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PP-156

2019–2020 Florida Citrus Production Guide: Phytophthora Foot Rot and Root Rot[1]

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Foot rot results from scion infection near the ground level, producing bark lesions that extend down to the bud union on tolerant rootstocks. Crown rot results from bark infection below the soil line when susceptible rootstocks are used. Root rot occurs when the cortex of fibrous roots is infected, turns soft, and appears water-soaked. Fibrous roots slough off their cortex, leaving only a white thread-like stele (inner tissue of the fibrous root). Foot rot, crown rot, and root rot can be caused by *Phytophthora nicotianae* or *P. palmivora*. When managing phytophthora-induced diseases, integration of cultural practices (e.g., disease exclusion with phytophthora-free planting stock, tolerant rootstocks, proper irrigation practices [see Chapter 12: Irrigation management of citrus trees]) and chemical control methods is necessary. Phytophthora management with chemical control should not be considered until other potential causes of decline in tree production are evaluated and corrected. See also chapters on Blight, Huanglongbing, and Nematodes.

Cultural Practices to Manage *P. nicotianae*

Field locations not previously planted with citrus are probably free of citrus-specific *P. nicotianae.* Planting stock should be free from *Phytophthora* spp. in the nursery, and inspection for fibrous root rot in the nursery or grove before planting is advised. If uncertain, testing of nursery stock for *Phytophthora* spp. is recommended. In groves with a previous history of foot rot, consider use of Swingle citrumelo or other tolerant rootstocks (see Florida Citrus Rootstock Selection Guide) for replanting. Tolerance to *Phytophthora* spp. can be compromised when planted in unfavorable soils for the rootstock (e.g., Swingle citrumelo in calcareous soils). Rootstocks tolerant to foot and root rot normally do not support damaging populations once trees are established. Cleopatra mandarin should be used with caution because it is prone to develop crown and foot rot when roots are infected in the nursery or when trees are planted in flatwoods situations with high or fluctuating water tables and fine-textured soils. When resetting, Cleopatra mandarin should never be used in a grove with a history of damaging phytophthora, regardless of region. Trees should be planted with the bud union more than 6 inches above the soil line and provided with adequate

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soil drainage. Overwatering, especially of young trees, promotes buildup of phytophthora populations in the soil and increases risk of foot rot infection. Prolonged wetting of the trunk, especially if tree wraps are used on young trees, should be avoided by using early to midday irrigation schedules. Control of fire ants prevents their nesting under trunk wraps and feeding damage to moist, tender bark, which is then susceptible to infection.

Sampling for *Phytophthora* Spp.

Population densities of the fungus-like organism in grove soils should be determined to assist decisions of whether to treat with fungicides. Soil samples containing fibrous roots should be collected from March to November from under the canopy within the irrigated zones. When sampling trees of average canopy condition, combine individual small amounts from the top ten inches of soil from 20 to 40 locations in the microsprinkler zones within a 10-acre into one resealable plastic bag to retain soil moisture. Samples must be kept cool but not refrigerated for transport to an analytical laboratory. Currently, populations in excess of 10 to 20 propagules per cm^3 soil of total *Phytophthora* spp. *(P. nicotianae + P. palmivora)* are considered damaging. The same soil sample should be tested for populations of nematodes to assess whether they occur at damaging levels.

Chemical Control

Use of fungicides in young groves should be based on rootstock susceptibility, likelihood of *Phytophthora* spp. infestation in the nursery, and history of phytophthora disease problems in the grove. For susceptible rootstocks, such as Cleopatra mandarin and sweet orange, fungicides may be applied to young trees for foot rot on a preventive basis. For young trees on other rootstocks, fungicide treatments should commence when foot rot lesions develop. The fungicide program for foot rot should be continued for at least one year for tolerant rootstocks but may continue beyond the first year for susceptible rootstocks. In mature groves, the decision to apply fungicides for root rot control is based on yearly soil sampling to determine whether damaging populations of *P. nicotianae* occur in successive growing seasons. Timing of applications should coincide with periods of susceptible root flushes after the spring leaf flush, usually from late spring to early summer and after the fall leaf flush in October to November. Soil application methods with fungicides should be targeted to irrigated areas under the canopy with the highest fibrous root density. To avoid leaching from the root zone, soil-applied fungicides should not be followed by excessive irrigation. Aliette, phosphite salts, Ridomil, or Presidio are effective, but alternation of the materials should be practiced to minimize the risk of the development of fungicide resistance. It is recommended to alternate the soil-applied Ridomil and Presidio on the major spring and fall root flushes as well as continue to apply Aliette or phosphite salts on a calendar schedule per the label.

Larval Feeding Injury to Citrus Roots and Its Relationship to Invasion by *Phytophthora* Spp.

Association of phytophthora root rot with root damage by larvae of *Diaprepes abbreviatus* has been called the *Phytophthora-Diaprepes* (PD) complex (see ENY-611, *Citrus Root Weevils* or the Diaprepes Root Task Force website). A far more severe interaction has been identified between *P. palmivora* and Diaprepes root weevil than for *P. nicotianae*. The damage caused by *P. palmivora* is often associated with poorly drained, fine-textured soils and rootstocks like Swingle citrumelo and Carrizo citrange that are normally tolerant of *P. nicotianae*. In the more severe form, structural roots collapse from what appears to be moderate larval damage followed by aggressive spread of *P. palmivora* through the structural roots.

Rootstock susceptibility to damage by the PD complex depends on which *Phytophthora* sp. is present and whether the soil and water conditions are conducive to the fungus-like organism or to rootstock stress. In most situations, *P. nicotianae* is the predominant pathogen, and Swingle citrumelo appears to perform acceptably as a replant in weevil-infested groves, provided soil conditions are suited for this rootstock (e.g., favorable pH and calcium carbonate status, sandy soil texture, well-drained, etc.). When *P. palmivora* is present in poorly drained soils high in clay, pH, or calcium carbonate, Diaprepes root weevils render normally tolerant Swingle citrumelo and Carrizo citrange susceptible to phytophthora root rot infection. Thus, tolerance of Swingle citrumelo is restricted to the ridge and certain flatwoods soils. For further information about rootstock selection, refer to the Rootstock and scion selection chapter and the Rootstock selection guide.

Management of the *Phytophthora-Diaprepes* Complex

Selection of tolerant rootstocks for replanting Diaprepes root weevil–affected groves is important for management of future losses. For existing trees, fungicides in conjunction with careful water and fertilizer management have been utilized to maintain tolerance to Diaprepes root weevil and

phytophthora damage. Fertigation maximizes water and nutrient uptake efficiency by roots in well-drained soils. However, use of fertigation to regenerate roots is limited in poorly drained soils and high water tables typical in the flatwoods. In these situations, there may be increased reliance on fungicides to control root damage by *Phytophthora* spp.

Based on studies of the PD complex, aggressive control of Diaprepes root weevil larvae and adult stages should be implemented as soon as infestation is discovered to minimize the more severe phytophthora damage that follows larval feeding on roots. The IPM program may include carefully scheduled fertigation in well-drained soils to promote regeneration of fibrous roots after damage. In the flatwoods, IPM may include use of fungicides under the following conditions: 1) the soils are fine textured, poorly drained, high in pH, or calcareous, 2) the trees are on rootstocks susceptible to either or both *Phytophthora* spp., and 3) populations are above the damaging levels (10 to 20 propagules per cm^3 soil). A key to assist growers making *Phytophthora-Diaprepes* management decisions is available at the Diaprepes Root Weevil Task Force website as well as the citrus rootstock selection guide.

Management of the Phytophthora-HLP Interaction

Management of phytophthora root rot is complicated by Huanglongbing [HLB; see PP-225, *Huanglongbing (Citurs Greening)*] because the causal bacterium infects all parts of the citrus tree, including the roots. HLB accelerates phytophthora infection and fibrous root damage. HLB predisposes roots to *P. nicotianae* infection apparently by increasing attraction of zoospores to roots, accelerating infection, and lowering resistance to root invasion. The spread of HLB has led to more frequent cases of damaging phytophthora populations. Most recently, there has been a multiyear cycling of phytophthora populations apparently associated with lower fibrous root density and bursts of root growth as trees continue to decline from HLB. This has heightened concern for the root health of HLB-affected trees and initiation of measures to reduce root stress, which includes *Phytophthora* spp., citrus nematodes, *Diaprepes*, and abiotic soil factors. While all of these factors need to be considered and assessed on a case-by-case basis depending on site and rootstock, specific factors must be considered when controlling phytophthora with high-incidence HLB.

Although HLB causes fibrous root dieback, it also increases new growth of fibrous roots. Similar to leaf flushing, new root growth is no longer as synchronized into flush events. This is important because phytophthora preferentially infects new root growth. Constant availability of new root growth is a likely cause of rapid development of damaging phytophthora populations under favorable conditions. The cycles of root dieback and root flushing caused by HLB leads to large swings in phytophthora propagule counts in a grove. Preliminary data indicate also that chemical management has reduced effectiveness for control of *Phytophthora* spp. and prevention of root loss. Therefore, it is important to monitor phytophthora propagule counts before major summer and fall root growth events. If a damaging population is developing, it is important to time chemical applications to protect those major root flushes.

Web addresses for links:

Diaprepes Root Weevil Task Force: http://www.crec.ifas.ufl.edu/extension/diaprepes/index.shtml

Citrus Rootstock Selection Guide: http://flrootstockselectionguide.org/

Irrigation practices chapter: http://edis.ifas.ufl.edu/cg093

Group 4 fungicides (metalaxyl and mefenoxam) are not recommended for Phytophthora control in citrus nurseries.

Recommended Chemical Controls

READ THE LABEL.

See Tables 1 and 2.

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 controls for Phytophthora foot rot, crown rot and root rot—fosetyl AL and phosphite salts products.

Pesticide	FRAC MOA[1]	Rate[2]	Method of Application	Comments
Aliette WDG[3,4]	P07	--	--	Protectant and curative systemic. Buffering to pH 6 or higher is recommended to avoid phytotoxicity when copper has been used prior to, with, or following Aliette.
Nonbearing		5 lb/100 gal.	Foliar spray	
		2.5–5 lb/5 gals	Trunk paint or spray[5]	
		Up to 5 lb/acre	Microsprinkler	Adjust rate according to tree size.
Bearing		5 lb/acre or 1 lb/100 gal	Foliar spray in 100–250 gal/acre. Do not exceed 500 gal/acre.	Apply up to 4 times/year (e.g., March, May, July and September) for fibrous root rot control.
		5 lb/10 gal/acre	Aerial	Fly every middle. Do not apply in less than 10 gal/acre.
		5 lb/acre	Surface spray on weed-free area followed by 0.5 inch irrigation or by microsprinkler in 0.1–0.3 inch of water.	Apply up to 4 times/year (e.g., March, May, July and September) for fibrous root rot control.
Phostrol	P07			Protectant and curative systemic. Do not apply when trees are under water stress or high temperature conditions.
Bearing or Nonbearing		4.5 pt/acre	Foliar spray	Apply up to 4 times/year (e.g., March, May, July and September).
Bearing or Nonbearing		2–5 pt/5 gal	Trunk paint or spray[5]	
ProPhyt	P07			Protectant and curative systemic. Do not apply when trees are under water stress or high temperature conditions.
Nonbearing		2 gal/100 gal	Drench	1/2 pt solution per seedling in 2 gallon pot; can be applied through microsprinkler.
Bearing		4 pt/acre	Foliar spray	Apply up to 4 times/year (e.g., March, May, July and September) for fibrous root rot control.

[1] Mode of action class for citrus pesticides from the Fungicide Resistance Action Committee (FRAC) 2018. Refer to ENY-624, *Pesticide Resistance Management*, in the 2019–2020 Florida Citrus Production Guide for more details.
[2] Lower rates may be used on smaller trees. Do not use less than the minimum label rate.
[3] For combinations of application methods, do not exceed 4 applications or 20 lb/acre/year.
[4] Fungicide treatments control fibrous root rot on highly susceptible sweet orange rootstock, but are not effective against structural root rot and will not reverse tree decline.
[5] Apply in May prior to summer rains and/or in the fall prior to wrapping trees for freeze protection.

Table 2. Recommended chemical controls for Phytophthora foot rot and root rot—mefenoxam and copper products.

Pesticide	FRAC MOA[1]	Rate[2]	Method of Application	Comments
Ridomil Gold SL[3,4]	4	--	--	Protectant and curative systemic. Do not apply tank mixes of Ridomil and residual herbicides to trees less than 3 years old. Apply herbicide first, then wait 3–4 weeks to apply Ridomil. Do not apply to bare roots. Do not apply rates higher than 1 qt/A to citrus resets or new plantings (less than 5 years old) to prevent potential phytotoxicity. Do not make trunk gummosis sprays and soil applications to the same tree in the same cropping season. Time applications to coincide with root flushes.
Nonbearing		1 qt/acre of treated soil surface	Surface spray on weed-free area, followed immediately by 0.5 inch irrigation or by microsprinkler in 0.1–0.3 inch of water.	Make the 1st application at time of planting. Make up to 2 additional applications per year at 3 month intervals for maximum control; in most cases a late spring and late summer application should be sufficient
		½ pt/grove acre	Through irrigation injection.	
		1.0–1.5 fl.oz/20 trees	Individual Tree Treatment for Resets/New Plantings: Mix desired amount of Ridomil Gold SL in a water solution. Apply as a directed spray to individual trees (generally 8–12 fl.oz./tree) around the base of the tree and outward to cover the fibrous root system. Follow with sprinkler irrigation to move product into root zone.	Make 1st application at time of planting. Make up to 2 additional applications per year at 3 month intervals for maximum control; in most cases a late spring and late summer application should be sufficient.
Bearing		1 pt/acre of treated soil surface if propagule counts are 10–20 propagules/cm^3 soil. 1 qt/acre of treated soil surface if propagule counts are >20 propagules/cm^3 soil.	Surface spray on weed-free area, followed immediately by 0.5 inch irrigation or microsprinkler in 0.1–0.3 inch of water.	Begin applications during the spring root flush period. Apply up to 3 times/year on 3-month intervals (late spring, summer, early fall).
		½ pt/grove acre if propagule counts are 10–20 propagules/ cm^3 soil. 1 pt/grove acre if propagule counts are>20 propagules/ cm^3 soil.	Through irrigation injection.	

Pesticide	FRAC MOA[1]	Rate[2]	Method of Application	Comments
Bearing		1 qt/10 gal	Trunk spray for Gummosis: Spray the trunks to thoroughly wet the cankers.	May be applied up to 3 times/yr.
Ridomil Gold GR[2]	4	--	--	
		--	--	Do not apply Ridomil Gold GR and residual herbicides to trees less than 3 years-old simultaneously. Apply herbicide first, then wait 3–4 weeks to apply Ridomil. Do not apply more than 240 lb of apply Ridomil Gold GR/acre/year. Time applications to coincide with root flushes.
Nonbearing		40–80 lb/acre of treated soil surface.	Apply as banded application under the canopy. For banded applications, use a band wide enough to cover the root system. If rain is not expected for 3 days, follow by 0.5–1.0 inch of irrigation.	Make 1st application at time of planting. Make up to 2 additional applications per year at 3 month intervals for maximum control; in most cases a late spring and late summer application should be sufficient.
Bearing		40–80 lb/acre of treated soil surface.	Banded application under the canopy. If rain not expected for 3 days, follow by 0.5–1.0 inch of irrigation.	Begin applications during the spring rot flush period. Apply up to 3 times/year on 3 month intervals (late spring, summer, early fall).
UltraFlourish[3,4]	4	--	--	Protectant and curative systemic. Do not apply tank mixes of Ultra-Flourish and residual herbicides to trees less than 3 years old. Apply herbicide first, then wait 3–4 weeks to apply UltraFlourish.
Nonbearing		2–4 qt/acre of treated soil surface.	Surface spray on weed-free area, followed immediately by 0.5 inch irrigation or by microsprinkler in 0.1–0.3 inches of water.	Apply every 3 months for maximum control; in most cases a late spring and late summer application should be sufficient.
		1 pt/grove acre	Through irrigation injection.	
		2–3 oz/100 gal	Soil drench; apply 5 gal of mix in water ring.	Apply every 3 months for maximum control; in most cases a late spring and late summer application should be sufficient.
Bearing		1 qt/acre of treated soil surface <20 propagules/cm^3 soil. 2 qt/grove acre >20 propagules/cm^3 soil.	Surface spray on weed-free area, followed immediately by 0.5 inch irrigation or micro-sprinkler in 0.1–0.3 inch of water.	Apply 3 times/year (late spring, summer, early fall).
		1 pt/grove acre	Through irrigation injection	
Presidio	43	--	--	Do not apply more than one application per year. Apply before disease development.
Non-bearing		3–4 fl oz./acre	Surface spray on weed-free area, followed immediately or microsprinkler in 0.5–0.75 inch of water plush flush time.	Minimum ground application volume 10 GPA.
		3–4 fl oz/20 gal	Individual trees for resets or new plantings. Apply 10 fl oz evenly around root zone of each tree.	If rainfall does not occur within 24 hours post-application, irrigate with sufficient water to move product into root zone. Depending on soil type and root depth, this could require 0.5–1 inch of water.

Pesticide	FRAC MOA[1]	Rate[2]	Method of Application	Comments
Bearing		3–4 fl oz/acre	Surface spray on weed-free area, followed immediately or microsprinkler in 0.5–0.75 inch of water plush flush time.	Minimum ground application volume 10 GPA.
Copper-Wettable Powder	M01	0.5 lb (metallic) Cu/1 gal water.	Trunk paint[5]	Protectant.
Copper-Count-N	M01	1 qt in 3 qt water.	Trunk paint[5]	Protectant. Do not apply to green bark; may cause gumming.

[1] Mode of action class for citrus pesticides from the Fungicide Resistance Action Committee (FRAC) 2018. Refer to ENY-624, *Pesticide Resistance Management*, in the 2019–2020 Florida Citrus Production Guide for more details.
[2] Lower rates may be used on smaller trees. Do not use less than the minimum label rate.
[3] Do not exceed the equivalent of 6 lb a.i./acre/year of mefenoxam-containing products.
[4] Do not apply to bare roots or higher than 1 qt/acre of treated soil surface to citrus resets or trees less than 5 years old to avoid potential phytotoxicity.
[5] Apply in May prior to summer rains and/or in the fall prior to wrapping trees for freeze protection.