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Nematode Management in Tomatoes, Peppers, and Eggplant[1]

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Solanaceous fruiting vegetable crops (tomato, pepper, eggplant) are widely grown in Florida and are very susceptible to damage from various plant-parasitic nematodes, which can severely reduce the vigor and yield of plants, and lead to symptoms like wilting, nutrient deficiency, plant stunting and overall crop failure. In Florida, root-knot nematodes (*Meloidogyne* spp.) are considered the most important nematode pest in these crops. This paper will help tomato, pepper and eggplant growers understand which plant-parasitic nematodes can affect their crop and what nematode management strategies are available to them.

Tomato, Pepper, and Eggplant Production in Florida

Tomato (*Solanum lycopersicum*), pepper (*Capsicum annum* and *C. chinense*), and eggplant (*Solanum melongena* and *S. macrocarpon*) are widely grown in Florida. Tomato is the most common (~ 20,000 acres), and in Florida, most varieties are fresh market tomato types (large round, grape and cherry tomatoes) (Frey et al, 2025). Pepper is grown on over 10,000 acres, and many different types of pepper are grown, with Bell peppers being the most common (Frey et al., 2025). Eggplants, also called aubergine and brinjal, are grown on a smaller acreage (~ 1,000 acres), mostly in South Florida (Roberts et al., 2025).

Main Plant-Parasitic Nematodes in Tomato, Pepper, and Eggplant

Plant-parasitic nematodes (PPN) are microscopic roundworms that feed on living plant tissues, mostly the belowground parts of plants like roots and tubers. All PPN have five life stages (egg, four juvenile stages and adult stage) and have a mouth stylet with which they feed by piercing and sucking on plant cells (mostly roots). Life cycles vary by species and with temperature and typically will range from 2–6 weeks. Different genera and species of nematodes can be important to tomato, pepper and eggplant in Florida. The most important ones are root knot nematodes (*Meloidogyne* spp.), followed by sting nematodes (*Belonolaimus longicaudatus*), reniform nematodes (*Rotylenchulus reniformis*), stubby root nematodes (Trichodoridae) and lesion nematodes (*Pratylenchus* spp.).

Root-knot nematodes (RKN, *Meloidogyne* spp.) cause the most significant yield losses on tomato, pepper and eggplant in Florida. The warm climate and sandy soil conditions are very conducive for these nematodes and many different species can be found in Florida. The main species of importance are *Meloidogyne incognita*, *M. enterolobii*, *M. javanica*, *M. arenaria*, *M. floridensis,* and *M. hapla*. RKN are endoparasitic nematodes, which means that they spend most of their life inside the root (Figure 1). The infective stage in the soil is the J2 (second-stage juvenile, about 0.5 mm long (Figure 2)) that emerges from the egg and will search for suitable roots. Once they enter the root, specialized cells ("giant cells") are formed with the sole purpose of feeding the developing nematode. Under favorable conditions, after about 2–4 weeks, females lay their eggs, which are secreted in egg masses on the root surface. RKN infection is usually accompanied by the formation of root galls, and when infestation is heavy, roots can appear severely swollen.

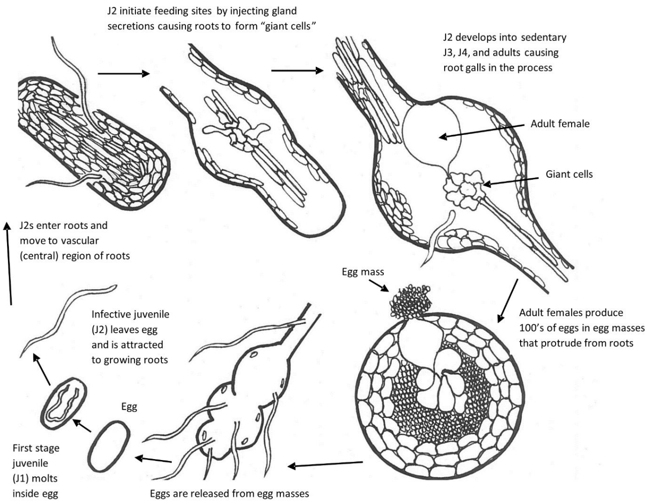

Figure 1. Life cycle of the root-knot nematode *Meloidogyne* spp.
Credit: H. Regier, adapted from G. Abawi and V. Brewster

Figure 2. Second-stage juvenile (J2) root-knot nematode (left) and adult female (right).
Credit: Left, H. Bui; Right, D. Moreira

Sting nematode (*Belonolaimus longicaudatus*) is also very common in Florida and probably the second most important nematode, especially on peppers. This nematode is a large (1–2 mm) ectoparasite (Figure 3 top), meaning they spend their entire life in the soil and feed by piercing and sucking on new emerging roots. This will stop the root from elongating, resulting in a short, stubby looking and ineffective root system. Stubby root nematodes (*Nanidorus minor*) are medium-sized (0.5–1 mm long) cigar-shaped nematodes with a curved stylet (Figure 3 bottom). They are very common in Florida and like sting nematodes, roots they infect can be shortened and "stubby" looking.

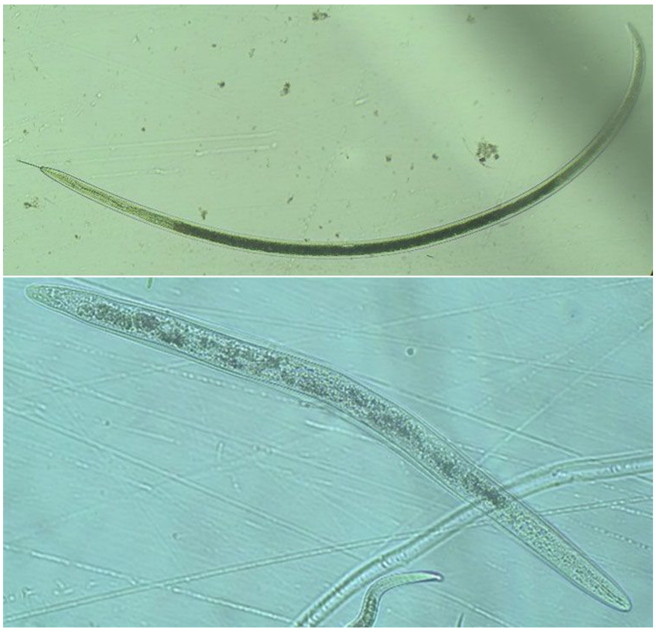

Figure 3. Sting nematode (*Belonolaimus longicaudatus*) (top): stubby root nematode (*Nanidorus minor*) (bottom).
Credit: J. Desaeger, UF/IFAS

Both root-knot, sting and stubby root nematodes have a high preference for soils with high sand content (>80% sand) and are common in sandy regions along the Gulf of America (formerly Gulf of Mexico) and Atlantic coasts.

Symptoms, Damage, and Diagnosis

Plant-parasitic nematodes (PPN) reduce the vigor and yield of plants. The typical symptoms of PPN damage are stunting, wilting, leaf discoloration and fruit malformation (Figures 4–10). All these symptoms can be (and often are) misidentified with other causes such as nutrient or water deficiency, plugged drip irrigation lines, or diseases related to bacteria or fungi. In Florida tomatoes, it is not uncommon to find combined infestations of Fusarium wilt (*Fusarium oxysporum* f. sp. *lycopersici*) together with root-knot nematodes, causing plants to prematurely die (Figure 5). The level of PPN damage is related to nematode population density, crop susceptibility, and prevailing environmental conditions. For example, under heavy nematode infestation, crop seedlings or transplants may fail to develop, maintain a stunted condition, or die, causing poor or patchy stand development (Figure 6).

Figure 4. Root-knot nematode damage to tomato (*M. javanica*): chlorotic and wilting plants (left), malformed roots with large, coalesced galls (right).
Credit: J. Desaeger, UF/IFAS

Figure 5. Root-knot nematode (*M. incognita*)—Fusarium wilt complex damage to tomato: wilted, dying plants (left), heavily galled roots (right).
Credit: J. Desaeger, UF/IFAS

Figure 6. Patchy stand development in pepper due to early root-knot nematode (*M. incognita*) damage, causing poor root development.
Credit: J. Desaeger, UF/IFAS

Under less severe infestation levels, symptom expression may be delayed until later in the crop season after several nematode reproductive cycles have been completed on the crop. In this case, aboveground symptoms will not always be readily apparent early within crop development, but with time and reduction in root system size and function, symptoms become more pronounced and diagnostic.

Whenever any of these aboveground symptoms are observed, roots should be checked to verify if nematodes are the cause. Root symptoms induced by root-knot nematodes can usually easily be seen as swollen areas (galls) on the roots of infected plants (Figures 4–10). Symptoms of root galling can in most cases provide positive diagnostic confirmation of nematode presence, infection severity, and potential for crop damage. While the presence of galls or knots on roots is usually a clear sign of root-knot nematode infection, nematode galls can be overlooked when small (early in the season, low nematode pressure) and when roots are covered with soil. Gall size may range from small to large depending on the interaction between the crop and RKN species, as well as the population density and time of infection. Northern RKN (*Meloidogyne hapla*) usually induces small galls while tropical species like guava RKN (*Meloidogyne enterolobii*) induce larger galls. That said, significant differences in virulence and damage may occur among geographical populations of different RKN species. In Florida, *M. hapla* is only found in fields where strawberries are grown and can be especially damaging when a solanaceous crop is planted as a double or relay-crop in early spring following the main strawberry crop. In fields where no strawberries are grown, the RKN species are mostly *M. incognita*, *M. javanica,* or *M. enterolobii*, all of them capable of causing significant root damage and crop loss.

Figure 7. Tomato plants showing dieback and wilting (left) and severely galled roots (right) due to guava root-knot nematode damage (*M. enterolobii*).
Credit: J. Desaeger, UF/IFAS

Figure 8. Pepper field showing patchy nematode hotspots showing yellowing and wilting (top), due to *M. incognita* (galled and swollen roots, bottom).
Credit: J. Desaeger, UF/IFAS

Figure 9. Root-knot nematode damage to pepper due to severe and mixed infestation of *M. enterolobii* and *M. incognita*: chlorotic and wilted plants (left), galled and swollen roots (right).
Credit: J. Desaeger, UF/IFAS

Figure 10. Root-knot nematode damage to eggplant; stunted plants (untreated) vs. treated with a nematicide (Vydate); bottom: eggplant root system showing root galls.
Credit: J. Desaeger, UF/IFAS

Root damage from other nematodes than root-knot is less conspicuous. Sting nematodes cause infected plants to form a tight mat of short roots, often with root tips having a swollen appearance. New root initials generally are killed by heavy infestations of the sting nematode, a symptom reminiscent of fertilizer salt burn. Sting nematodes can be particularly damaging to pepper (Figure 11).

Figure 11. Sting nematode (*Belonolaimus longicaudatus*) damage to pepper; patches with stunted plants (top), and severely reduced root system (bottom; infected plant left, healthy plant right).
Credit: J. Desaeger, UF/IFAS

Stubby root nematode infection can cause roots to have a bearded appearance and can look like sting nematode damage. Lesion nematodes may cause necrotic spots and dark lesions on the roots. Stubby root nematodes have been suspected by tomato growers of causing late season "yellow top" (Figure 12). However, such symptoms can also be caused by RKN, and other biotic and abiotic factors.

Figure 12. Late season "yellow top" symptoms on tomato; possibly caused by stubby root (or root-knot) nematode feeding.
Credit: J. Desaeger, UF/IFAS

Whenever plants grow poorly, the first course of action always should be to look at the roots. Abnormal looking roots are often a telltale sign of nematode damage (or another soilborne pathogen). However, for most nematodes, other than root-knot nematodes, diagnostic root symptoms may not be easily observed, and proper diagnosis will need to be done at a nematology lab. Sampling and diagnosis will require collecting soil and root samples from infected plants or hotspots, which typically occur as irregular patches of poorly growing plants. Sampling and diagnostic protocols are described in other Ask IFAS publications. It is always advisable to send both soil and roots for diagnosis. Check with your local UF/IFAS Extension office for assistance with nematode sample analysis. Samples can be sent for verification to the nematology lab at the UF/IFAS Gulf Coast Research and Education Center (UF/IFAS GREC) in Balm, FL, or to the UF/IFAS Nematology Assay Lab in Gainesville, FL.

Nematode Management

Field Sanitation and Monitoring

Nematodes are often introduced into new fields through infected plant material (transplants) and equipment. Therefore, sanitation should always be the first resource against PPN. When transplants are used, these should be healthy and nematode-free. Farm equipment should be cleaned when moving between fields, especially when fields are known to have (or have had) nematode problems. Nematodes are aquatic organisms and movement within a field is mostly with water. Therefore, limiting run-off water within a field is advisable.

After harvesting, the crop should be killed or rogued to stop any further nematode reproduction. Whenever feasible, removing nematode-infested (galled) roots from the field immediately after harvest is a good practice as this will reduce the nematode inoculum in the field. Also, as many weeds are known to be good hosts for PPN, good weed control during and after the crop will help with reducing nematode build-up.

Field monitoring by regularly checking roots for nematode symptoms and having soil analyzed for nematodes will allow identification of nematode hotspots in the field and adoption of more targeted management. Nematode hotspots may be associated with differences in field management but usually appear to be random.

Cultivar and Transplant Selection

Tomato and pepper are some of the few vegetable commodities in which host resistance against root-knot nematode is well established. Resistance in tomato against root knot nematode is governed by a single dominant gene *Mi*, which confers resistance to *M. incognita*, *M. arenaria*, and *M. javanica* (Regmi and Desaeger, 2019). *Mi* gene in tomato has also induced resistance to some piercing and sucking insects such as aphids and whiteflies (Kaloshian et al. 1995), although this effect is generally insufficient for providing field-level resistance against such pests. The level of RKN resistance in Mi-gene-bearing tomatoes can vary from good to intermediate among cultivars. Some of the RKN-resistant tomato cultivars grown in Florida are Sanibel, Daytona, Mariana, Skyway 687, Southern Ripe, SV 7631TD, and Felicity. More information on these and other cultivars, as well as their limitations can be found at https://edis.ifas.ufl.edu/publication/IN1250.

In pepper several genes (*N* and *Me* genes) have been identified that convey resistance to the same RKN species as the *Mi* gene in tomato (Fery et al., 1998). Similar to tomato, resistance can vary from good to intermediate. Some examples of RKN-resistant Bell pepper cultivars are Charleston Belle, Carolina Wonder and Hammerhead, and for specialty peppers Carolina Hot Pepper (Cayenne), Truhart-NR and Mississippi Nemaheart (Pimento), TigerPaw-NR (Habanero), and Flaming Jade (Serrano).

Grafting nematode-resistant rootstocks is another option that can be used for smaller growers, as cost is usually prohibitive for larger growers. Any of the RKN- resistant cultivars can be used as rootstock for this.

No resistant cultivars are available for eggplant, but a wild relative *Solanum torvum* can be used as a resistant rootstock. While eggplant is an excellent host for RKN, the crop often seems to be more tolerant to nematode damage, probably because of its deep and extensive root system.

Crop Rotation/Cover Crop

Crop rotation with non- or poor nematode host crops is difficult when dealing with nematodes that have a wide crop host range, like root-knot and sting nematodes. Some options of non/poor host rotation crops are root-knot-resistant tomato and pepper cultivars (see above). Also, if the RKN species present is *M. javanica*, even non-resistant pepper cultivars can be good rotation crops, as most populations of *M. javanica* do not infect pepper. Several crops from the Brassicaceae family, like cabbages and other crops, could also be good rotation crops as they are generally poorer hosts and suffer less yield loss than cucurbits.

Alternatively, if rotation crops are not an option, cover crops can be planted in between. In Florida, sunn hemp and sorghum-sudangrass are poor hosts to RKN, and good options to help manage RKN (Figure 13). In addition, the biomass from both cover crops produces nematicidal compounds when incorporated in the soil (Bui and Desaeger, 2021).

Figure 13. Sunn hemp (*Crotalaria juncea*) is a popular cover crop to help manage nematodes in Florida.
Credit: J. Desaeger, UF/IFAS

When using cover crops to help manage nematodes, one must keep in mind that almost always a mixed community of plant-parasitic nematodes is present in a field, often with different plant host preferences. For instance, sorghum-sudangrass is a poor host for most RKN species, but it is a good host for many other nematodes, including sting and stubby root nematodes. Also, the cover crop cultivar and RKN species can make a difference. For instance, cowpea (*Vigna unguiculata*), which is another common cover crop in Florida, can behave very differently depending on cultivar and RKN species (Wang et al., 2021). Cowpeas are generally very good hosts for RKN species like *M. arenaria*, *M. enterolobii,* and *M. javanica*, but not so much for *M. incognita* (Bui and Desaeger, 2021).

Nematicides

Nematode infestation in Florida fields is often so severe that nematicide applications are necessary. Nematicides can be separated into fumigants and non-fumigant products. Soil fumigants are 1,3-Dichloropropene (1,3-D, Telone), chloropicrin (Pic) or MITC/AITC-based products (KPam, Vapam, Dominus). Non-fumigant nematicides registered for cucurbit crops are oxamyl (Vydate®), ethoprophos (Mocap®, only for cucumber), fluensulfone, (Nimitz®), fluopyram (Velum®), and fluazaindolizine (Salibro®).

Biological nematicides include fungal (*Purpureocillium lilacinum*), bacterial (*Burkholderia rinojensis*) and plant-based (azadirachtin, thyme oil and others) products.

For more information and application rates on nematicides check the UF/IFAS Vegetable Production Handbook (Frey et al., 2024; Peres et al., 2024), and other EDIS publications ENY033 (“Non-Fumigant Nematicides Registered for Vegetable Crop Use”), and ENY065 (“Fumigant and Non-Fumigant Nematicides Labeled for Agronomic Crops in Florida”).

All chemical nematicides require a pesticide applicator license and in the case of fumigants a separate fumigant applicator license (check with your local UF/IFAS Extension office).

Cultural and other practices

Organic amendments: frequent applications of organic amendments (animal and green manures, compost, etc.) will increase soil organic matter and microbial activity while stimulating natural enemies that help to reduce the damage caused by PPN.Organic amendments also will increase the water- and nutrient-holding capacity of the soil, especially in sandy soils. Because nematodes will cause more damage to water-stressed plants, this can lessen the effects of nematode injury without reducing levels of damaging nematodes.

Fallowing is the practice of leaving the soil bare; it tends to be more effective when the soil is kept moist, which induces nematode eggs to hatch and emerging nematodes to starve because there is no food source. As many weeds are good hosts for nematodes, it is important to control weeds on which nematodes can survive during the fallow period. Fallowing is also more effective when combined with frequent tillage which can reduce nematode populations further by bringing them to the surface and exposing them to the sun.

Solarization by covering and heating up the soil with clear plastic for four to six weeks is another method that can be used to reduce nematodes in a field (Baker and Roistacher, 1957). However, as nematodes move downwards, nematode control tends to be limited to the upper soil layers. Another method of using heat to control nematodes is through the application of steam using specialized steam applicators (Fennimore and Goodhue, 2016).

Flooding: temporary and seasonal flooding of fields is practiced in some areas in south Florida and can provide good nematode control if flooding conditions can remain for at least 1–2 months. A variant of this method is anaerobic soil disinfestation (ASD) which includes applying a labile carbon source (molasses, rice bran, etc.) in combination with a high amount of water (Butler et al., 2012).

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Table 1. Nematode management options in solanaceous crops.

Nematode	Rotation	Cover crops	Resistance cv's	Nematicides
Root knot	Resistant tomato and pepper cv's, cabbages, grains	Sunn hemp, sorghum sudangrass	*Mi* tomato, *N/Me* pepper	Fumigants, Vydate, Nimitz, Velum, Salibro, biological products[1]
Sting	None	Sunn hemp	None	

[1]See details: https://edis.ifas.ufl.edu/publication/IN1250

For more information on general nematode management, see also Ditmar et al., 2024.

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