

The Peach Root-Knot Nematode: *Meloidogyne floridensis*, and its Potential Impact for the Peach Industry in Florida¹

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INTRODUCTION: Recent advances have been made with the development of low chill peach [*Prunus persica* (L.) Batsch] cultivars that are suitable for production in Florida (Olmstead *et al.* 2011). Peach is being promoted as an alternative crop for the declining citrus industry in Florida. At present there are approximately 1,000 acres of peach plantings in the north central portion of the Florida peninsula.

There are numerous pest and pathogen problems that will confront growers as this industry moves forward, and among the most troublesome soilborne pathogens are plant-parasitic nematodes. Root-knot nematodes (*Meloidogyne* spp.) are among the most important soilborne pathogens of peach. They are reported on peach in all the major production regions of the United States, which includes California, South Carolina and Georgia (Nyczepir *et al.* 1997). They are expected to be especially troublesome in Florida peach production because they are commonly encountered, and our soils are ideal for population increase.

Reported species that infect peach worldwide include *M. arenaria* (Neal, 1889) Chitwood; 1949, *M. hapla* Chitwood, 1949; *M. incognita* (Kofoid & White, 1919) Chitwood, 1949; and, *M. javanica* (Treub, 1885) Chitwood, 1949. In Florida, *M. javanica* and *M. incognita* have been found infecting peach. In a survey carried out in South Carolina, *M. incognita* was found in 95% of peach orchards, whereas *M. javanica* was found in only 5% (Nyczepir *et al.* 1997). Although it has been found in the southern United States (Wehunt 1984), *Meloidogyne arenaria* occurs less frequently than those other species. Nonetheless, there is no specific information regarding the occurrence of these nematode species infecting peach in Florida. It is worth mentioning that of these four root-knot nematode species, *M. arenaria* was the most prevalent species encountered in peach orchards in France (Scotto La Massese *et al.* 1990). Although the northern root-knot nematode, *M. hapla*, is reported infecting peach in some locations, it develops poorly (Esmenjaud *et al.* 1994). *Meloidogyne hapla* is rarely encountered in Florida soils except in strawberry fields located around Dover, Florida.

PEACH ROOTSTOCKS RESISTANT TO ROOT-KNOT NEMATODES: Many peach genotypes with different chill requirements have been screened for resistance to root-knot nematodes. The rootstocks ‘Nemaguard’ and ‘Okinawa’ were released as resistant to *M. incognita* and *M. javanica* many decades ago (Sharp *et al.* 1969). In subsequent breeding programs, two additional rootstocks, ‘Nemared’ and ‘Guardian’ were also selected as resistant to these two nematode species (Nyczepir *et al.* 1998). However, all of these rootstocks, were found to be susceptible to a Florida population of a root-knot nematode that was previously identified as *M. incognita* race 3 (Sherman and Lyrene 1983). After more careful study, the nematode was identified as a new species, *Meloidogyne floridensis*, and given the common name, the peach root-knot nematode (Handoo *et al.* 2004). This identification was based on more advanced morphological, molecular and host range studies.

Horticulturists at the University of Florida have been making a concerted effort to develop a low chill peach rootstock with resistance to this new nematode species. This research resulted in the release of the peach rootstock ‘Flordaguard’ (Sherman *et al.* 1991) (Fig. 1), and is currently recommended for all commercial peach in Florida. It is reported to provide resistance to the major root-knot nematode species in Florida, including *M. floridensis* (Olmstead *et al.* 2007). Recently, populations of *M. floridensis* infecting ‘Flordaguard’ have been reported, albeit in small numbers in commercial orchards (Brito and Stanley 2011) (J. A. Brito and D. W. Dickson, personal communication).

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Fig. 1. Peach 'Flordaguard' rootstock plants exhibiting red leaves in the new growth, a typical characteristic of this cultivar. Photography credit: Janete Brito.

GEOGRAPHICAL DISTRIBUTION: *Meloidogyne floridensis* has only been reported in Florida, where it has been found infecting different crops and a weed species in 12 counties including: Alachua, Collier, Miami-Dade, Hendry, Hillsborough, Indian River, Lake, Marion, Pasco, Seminole, St. Johns and St. Lucie (Brito *et al.*, 2008; 2010; Brito and Stanley, 2011; Church, 2005). In Florida, *M. floridensis* has been found infecting peach in a peach nursery, orchards and the horticultural field laboratory, University of Florida in Alachua County.

HOST STATUS: *Meloidogyne floridensis* was initially thought to be primarily a pathogen of peach, but recently other economically important crops and weeds have been reported as hosts.

Horticultural crops reported as hosts include: Basil (*Ocimum basilicum*) cv. Genovese; common bean (*Phaseolus vulgaris*); corn (*Zea mays*) cvs. Dixie 18 and Mp 710; crimson clover (*Trifolium incarnatum*); cucumber (*Cucumis sativus*); dill (*Anethum graveolens*); eggplant (*Solanum melongena*); gourd (*Cucurbita pepo*); green bean (*Phaseolus vulgaris*) cvs. Fortex and Heavyweight II; lima bean (*Phaseolus lunatus*) cv. Big Mama; mustard (*Brassica juncea*) cv. Florida Broadleaf; pepper (*Capsicum annuum*) cvs. California Wonder, Charleston Bell; snapbean (*Phaseolus* sp.); squash (*Cucurbita moschata*) cv. Yellow Crookneck; sugarbeat (*Beta vulgaris*) cvs. Alota, Bobcat, Mandella and Trinita; tobacco (*Nicotiana tabacum*) cv. NC 95; tomato (*Solanum lycopersicon*) cvs. Florida 47, Rutgers, Solar Set, and tomato hybrid Crista; vetch (*Vicia sativa*); and watermelon (*Citrullus lanatus*) (Brito *et al.* 2008, 2010; Cetintas *et al.* 2007; Church, 2005; Esmenjaud, 2009; Mendes and Dickson, 2010a, 2010b; Kokalis-Burelle and Nyczepir, 2004; Stanley *et al.* 2006; 2009). Ornamental plant hosts include: Calendula (*Calendula officinalis*) cv. Oktoberfest; dracaena (*Dracaena* sp.); hibiscus (*Hibiscus* sp.); impatiens (*Impatiens wallerana*); snapdragon (*Phaseolus* sp.); and verbena (*Verbena rigida*) (Brito *et al.* 2010; Mendes and Dickson, 2010b; Kokalis-Burelle and Nyczepir, 2004). Plant species reported as non-hosts include: Aster (*Aster* sp.) cv. Purple burst; basil cv. Summerlong; begonia (*Begonia* sp.); collards (*Brassica oleracea*); cosmos (*Cosmos bipinnatus*); cotton (*Gossypium hirsutum*); marigold (*Tagetes* sp.); myrobalan plum (*Prunus cerasifera*); parsley (*Petroselinum crispum*); passion fruit (*Passiflora edulis*); peanut (*Arachis hypogaea*); pepper cvs. Big Dad and Hot Lemon; sage (*Salvia officinalis*); sorghum sudangrass (*Sorghum bicolor*); soybean (*Glycine max*) cvs. Forrest and S64-J1; strawberry (*Fragaria virginiana*) cv. Quinault; and sum hemp (*Crotalaria juncea*) (Esmenjaud *et al.* 1997, Kokalis-Burelle and Nyczepir, 2004; Stanley *et al.* 2006; 2009; Mendes *et al.* 2009; Mendes and Dickson, 2010b). Plant species reported as poor hosts include: Sesame (*Sesamum indicum*) (Stanley *et al.* 2006). Weed species reported as hosts include (host status studies conducted under greenhouse conditions): Amaranth (*Amaranthus spinosus*); American pokeweed (*Phytolacca americana*); barnyard grass (*Echinochloa muricata*); cyprusvine (*Ipomoea quamoclit*); dichondra

(*Dichondra repens*); English watercress (*Nasturtium officinale*); molinillo (*Leonotis nepetaefolia*); morning glory (*Ipomoea triloba* and *I. violacea*); redroot pigweed (*Amaranthus retroflexus*); spurge nettle (*Cnidoscolus stimulosus*); velvet leaf (*Abutilon theophrasti*); wild mustard (*Brassica kaber*); wild cucumber (*Cucumis anguria*); and zebrina (*Zebrina pendula*). Weed species considered as poor hosts include: Sickie pod (*Senna obtusifolia*) and jimsonweed (*Datura stramonium*). Weed species considered as nonhosts include: Beggarweed (*Desmodium purpureum*); coffee senna (*Cassia occidentalis*); crabgrass (*Digitaria sanguinalis*); crowfootgrass (*Dactyloctenium aegyptium*); evening primrose (*Oenothera biennis*); fall panicum (*Panicum dichotomiflorum*); johnson grass (*Sorghum helepense*); showy croton (*Crotalaria spectabilis*); sorghum (*Sorghum bicolor*); and yellow foxtail (*Setaria pumila*) (Kaur *et al.* 2007). Under field conditions, only one weed species, lilac tassel flower (*Emilia sonchifolia*) has been found infected with this nematode (Brito *et al.* 2008).

MORPHOLOGICAL CHARACTERISTICS AND DIAGNOSIS: Morphology: *Meloidogyne floridensis* females are pear-shaped, white colored, and sometimes transparent; whereas the males and second-stage juveniles are vermiform. Females: Body length 525-890 µm; body width 356-648 µm; stylet length 10-16.6 µm; vulval slit length 19.6-31.3 µm. Perineal pattern with high narrowly broken network-like striae in and above anal area, faint lateral lines interrupting transverse striae and smooth wavy lines in the outer field. Prevalval region, typically without striae; vulva and anus sunken. Males: Body length 564-2,038 µm; body width 17-41 µm; stylet length 17-24.5 µm; tail length 6-18.6 µm. Second-stage juveniles: Body length 310-482 µm; body width 12-16 µm; stylet length 10-11.4 µm; tail length 34-48 µm; hyaline tail terminus length 5.9-12 µm. Lateral field with four lines. *M. floridensis* closely resembles *M. incognita*, *M. christiei*, *M. graminicola* and *M. hispanica*, but in studies involving both light microscope and scanning electron microscope, it differs from these root-knot nematode species either by the body length, shape of head, tail and tail terminus of second-stage juveniles; body length and shape of spicules in males, and a distinctive female perineal pattern (Handoo *et al.*, 2004; Stanley *et al.*, 2009). Isozyme assisted diagnosis: The isozyme phenotypes, particularly esterase (EST) and malate dehydrogenase (MDH) (Dickson *et al.* 1970; Esbenshade and Triantaphyllou 1985), have been used successfully for the identification and differentiation of *M. floridensis* from other root-knot nematodes occurring in Florida (Brito *et al.* 2008, 2010). The species specific EST phenotype (F3) (Fig. 2) found in *M. floridensis*, can be used to distinguish this nematode species from *M. arenaria*, *M. graminis*, *M. graminicola*, *M. hapla*, *M. incognita*, *M. javanica*, *M. enterolobii* and *M. partityla*, whereas MDH, is useful to separate *M. floridensis* from *M. hapla*, *M. graminis*, *M. graminicola*, *M. enterolobii* and *M. partityla*. However, MDH has a lower diagnostic value than EST because the MDH phenotype (N1) pattern from *M. floridensis* is identical to that of *M. arenaria*, *M. incognita* and *M. javanica*. This fact should be taken into consideration, mostly when dealing with mixed root-knot nematode species. In our laboratory, these analyses are often used in combination with classical morphological methods for a reliable identification of *Meloidogyne* spp. Although isozyme analysis has a high diagnostic value for separation of *Meloidogyne* spp., it can only be performed using females. DNA marker assisted diagnosis: Research has been carried out by DPI nematologists in collaboration with IFAS/University of Florida to find DNA markers, which are both independent of nematode life stages, and useful to identify and distinguish root-knot nematodes found in Florida, including *M. floridensis*. Results have shown that the PCR products using C2F3/1108 primer set were 1.2 kb for both *M. floridensis* and *M. arenaria*, and 1.7 kb for *M. javanica* and *M. incognita*. *M. enterolobii* produced a fragment of ca. 700 bp, whereas *M. graminis*, *M. graminicola*, *M. hapla* and *M. partityla* produced a fragment of ca. 530 bp. This primer set has been useful for distinguishing *M. floridensis* from all other root-knot nematode species except *M. arenaria*. Further studies are in progress to discriminate these two nematode species.

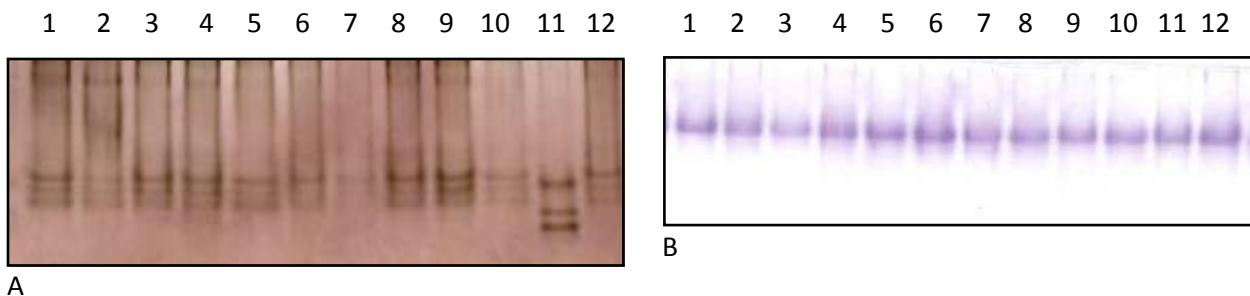


Fig. 2. Enzyme phenotypes of *Meloidogyne floridensis* from Florida. A) Esterase phenotypes (EST). Lanes 1 through 10 and 12: extract of a single female of *M. floridensis* (EST=F3), and lane 11: extract of a single female of *Meloidogyne javanica* (control) (EST=J3). B) Malate dehydrogenase phenotypes. Lanes 1 through 10 and 12: extract of a single female of *M. floridensis* (Mdh=N), and lane 11: extract of a single female of *M. javanica* (Mdh=N1).

SYMPTOMS: *Meloidogyne floridensis* induces the same typical symptoms as those reported for other agriculturally important species of root-knot nematodes. The above ground symptoms include stunted growth, leaf yellowing, canopy dieback and plant wilting. Depending on the population density occurring within a field, plant symptoms may appear as patches of damaged plants, with the severity of damage being variable. Infected plants exhibit root swellings and galls on young root hairs as well as major roots (Fig. 3). Root galls harbor the nematode in different stages of development. One can expect to find second through fourth stage juveniles, pear-shaped females, and egg masses with varying numbers of eggs contained within. The latter is mostly found adhering to the root surface. The females are sedentary (immobile), whereas the second-stage juvenile, commonly referred to as the preparasitic stage, is mobile and can move freely in soil as well as within root tissue. *M. floridensis* has been found in agricultural fields commingled with other species of root-knot nematodes, including *M. incognita*, *M. javanica* and *M. enterolobii*, infecting common bean and tomato, respectively (Brito *et al.* 2008).



Fig. 3. Peach (*Prunus persica*) rootstock cv. Flordaguard showing root galling induced by *Meloidogyne floridensis* infection. Photography credit: M. Beckman and J. A. Brito.



Fig. 4. Peach tree in the foreground infected by root-knot nematodes. Growth is greatly reduced. Infected trees generally continue to decline, and produce poor quality fruit.
Photography credit: Janete Brito.

ECONOMIC IMPORTANCE: In recent years, many abandoned citrus groves have been replaced with peach orchards. This is primarily due to the pressure of several diseases of citrus in Florida. Peach has the potential to become a growing industry in the state because of early fruit production that reaches the market before that of other peach-growing states. In some of these peach orchards, many young peach trees grafted on Flordaguard rootstock have shown serious declining symptoms caused by root-knot nematode infection (Fig. 4) (Dickson and Brito, unpublished). Nematode surveys in these new peach orchards are in progress to assess the root-knot nematode species involved in the decline of the peach trees. The detection of heavily galled Flordaguard may be due to outcrossed seedlings; however, it is possible that some infected plants may be a result of resistance-breaking races of the most frequently encountered root-knot nematode species, *M. arenaria*, *M. incognita* and *M. javanica*. These hypotheses deserve further investigation. It is known that *M. floridensis* has the ability to reproduce on other crops reported to be resistant to root-knot nematodes, namely, tomato hybrid cv. Crista and corn cv. Mp 710 (Stanley *et al.*, 2009). With its resistance-breaking ability, the impact of this nematode species as well as other species of root-knot nematodes will likely increase as growers rely more on the use of root-knot nematode resistance in high-value crops, especially since fumigant and nonfumigant nematicides are becoming less available on the market.

PREVENTION AND MANAGEMENT: The ability of root-knot nematodes to reproduce on resistant peach cultivars and other crops poses a challenge for the implementation of management strategies in infested areas. The following management practices have been suggested:

- Exclusion is the most economical and effective management method for avoiding plant-parasitic nematodes prior to introduction of peach seedlings into new orchards.
- Plant only healthy peach seedlings obtained from a reliable commercial source known to produce healthy disease-free seedlings.
- Sanitation practices should be implemented to avoid the spread of root-knot nematodes and any other plant-pathogenic nematode within and between nursery stock production sites, agricultural fields and orchards.
- Growers should contact their county Extension personnel and nematologists at the University of Florida for proper sampling procedures, sample submission methods, nematode species identification and management strategies.

LITERATURE CITED

- Brito, J.A., R. Kaur, R. Cetintas, J.D. Stanley, M.L. Mendes, E.J. McAvoy, T.O. Powers, and D.W. Dickson. 2008.** Identification and isozyme characterization of *Meloidogyne* spp. infecting horticultural and agronomic crops, and weed plants in Florida. *Nematology* 10: 757-766.
- Brito, J.A., R. Kaur, R. Cetintas, J.D. Stanley, M.L. Mendes, T.O. Powers, and D.W. Dickson. 2010.** *Meloidogyne* spp. infecting ornamental plants in Florida. *Nematropica* 40: 87-103.
- Brito, J.A., and J.D. Stanley. 2011.** Nematology Section in Dixon, W. and Andson, P. (Eds.). Tri-ology, FDACS/DPI, Vol. 50. Number 1 <http://www.freshfromflorida.com/Divisions-Offices/Plant-Industry/Plant-Industry-Publications/Tri-ology-FDACS-DPI/Volume-50-Number-1-January-February-2011/January-February-2011-Nematology-Section> (Accessed 2014 August 15).
- Cetintas, R., R. Kaur, J.A. Brito, M.L. Mendes, A.P. Nyczepir, and D.W. Dickson. 2007.** Pathogenicity and reproductive potential of *Meloidogyne mayaguensis* and *M. floridensis* compare with three common *Meloidogyne* spp. *Nematropica* 37: 21-31.
- Church, G.T. 2005.** First report of the root-knot nematode *Meloidogyne floridensis* on tomato (*Lycopersicon esculentum*) in Florida. *Plant Disease* 89: 527.
- Dickson, D.W., J.N. Sasser, and D. Huisingh. 1970.** Comparative disc-electrophoretic protein analysis of selected *Meloidogyne*, *Ditylenchus*, *Heterodera*, and *Aphelenchus* spp. *Journal of Nematology* 2: 286-293.
- Esbenshade, P.R., and A.C. Triantaphyllou. 1985.** Use of enzyme phenotypes for identification of *Meloidogyne* species. *Journal of Nematology* 17: 6-20.
- Esmenjaud, D., J.C. Minot, R. Voisin, J. Pinochet, and G. Salesses. 1994.** Inter- and intraspecific resistance variability in Myrobalan plum, peach and peach-almond rootstocks using 22 root-knot nematode populations. *Journal of American Society of Horticultural Science* 119: 94-100.
- Esmenjaud, D., J.C. Minot, R. Voisin, J. Pinochet, M.H. Simard, and G. Salesses. 1997.** Differential response to root-knot nematodes in *Prunus* species and correlative genetic implications. *Journal of Nematology* 29: 370-380.
- Esmenjaud, D. 2009.** Resistance to root knot nematodes in *Prunus*: Characterization of sources, marker-assisted selection and cloning strategy for the *Ma* gene from myrobalan plum. *Acta Horticulturae* 814: 707-714.
- Handoo, Z.A., A.P. Nyczepir, D. Esmenjaud, J.G. vander Beek, P. Castagnone-Sereno, L.K. Carta, A.M. Skantar, and J.A. Higgins. 2004.** Morphological, molecular, and differential-host characterization of *Meloidogyne floridensis* n. sp. (Nematoda: Meloidogynidae), a root-knot nematode parasitizing peach in Florida. *Journal of Nematology* 36: 20-35.
- Kaur, R., J.A. Brito, and J.R. Rich. 2007.** Host suitability of selected weed species to five *Meloidogyne* species. *Nematropica* 37: 107-120.
- Kokalis-Burelle, N., and A.P. Nyczepir. 2004.** Host range studies for *Meloidogyne floridensis*. *Journal of Nematology* 36: 328.
- Mendes, M.L., R. Kaur, and D.W. Dickson. 2009.** Reaction of marigold genotypes to three new root-knot nematodes occurring in Florida. *Nematologia Brasileira* 33: 307-308.
- Mendes, M.L., and D.W. Dickson. 2010a.** Reproduction of root-knot nematodes on four sugarbeet cultivars. *Journal of Nematology* 42: 258.
- Mendes, M.L., and D.W. Dickson. 2010b.** Suitability of some annual crops to three species of root-knot nematodes. *Nematropica* 40: 142.
- Nyczepir, A.P., R.W. Miller, and T.G. Beckman. 1997.** Root-knot nematodes on peach in the southeastern United States: An update and advances. *African Plant Protection* 3: 115.
- Nyczepir, A.P., D. Esmenjaud, and J.D. Eisenback. 1998.** Pathogenicity of *Meloidogyne* sp. (FL-isolate) on *Prunus* in the southeastern United States and France. *Journal of Nematology* 30: 509.
- Olmstead, M., J. Chaparro, and J. Ferguson. 2007.** Rootstocks for Florida stone fruit. Florida Cooperative Extension Service, Institute of Food and Agricultural Services, University of Florida. <http://edis.ifas.ufl.edu/pdf/HS/HS36600.pdf>. [accessed 2014 September 02].

- Olmstead, M., J. Williamson, J. Chaparro, and T. Crocker. 2011.** Alternative opportunities for small farms: Peach and nectarine production review. <http://edis.ifas.ufl.edu/pdf/HS/HS36600.pdf>. [accessed 2014 December 01].
- Scotto La Massese, C., D. Esmenjaud, J.C. Minot, and R. Voisin. 1990.** Host suitability in the genus *Prunus* to *Meloidogyne arenaria* particularly clones and intra-specific hybrids of *P. cerasifera*. *Acta Horticulturae* 283: 275-284.
- Sherman, W.B., and P.M. Lyrene. 1983.** Improvement of peach rootstock resistant to root-knot nematodes. *Proceedings of the Florida State Horticultural Society* 96: 207-208.
- Sherman, W.B., P.M. Lyrene, and R.H. Sharpe. 1991.** Flordaguard peach rootstock. *HortScience* 26: 427-428.
- Sharp, R.H., C.O. Hesse, B.A. Lownsberry, V.G. Perry, and C.J. Hansen. 1969.** Breeding peaches for root-knot nematode resistance. *Journal of the American Society for Horticultural Science* 94: 209-212.
- Stanley, J.D., J.A. Brito, N. Kokalis-Burelle, J.H. Frank, and D.W. Dickson. 2009.** Biological evaluation and comparison of four Florida isolates of *Meloidogyne floridensis*. *Nematropica* 39: 255-271.
- Stanley, J.D., N. Kokalis-Burelle, and D.W. Dickson. 2006.** Host status of *Meloidogyne floridensis* on selected weeds and cover crops common to Florida. *Nematropica* 36:148 (Abstr.).
- Wehunt, E.J. 1984.** Nematode parasites of peach and other crops. Pp. 435-455 in W.R. Nickle (ed.). *Plant and Insect Nematodes*. Marcel Dekker: New York.