *Citrullus lanatus* var. *citroides* rootstocks such as 'Carolina Strongback' exhibited resistance to both root-knot nematode (*M. incognita*) and Fusarium wilt, and could be used for grafting watermelon by growers to control these two pathogens in co-infected fields.

Chemical control

Using chemical products to control root-knot nematodes in infested soils relies on exposing nematodes to lethal concentrations (rates) of nematicides. Previously, managing root-knot nematodes and other soilborne pests and weeds was mainly dependent on a highly toxic chemical, methyl bromide. Following the Montreal Protocol (2005), which mandated an end of the use of methyl bromide, efforts have been made to seek nonfumigant alternatives for controlling parasitic nematodes. Some of the available fumigants for *Meloidogyne* spp. management are Telone II (a.i. 1,3-D dichloropropene), Vapam (metam sodium), and chloropicrin. Likewise, some of the non-fumigant nematicides that are registered for use in watermelon are Nimitz (a.i. fluensulfone), Vydate (oxamyl), Velum Prime (fluopyram), and Movento (spirotetramat). For more information concerning chemical management of plant-parasitic nematodes in vegetable crops, refer to UGA Extension Bulletin 1502, "Chemical Nematicides for Control of Plant-Parasitic Nematodes in Georgia Vegetable Crops."

Conclusion

Root-knot nematodes have increased in prevalence and damage severity in recent years due to the phase-out of methyl bromide. In watermelon, the pathological interaction between root-knot nematode and Fusarium wilt disease has also increased the complexity of control measures. Growers continue to suffer from economic losses despite the available management practices. Current efforts have been focused on using cultural and chemical controls as well as grafted watermelons on appropriate disease-resistant rootstocks. Using a combination of these management tactics is recommended when growers have serious problems with root-knot nematodes.

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Bulletin 1529 **March 2020**

Published by the University of Georgia in cooperation with Fort Valley State University, the U.S. Department of Agriculture, and counties of the state. For more information, contact your local UGA Cooperative Extension office.