2019–2020 Florida Citrus Production Guide: Citrus Root Weevils[1]

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Citrus root weevils represent a complex of species known to infest citrus trees and various alternate host plants in Florida. The most common species infesting citrus in order of greatest geographical distribution are the Diaprepes root weevil, *Diaprepes abbreviatus*, the blue-green citrus root weevils, *Pachnaeus litus* and *Pachnaeus opalus*, the little leaf notcher, *Artipus floridanus*, and the Fuller rose beetle, *Asynonychus godmani*. Other lesser species inhabit citrus on occasion.

All citrus root weevils have a similar life cycle. They have three immature stages: egg, larva, and pupa. Adult weevils emerge from the soil and lay eggs on host plants aboveground, the larvae drop to the soil to feed on roots, and the pupae and teneral adult stages are spent belowground. Adults emerge from the soil throughout the year. Peak emergence varies within species and by geographical region (ridge vs. coastal and interior flatwoods). Peak adult emergence for the blue-green root weevils and Fuller rose beetle is normally April and May. Diaprepes adult emergence from the soil peaks in late May to early July, while peak adult abundance on the tree canopy parallels adult emergence in May/June but can have a second peak in late August to mid-October. The second peak is sporadic. Little leaf notcher has three generations per year. Although there is some overlap of generations, adults appear most abundant on trees in April/May, July/August, and October/November. All adult weevils are attracted to the nonreflective silhouette of the citrus tree trunk. Little leaf notcher and Fuller rose beetle are flightless and must crawl up the trunk, but other species will fly to the canopy.

The most visible plant damage resulting from adult feeding is notching of the margins of leaves of young, tender shoots. Notching patterns differ slightly among species and can be confused with grasshopper injury. Prolonged leaf feeding by adults appears to cause no economic effects in mature groves; however, on occasion, feeding will cause virtual defoliation of small replants.

With the exception of little leaf notchers, which prefer a weed host, larval feeding injury to the roots by other root weevils, particularly Diaprepes root weevil, can have a devastating effect on citrus trees because all larval stages feed on the roots for most of the year. Tiny hatchlings feed on fibrous roots, whereas larger larvae feed on the larger structural roots, forming deep grooves as they consume the outer bark, including the cambium layer. Roots may

1. This document is ENY-611, one of a series of the Entomology and Nematology Department, UF/IFAS Extension. Original publication date July 2000. Revised September 2013, April 2016, May 2018, and March 2019. Visit the EDIS website at https://edis.ifas.ufl.edu for the currently supported version of this publication. This publication is included in SP-43, *2019–2020 Florida Citrus Production Guide*. For a copy of this handbook, request information on its purchase at your local UF/IFAS Extension office.

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be girdled and killed in the process, or the crown may be girdled causing tree death. Larval feeding sites predispose the root system to infection and girdling by *Phytophthora* spp., thereby exacerbating economic loss. The rootstocks trifoliate orange and hybrid Swingle citrumelo are resistant to the complex of *P. nicotianae* and Diaprepes root weevil, while Cleopatra mandarin is susceptible to this complex. When *P. palmivora* is coincident with *P. nicotianae* in fine-textured, poorly drained soils, Swingle citrumelo is more vulnerable to attack by the complex than is Cleopatra mandarin. See also PP-156, *Phytophthora Foot Rot and Root Rot* and the Diaprepes Task Force website (http://www.crec.ifas.ufl.edu/ extension/diaprepes/index.shtml), especially the management key on the website (http://www.crec.ifas.ufl.edu/extension/diaprepes/key.shtml).

Pest Management

Methods of Sampling Root Weevil Larvae and Adults

The population abundance and distribution of endemic citrus root weevils, regardless of species, vary from grove to grove, within a grove, and within a season. The seasonal abundance of adults within a citrus grove can be monitored using ground traps to capture emerging adults or via visual sighting of adults in the tree. No methods exist for monitoring larvae in the soil. By monitoring adult emergence using traps, the approximate time and intensity of adult emergence can be estimated for each infestation. By knowing the species of weevil and their seasonal emergence pattern from soil, a grower can apply adult control measures when weevil populations are highest. Research suggests that adult emergence often coincides with the onset of summer rains in late May through June, soil temperature, and the summer flush in central Florida groves.

Cultural Considerations

Citrus root weevil management begins with the selection of a Phytophthora-resistant rootstock that is certified weevil-free. Optimal soil drainage is fundamental to citrus root weevil management, particularly in heavier soils common to the coastal and interior flatwoods where insect and pathogen populations are highest. Tree decline associated with Diaprepes distribution is often patchy within groves and most obvious in lowlands. Stressed trees frequently harbor higher populations of adults because these stressed trees frequently generate more leaf flushes as food for adults. Spot-treating these locations with a chemical or biological agent should help. Regular fertilization and irrigation are crucial to new root growth in weevil-infested groves. Fertigation at monthly intervals has been used by growers to promote the growth of fibrous roots after Diaprepes has destroyed the taproot and inner crown of the tree. Skirt pruning and trunk banding can be effective in controlling flightless weevil species. Weed control is also needed to prevent movement into trees from stems of grasses and/or broadleaf weeds. Weed control is probably beneficial in reducing populations of alternate host plants. **The use of sound cultural practices by the grower should be adequate for managing all citrus root weevils on mature trees except for the Diaprepes root weevil and blue-green citrus root weevils.**

A wide range of parasites, predators, and pathogens attack citrus root weevils at one or more developmental stages within the tree canopy or in the soil. Most of these natural enemies are widely distributed and are general feeders. When focusing on cultural tactics favoring tree health and not using chemical methods, growers are conserving and augmenting the natural enemies of citrus root weevils.

Pest Control Considerations

Pest management of Diaprepes and, to a lesser extent, other citrus root weevils must begin with control of different life stages, particularly adult weevils, using the following options: 1) foliar sprays for egg and adult suppression, 2) chemical barriers for larval control, and 3) biological control of all subterranean stages with nematodes. The application of these control tactics is timed according to monitoring of adult emergence and the onset of leaf flushing in the spring/summer period. Any of these tactics should reduce root injury and help sustain root health from grove to grove. For many groves, however, pest management might differ according to: 1) rootstock susceptibility to soil-borne diseases (i.e., *Phytophthora* spp.) and 2) root stress caused by excessive flooding and poor drainage of sandy loam soils. In certain grove situations, a soil fungicide for control of *Phytophthora* spp. should be advised (see fungicide section below).

Newly planted resets and groves younger than 5 years old with an established Diaprepes infestation on a susceptible rootstock can decline within 2 years without adult and/or larval control. A similar grove situation involving a resistant rootstock will have lesser tree decline but will require adult suppression. **Remember, groves planted on deep, sandy soils will often require no supplemental control and can rely on biological control agents.**

Foliar sprays of different contact (knockdown) insecticides that include petroleum oil to improve residual effect are used to target adult weevils in the tree canopy. Although foliar sprays have been used by growers to suppress adults any time of the year, research in central Florida has shown conclusively that root injury is lessened and overall tree health improved when two foliar sprays are used 4 weeks apart during peak summer flush in late May through June, along with an egg sterilant in the last application. The purpose of adult suppression with foliar sprays is to limit the number of gravid females and egg deposition, thereby reducing the number of larvae entering the soil. An egg sterilant such as Micromite 80WGS has a 6-week residual effect, during which females lay sterile eggs and eggs contacting the leaf surface are nonviable. The addition of petroleum oil to the spray mixture affects the bonding characteristics of the substance, bonding the egg mass to the leaf.

Multiple applications of most foliar sprays within a season can incite an abnormal increase in spider mite populations; any pesticide, when used frequently, might cause secondary pest outbreaks or lead to resistance.

A chemical barrier applied as a band to the soil surface beneath the tree through an herbicide applicator provides a treated surface that will kill newly hatched invasive larvae before they reach the root system. The chemical must be uniformly applied from the trunk to the dripline of the tree to a moistened soil surface devoid of litter. Greater spray volume (~40 gal/A) should ensure greater uniformity of coverage. Disturbance of the soil beneath the trees should be minimized to protect the soil barrier. Since neonates are killed upon exposure to treated soil as they pass through the barrier, this control tactic is best used for resets and young plantings infested with Phytophthora and where root injury by larvae must be minimal.

Timing chemical application to the time of year when larval entry into the soil is highest requires monitoring of adult weevils in the tree. Since highest larva recruitment occurs just after peak adult emergence, growers should apply soil treatment in early July, about 2 weeks after peak adult emergence in central Florida. Peak adult emergence is generally 2 to 3 weeks earlier in coastal groves.

Currently, Brigade WSB, a synthetic pyrethroid, is the only chemical registered for neonatal larvae control and applied as a soil barrier. Brigade has about 3 weeks residual presence in the soil and will suppress ants foraging on the soil surface. Generally, ant predators will recover after 30 days.

Parasitic nematodes that specifically attack insects are infectious to all larval stages of citrus root weevils. They are naturally found in citrus soils, where they inflict mortality to all weevil life stages they contact. Depending on availability, nematodes are also sold as biopesticides to control citrus root weevil larvae. They should be applied during months when soil surface temperatures are expected to exceed 70°F. Weevil larvae are generally most abundant in the soil during the summer (mid-July through September); therefore, one or more nematode applications are recommended at this time of year if soil moisture via natural causes and/or irrigation is adequate. Nematodes should not be applied within 4 weeks of nematicide use. Properly modified herbicide applicators or microsprinkler irrigation systems are used to deliver nematodes into pre-moistened soil. Application of approximately one acre-inch of water should also be applied to the irrigated acre immediately following application. Application late in the day or on cloudy days is encouraged to reduce nematode desiccation and exposure to lethal UV radiation.

Nematode products are most effective when applied in sandy soils with coarser soil texture and are less effective in very fine-textured soils at recommended rates. Higher rates can be applied to very fine-textured soils.

A fungicide for control of *Phytophthora* spp. may be recommended under the following conditions as a supplemental strategy to larval and adult weevil control: 1) the soils are fine-textured, poorly drained, or high in pH and calcium carbonate, 2) the trees are on rootstocks susceptible to *Phytophthora* spp., and 3) populations are above the damaging levels (20 and 40 propagules per cm^3 soil) for *P. nicotianae* and *P. palmivora*, respectively. Remember, larval and/or adult weevil control must be effective before fungicide treatment is justified.

Recommended Chemical Controls

READ THE LABEL.

See Table 1.

Rates for pesticides are given as the maximum amount required to treat mature citrus trees unless otherwise noted. To treat smaller trees with commercial application equipment including handguns, mix the per acre rate for mature trees in 250 gallons of water. Calibrate and arrange nozzles to deliver thorough distribution and treat as many acres as this volume of spray allows.

Table 1. Recommended chemical and biological controls for citrus root weevils.

IRAC MOA[1]	Pesticide Trade name	Rate/Acre[2]	Comments	Pests controlled
Parasitic nematodes				
NR	**Nemasys R**			
	Nemasys R	18,000–40,000 nematodes or greater per square foot	Nemasys R contains live nematodes to reduce *Diaprepes* and *Pachnaeus* sp. subterranean stages. Make one or more applications per year during the rainy season through fall. Apply through microirrigation or through herbicide boom to moist soil; one-half to one inch irrigation needed after application.	**Root weevils**
Soil Barrier				
3	**Bifenthrin**			
	Brigade WSB	0.25–0.5 lb ai	*Restricted use pesticides. Apply uniformly to moist, weed-free soil. Do not apply via irrigation. Do not exceed 32 oz per season.	**Root weevils**, fire ants, Asian cockroach
Foliar Spray				
1A	**Carbaryl**			
	Sevin 80 S + Petroleum Oil 97+% (FC435-66, FC 455-88, or 470 oil)	5–10 lb + 1 gal oil	Contact/residual foliar spray. Lower rates will result in reduced residual activity. Do not exceed 20 lb a.i./acre/year for all uses. Do not exceed 2 applications per season. May increase spider mite populations. Do not apply when temperature exceeds 94°F. 470 weight oil has not been evaluated for effects on fruit coloring or ripening. Heavier oils are more likely to be phytotoxic than lighter oils.	**Root weevils**, orangedog, katydids, grasshoppers, crickets, scale
	Sevin 4 F + Petroleum Oil 97+% (FC435-66, FC 455-88, or 470 oil)	1–2 gal + 1 gal oil		
	Sevin XLR + Petroleum Oil 97+% (FC435-66, FC 455-88, or 470 oil)	1–2 gal + 1 gal oil		
1B	**Acephate**			
	Orthene 97	0.5–.075 lb	Contact/residual spray. Nonbearing only. Apply at 100 gal water/ acre or less.	**Root weevils**
1B	**Phosmet**			
	Imidan 70 WP	1–2 lb	Contact foliar spray.	**Root weevils**
3	**Fenpropathrin**			
	Danitol 2.4 EC	16–21 oz	*Restricted use pesticide. Contact foliar spray. Do not apply when temperatures exceed 94°F	**Root weevils**, thrips, citrus psyllid
15	**Diflubenzuron**			
	Micromite 80 WGS + Petroleum oil 97+% (FC435-66, FC 455-88, or 470 oil)	6.25 oz + 1 gal oil	*Restricted use pesticide. Residual foliar spray. Maximum of 3 applications per season. Do not apply when temperature exceeds 94°F. 470 weight oil has not been evaluated for effects on fruit coloring or ripening. Heavier oils are more likely to be phytotoxic than lighter oils. Do not combine with Boron within 21 days to harvest.	**Root weevils**, citrus leafminer, citrus rust mites

[1] Mode of action class for citrus pesticides from the Insecticide Resistance Action Committee (IRAC) Mode of Action Classification V.8.4 (2018).
[2] Lower rates may be used on smaller trees. Do not use less than the minimum label rate.

ENY-606

2019–2020 Florida Citrus Production Guide: Nematodes[1]

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Integrated pest management (IPM) for nematodes requires: 1) determining whether pathogenic nematodes are present within the grove; 2) determining whether population densities of some nematodes are high enough to cause economic loss; and 3) selecting a profitable management option. Attempting to manage nematodes may be unprofitable unless the above procedures are carefully followed. Similarly, some management methods pose risks to people and the environment, and therefore it is important to know that their use is justified by the actual conditions in a grove.

Nematode Pests

Although many different species of nematode have been found in association with citrus roots, relatively few have been documented to be economically important. The nematode species of major economic importance in Florida include the citrus nematode (*Tylenchulus semipenetrans*), causal agent of "slow decline" of citrus, and the burrowing nematode (*Radopholus similis*), causal agent of "spreading decline" of citrus. Other species of limited economic importance because they are more localized include the sting nematode (*Belonolaimus longicaudatus*) and two species of lesion nematode (*Pratylenchus coffeae* and *P. brachyurus*). The incidence and abundance of dagger nematodes (*Xiphinema vulgare* and *Xiphinema americanum* group) in citrus groves appears to be increasing. The ecology and economic importance of these dagger nematodes in citrus are the subjects of ongoing research.

Typical Symptoms

Most nematode species that are known pathogens of citrus do not actually kill the tree but can significantly reduce tree vigor, growth, and grove productivity. Nematode-infested trees generally grow more slowly and may ultimately be of smaller size and quality. Aboveground symptoms that develop due to root damage include thinner canopies with less new foliar growth and twig dieback within the upper tree canopy. Symptoms of decline frequently increase with time and are more apparent during periods of environmental stress (i.e., drought or freezing temperature) or when combined with other damaging soil pests (i.e., root weevils, *Phytophthora*).

Monitoring Nematodes

The distribution and abundance of nematodes in soil prior to or after planting will affect the severity of the problem and define the need for nematode management. The only effective way of determining the presence or distribution of nematodes within a grove is by soil and root tissue sampling of undercanopy areas of individual trees. A representative

1. This document is ENY-606, one of a series of the Entomology and Nematology Department, UF/IFAS Extension. Original publication date December 1995. Revised September 2013, April 2016, May 2018, and March 2019. Visit the EDIS website at https://edis.ifas.ufl.edu for the currently supported version of this publication.

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grove sample for most nematode species consists of soil and roots (using a shovel or soil sampling tube) collected from the undercanopy areas of 20–30 trees within a 5-acre block. When sampling for burrowing nematodes, collect a large quantity of fibrous roots from the surface 0–12 inches beneath 10–12 declining trees (enough to loosely fill a 1-gallon freezer bag). Immediately after collecting the sample, thoroughly rinse soil from the roots and from inside the bag and place the roots back in the freezer bag. Once soil and root samples have been collected, they should never be subjected to overheating, freezing, drying, or to prolonged periods of exposure to direct sunlight. Samples should be submitted immediately to a commercial laboratory or to the UF/IFAS Nematode Assay Laboratory for analysis and recommendations.

Managing Nematodes

Nematode management should be considered only after the results of soil and root sampling are available. The agency or company that processed the samples should be able to indicate whether potential nematode problems exist within a grove. In most cases, nematode management should not be considered until all other potential causes of tree decline are evaluated and corrected. For more detailed information on treatment decisions and methods of nematode management in citrus, consult the *Florida Citrus Rootstock Selection Guide* SP 248, *Best Management Practices for Soil-Applied Agricultural Chemicals* in this guide, or local UF/IFAS Extension personnel.

Sanitation

Once established, nematodes cannot be eradicated from groves, so the best method to manage plant-parasitic nematodes in new plantings is to exclude them from a grove by using only trees from nurseries certified to be nematode-free by FDACS Division of Plant Industry. Use of certified trees will virtually eliminate the possibility of nematode problems in new groves planted in virgin soils or in old citrus soils never infested by nematodes, provided that care is taken to always use clean equipment in those groves. Use of certified trees also reduces damage during the early years of growth in old, previously infested groves if soil nematode populations are low. High soil nematode densities hinder the beneficial effects of the use of certified trees. Sanitation of equipment to remove soil and root debris before moving between groves is an effective means of preventing the spread of nematodes.

Cultural Practices

Proper grove management is critical to mitigate damage caused by plant-parasitic nematodes. There is no value to managing nematodes if other problems (poor soil drainage, insufficient irrigation, foot rot and fibrous root rot, root weevils, improper fertilization, poor disease control) limit root function and/or reduce tree quality. In the case of burrowing nematodes, specific cultural practices (avoidance of disking, frequent irrigation, and fertigation) are critical to maintain a vigorous root system in the shallow soil horizons where the nematode is much less active.

Rootstock Resistance

Resistant rootstocks are also available to manage citrus and burrowing nematodes. Swingle citrumelo is a widely planted rootstock with resistance to citrus nematode. Milam lemon, Ridge Pineapple, and Kuharski Carrizo citrange are all resistant to burrowing nematode. The existence of races of these nematodes capable of breaking resistance compromises their value somewhat; nevertheless, large numbers of groves are currently growing well on resistant rootstocks in the presence of these nematodes.

Chemical Control

Environmental concerns and deregistration of numerous pesticides have dramatically reduced the availability of chemical products for nematode management. Currently, there are no soil fumigants recommended for preplant nematode control. Postplant nematicides can provide temporary suppression of nematodes in the shallow part of the root zone. Because of Florida's uniquely porous soils, soil-applied pesticides have the potential to contaminate groundwater. Consequently, their use should be restricted to the late autumn and early spring, when rainfall is least in Florida. These materials should not be applied near irrigation or drinking-water wells or where the water table is close to the soil surface. Irrigation systems should always be inspected prior to pesticide application to soil to prevent overapplication of pesticide or water due to line breaks, faulty line-end pressure valves, or missing emitters. Additional considerations for the application of fumigants and nematicides to soil are outlined below.

Tree response to postplant chemical treatment often requires a period of one to two years of repeated treatment for growth improvement and significant yield returns. Response to preplant fumigants in newly planted young trees may be particularly slow, since nematode population increase may be delayed until canopy closure of adjacent trees occurs. Note that to protect groundwater, preplant fumigants can only be used in areas with an underlying impermeable layer within 6 feet of the soil surface capable of supporting seep irrigation. Since nematicides are not eradicants, repeated treatments are required to periodically suppress nematode repopulation of soil and roots to maintain high grove productivity. Preplant nematode management programs (sampling, selection of appropriate rootstocks, use of certified trees) are therefore important considerations for maximizing young tree growth and eventual long-term productivity, since it may not be possible to assure satisfactory tree growth with postplant chemical management programs alone. However, if nematode problems do arise on young trees, early management of the populations can have a prolonged beneficial effect on subsequent growth and productivity of the trees. Nematode control with postplant, nonfumigant nematicides occurs primarily within the zone of application and, to a much lesser degree, within and around roots outside of the zone of application due to the systemic activity of these pesticides.

Since a large majority of fibrous roots grow within the surface 24–30 inches of soil and decrease in abundance from the tree trunk to the row middle, proper nematicide placement to maximize undercanopy coverage is of critical importance. Nematicide placement under the tree canopy can significantly improve overall nematode control by targeting applications to areas of highest fibrous root and nematode density. Treatments will be most effective if made when soil temperatures are warm enough for nematode development and uptake by the tree. Natural degradation of nematicides moving downward in soil also increases with increasing soil temperature, thereby reducing the likelihood of groundwater contamination. To confirm the value of treatment programs, it is wise to designate areas of grove that will remain untreated in order to evaluate product performance and tree growth response.

A lack or loss of nematicidal efficacy and citrus yield response can be associated with factors other than improper pesticide application rate, placement, and application timing. The repeated use of nematicides often results in diminished efficacy in successive years due to accelerated microbial degradation. This process is caused when populations of microorganisms capable of metabolizing these products increase in soil following use of the compound. The degradation process can be initiated after a single treatment. Most postplant nematicides do not necessarily kill nematodes upon direct contact: efficacy usually requires long, continuous exposure to sublethal, yet toxic, concentrations in soil. Nematode population reduction results from a disruption of normal nematode behavior necessary to complete the life cycle. Disappearance rates of nematicides in soil (due to leaching and/or microbial degradation) are therefore critical determinants of treatment efficacy.

Pesticide leaching to depths below the primary root zone can occur as a direct result of excessive irrigation or rainfall. Given the sandy, permeable nature of citrus soils and generally low soil organic matter content, irrigation schedules based on soil moisture deficits are likely to improve nematode control and grove response to treatment by maximizing retention of toxic concentrations within the citrus tree root zone and prevent problems of environmental contamination. Undercanopy weed growth may reduce nematicide effectiveness by interception or absorption of pesticide residues targeted for citrus roots or nematodes in soil. Undercanopy weeds also interfere with microsprinkler operation and can prevent uniform coverage of chemigated nematicides.