



UNIVERSITY OF
FLORIDA

IFAS EXTENSION

Diaprepes Root Weevil: A Pest of Citrus, Ornamentals and Root Crops in Florida¹

J.L. Knapp, H.N. Nigg, S.E. Simpson, L.W. Duncan, J.H. Graham, J.E. Peña, C.W. McCoy and C.M. Mannion²

The Diaprepes root weevil, *Diaprepes abbreviatus*, is a major pest of citrus and many other commercial crops grown in Florida including numerous ornamental plants and root crops. Diaprepes root weevil (Fig. 1) is a native of the Caribbean Islands and was first reported in Florida in 1964 on citrus. It is thought to have been transported here on ornamental plants imported from Puerto Rico.

This pest has now spread to parts of most agricultural areas of the state. Its widespread distribution can be attributed to man moving infested plants. Diaprepes root weevils have been recently detected in the Texas Rio Grande Valley.

Life Cycle

In Florida, adult weevils emerge from the soil throughout the year (Fig. 2). There appear to be two peak emergence periods of adult activity spring (May-June) and fall (August-September). Mating and egg-laying occur throughout this period. Eggs are generally laid in clusters of from 25 to 250 between



Figure 1. Adult Diaprepes root weevil.

mature leaf surfaces held together by an adhesive produced by the female. Eggs can also be laid on a single leaf, by folding parts of the leaf to cover the egg mass. A single female may lay as many as 5,000 eggs during her life of three to four months.

-
1. This document is ENY-645, one of a series of the Entomology and Nematology Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Published May 2001. Reviewed: December 2005. Visit the EDIS Web Site at <http://edis.ifas.ufl.edu>.
2. J.L. Knapp, professor, Citrus REC, Lake Alfred, Florida; H.N. Nigg, professor, Citrus REC, Lake Alfred, Florida; S.E. Simpson, Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Winter Haven, Florida; L.W. Duncan, professor, Citrus REC, Lake Alfred, Florida; J.H. Graham, professor, Citrus REC, Lake Alfred, Florida; J.E. Peña, professor, Tropical REC, Homestead, Florida; C.W. McCoy, professor, Citrus REC, Lake Alfred, Florida; C.M. Mannion, assistant professor, Tropical REC, Homestead, Florida; Entomology and Nematology Department, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611.

The Institute of Food and Agricultural Sciences (IFAS) is an Equal Opportunity Institution authorized to provide research, educational information and other services only to individuals and institutions that function with non-discrimination with respect to race, creed, color, religion, age, disability, sex, sexual orientation, marital status, national origin, political opinions or affiliations. U.S. Department of Agriculture, Cooperative Extension Service, University of Florida, IFAS, Florida A. & M. University Cooperative Extension Program, and Boards of County Commissioners Cooperating. Larry Arrington, Dean

The eggs hatch in 7-10 days after they are laid (Fig. 3). Larvae drop to the ground, burrow into the soil, and begin to feed on fibrous roots of host plants, moving to larger roots as they mature (Fig. 4). After a period of feeding, they pupate in the soil, emerging later as adults.

The length of time spent in the larval and pupal stages varies from several months to more than a year. Thus, the total life cycle of any single weevil may last from six to 15 months resulting in multiple overlapping generations.

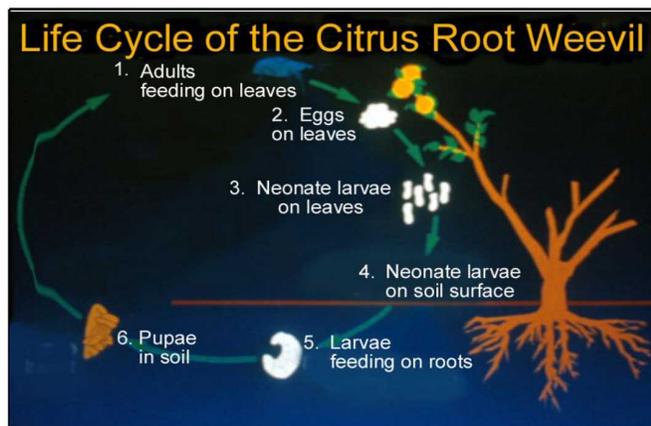


Figure 2. Life cycle of Diaprepes root weevil.

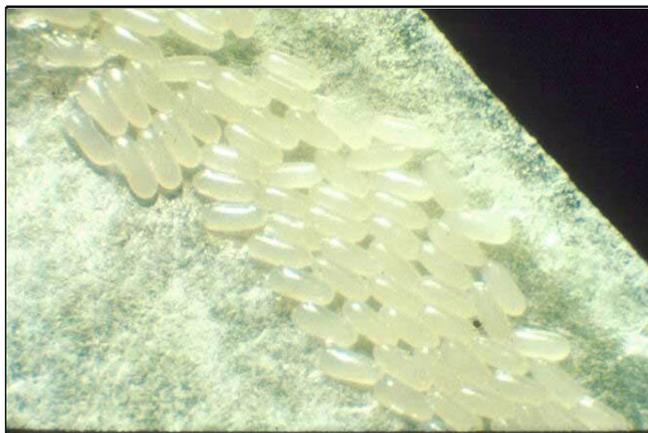


Figure 3. Diaprepes root weevil egg mass.

Economic Loss

There is no estimate of the total economic loss caused by the weevil to Florida agriculture. For individual growers, Diaprepes root weevil can result in a total loss (Fig. 5). For citrus, over 30,000 acres are currently known to be infested. For ornamentals, root crops, and tropical fruit more than 1,000 acres in 2 counties are known to be infested. Grower returns have been negatively affected by both



Figure 4. Mature larvae of Diaprepes root weevil.

reduced yields and increased production costs. Without adequate control measures, this pest can render a citrus grove operation non-profitable.



Figure 5. Mature citrus tree being pushed out due to Diaprepes root weevil damage.

Damage to Citrus Trees

Adult *Diaprepes* root weevils feed on young, tender, citrus foliage (Fig. 6) and occasionally on fruit. The primary economic damage is caused by larvae feeding on roots (Fig. 7) and the crown area. A few large larvae can girdle and render a mature, healthy citrus tree non-productive. This behaviour apparently makes *Diaprepes* root weevils unique among the citrus root weevil species found in Florida. A combination of root-debilitating factors such as *Phytophthora* root rot, nematodes and/or moisture stress can hasten decline of an infested tree.

Phytophthora spp. root rot organisms commonly infect the margin of larval feeding sites in the root bark. This causes girdling of large structural roots and accelerated tree decline on *Phytophthora* susceptible and moderately resistant rootstocks.



Figure 6. Typical leaf notching caused by adult *Diaprepes* root weevils.



Figure 7. Typical root damage caused by larval feeding.

Damage to Ornamental and Root Crops

Adult and larval *Diaprepes* root weevils attack ornamental trees and agronomic root crops. However, some crops may show only adult feeding damage and others are fed on only by larvae. The presence of adult *Diaprepes* root weevils is indicated by irregular semicircular feeding areas on the leaf edges of ornamental crops, similar to citrus (Fig. 6). Adult weevil injury can also be observed on palm flowers as well as roots. Adults are generally found on plants at the time of leaf flushing but can also be found continuously on ornamental trees with permanent tender foliage, e.g. silver and green buttonwood (Fig. 8). In south Florida, root crops such as potato and malanga almost never have their leaves injured by adult *Diaprepes* root weevils. These crops may only serve as alternate host plants for larvae. Papaya foliage is often cut irregularly, or entire leaves may be eaten by these weevils. Injury can also be observed on ripe and overripe papaya fruit, where adult weevils may aggregate.

Many ornamental trees support advanced larval injury before external symptoms (leaf yellowing, wilting, defoliation) are observed. Other hosts, such as oaks, appear to be susceptible to root-debilitating factors such as *Phytophthora* root rot following larval feeding. Crops with a succulent root system, fleshy roots, or tubers (Cassava, malanga, potatoes) can tolerate several larvae before any external symptoms appear. Damage to root crops in Florida is manifested by shallow to deep larval feeding on fleshy roots or tubers (Fig. 9).

Monitoring

Monitoring is the most important aspect of managing a *Diaprepes* root weevil infestation. Visual monitoring of adults can be effective if the grove is examined on a regular basis. Monitor groves not known to be infested by looking for distinctive feeding signs on flush leaves when scouting for other pests. If leaf notching is observed, look for adult weevils to obtain a positive identification. In known infested groves, look for adults and leaf feeding signs every two weeks during periods of leaf flush.



Figure 8. Adult *Diaprepes* root weevil feeding on silver buttonwood.



Figure 9. Larval feeding damage on white potato.

The modified Tedders' trap (Fig. 10) is used to monitor adult populations in known infested groves. These traps are placed within the drip line of a citrus tree and must be monitored on a weekly basis. Adult weevils emerge from the soil and crawl to the base of the trap. They climb up the base of the trap and enter the modified boll weevil trap at the top. Some reports indicate that grove maintenance problems have been associated with this trap, especially with herbicide applications. The number of traps per acre has not been established. Also, the Tedders' trap threshold (i.e., how number of weevils trapped relates to the population in the grove) and efficiency have not been determined. Until a chemical attractant can be

developed and incorporated into this trap, its commercial usefulness is limited.

The umbrella or shake and catch method (Fig. 11) has been used by growers and researchers. This method takes advantage of the behavior of the weevil that, when disturbed, it falls to the ground and pretends to be dead. If an open umbrella is placed between the tree and the ground, the weevil is captured. This is an effective method the grower can use to estimate the number of weevils on a tree but is very labor intensive. Several researchers have used this method to collect large numbers of weevils and to obtain adult emergence data for utilization of control measures.



Figure 10. Modified Tedders' trap.

Surveys

Surveys should be conducted in nurseries and commercial groves surrounding known infestations to detect and monitor weevil spread.



Figure 11. Collecting adult weevils using the beating/umbrella method.

Larval Feeding Injury to Citrus Roots and Its Relationship to Invasion by Soil-borne Plant Pathogens

Constant association of *Phytophthora* root rot with root damage by larvae has long been observed. Surveys have identified a far more severe interaction of *P. palmivora* with Diaprepes root weevil than where *P. nicotianae* is the predominant interacting pathogen. The damage caused by *P. palmivora* is often associated with poorly-drained, fine-textured soils and with the rootstocks normally tolerant of *P. nicotianae*, Swingle citrumelo and Carrizo citrange. In the more severe form, structural roots collapsed from what appears to be moderate larval damage followed by aggressive spread of *P. palmivora* through the roots. Bark infection leads to rapid collapse and a gummy residue in the bark. Because trees on Swingle citrumelo are more severely affected by the Diaprepes root weevils than surrounding groves on sour orange, there is a particular concern about young plantings on Swingle citrumelo that replace blocks on sour orange. Swingle citrumelo consistently supports higher soil populations of *P. palmivora* than trees on Cleopatra mandarin or sour orange. This indicates that rootstocks of trifoliolate orange hybrid origin might be more susceptible to this newly discovered *Phytophthora* spp.

Rootstock susceptibility to feeding by Diaprepes root weevils depends on which *Phytophthora* spp. is present and whether the soil and water conditions are conducive to the fungus 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., sandy soil texture, well-drained, favorable pH, calcium status, etc.). When *P. palmivora* is present in poorly-drained soils high in clay, pH and calcium, 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.

After larvae feed, the increase in leakage of compounds from wounded roots of trifoliolate orange and Cleopatra mandarin is similar. Feeding damage to Cleopatra mandarin leads to severe root rot by *P. nicotianae* above a threshold of root damage and exudation, whereas resistance of trifoliolate orange to *P. nicotianae* is maintained despite the wounding and greater availability of exudates for fungal growth. Resistance compounds present in roots of trifoliolate orange and the hybrid Swingle citrumelo counteract growth of *P. nicotianae* into root tissues and allow roots to readily heal and regenerate. These inhibitory compounds are less active against *P. palmivora*, which infects roots of trifoliolate orange at a higher rate than *P. nicotianae*. The breakdown of resistance of both rootstocks to *P. palmivora* occurs at a substantially lower threshold of larval damage than for *P. nicotianae*.

Management Program

Fungicides

Selection of tolerant rootstocks for replanting Diaprepes root weevil-affected groves aids in 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 efficiency of water and nutrient uptake by the 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 is increased reliance on fungicides to control root damage by *Phytophthora* spp.

Severe infections by *Phytophthora* spp. follow larval damage from Diaprepes root weevil feeding on structural roots. *P. palmivora* is present in very high populations under conditions of fine-textured soils and restricted drainage. Tree decline is accelerated by excessive rainfall and irrigation. Also confirmed is that *Phytophthora* infection and girdling of roots contributes as much to the damage of the root system as larval feeding at advanced stages of decline. Based on population dynamics, *P. palmivora* may be more damaging to structural roots than *P. nicotianae*, although the level of both pathogens is usually high in these cases. Ridomil Gold[®] at the full rate (1 qt./acre area/application) twice a year is effective for controlling both *Phytophthora* spp. resulting in an immediate improvement in tree vigor, root growth, and higher yield even though tree health may be declining. This paradox may be explained by the differential activity Ridomil Gold[®] has in controlling fibrous root damage compared to larger roots. At advanced stages of decline, Ridomil Gold[®] may not be effective enough to control *Phytophthora*-induced girdling of structural roots. Phosphite containing products have shown minimal response. In summary:

1. Sour orange, Cleopatra mandarin and even normally tolerant Swingle citrumelo and Carrizo citrange are rendered highly susceptible to *P. palmivora* or *P. nicotianae* under field conditions of Diaprepes root weevil infestation, fine-textured, poorly-drained soils, and wet conditions.
2. Diaprepes root weevil larval feeding breaks resistance of structural roots to infection by *Phytophthora* spp., especially *P. palmivora*. This resistance-breaking activity may negate the activity of phosphite compounds that act to increase resistance of roots to *Phytophthora* infection.
3. Systemic activity of Ridomil Gold[®] is sufficient to reduce damage of fibrous roots by both *Phytophthora* spp. and promote tree responses. Fungicide activity may not be adequate to prevent infection and girdling of structural roots that eventually kills trees especially under conditions conducive for *P. palmivora*.

4. Under conditions non-conducive to *Phytophthora*-Diaprepes root weevil complex (e.g., an aggressive weevil control program, resistant rootstocks, well-drained soils, proper water and nutrient management) root tolerance of *Phytophthora* damage may be maintained such that fungicides in the IPM program are unnecessary.

Based on studies of the 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 Ridomil Gold[®] under the following conditions: 1) the soils are fine textured, poorly-drained or high in pH and calcium status, 2) the trees are on rootstocks susceptible to either or both *Phytophthora* spp., and 3) populations are above the damaging levels (20 and 40 propagules per cm³ soil for *P. nicotianae* and *P. palmivora*, respectively).

Parasitic Nematodes

Some nematode parasites of insects are known as entomopathogenic nematodes (EPN) because they are intimately associated with bacteria that are lethal to insects. There is currently a great deal of interest in using these nematodes as biological insecticides. Large numbers of EPNs can be produced within insects. Alternatively, the symbiotic bacteria can be grown using fermentation technology, after which nematodes are introduced to feed on the bacteria and quickly multiply. Both of these methods are used by companies to produce commercial EPNs intended for control of Diaprepes root weevils.

When added to soil, EPNs locate and parasitize insect larvae by invading body openings and penetrating into the body cavity. The nematode then releases its bacterium which multiplies resulting in the death of the larvae within a day or two. The nematode feeds upon the bacterium and insect tissues producing several generations of offspring which emerge from the host in 1-2 weeks. Several hundred thousand new EPNs can be produced within a single

dead larvae. These new nematodes are capable of killing many species of insects they may encounter, but neither they nor their bacterial symbiont pose any threat to other wildlife, humans, or the environment.

There are numerous species of EPNs that can be used for insect management. Each species has its own biological characteristics that should be matched to the biology of the target pest and to the environment in which it will be introduced. The two species found thus far to provide the best control of *Diaprepes* root weevils in Florida are *Heterorhabditis indica* and *Steinernema riobrave*. The former species is currently sold under the trade name Grubstake Hi[®] and the latter under the name BioVector 355[®]. Grubstake[®] is produced using insects to rear nematodes and BioVector 355[®] is produced using fermentation technology.

Despite important constraints to achieving consistent or effective management of *Diaprepes* root weevils with EPNs, additional research and new strains may help to improve their performance. Indigenous, undescribed species of EPNs have been isolated from citrus groves in Florida. During mid-summer months, naturally occurring populations of these native EPNs have been found to kill more than 50% of caged root weevil larvae buried beneath trees in commercial orchards. The possibilities for mass-rearing and inundative release of these newly discovered nematodes is of great interest.

Entomopathogenic nematodes are applied to citrus groves during months when soil surface temperatures are expected to exceed 70 degrees to provide adequate warmth for their activity. EPN application to groves should be planned carefully, because the viability of these organisms decreases rapidly in commercial formulations. Liquid formulations must be used on the day they are received. Granular formulations can be stored in cool conditions for a few days. Properly modified herbicide applicators or microsprinkler irrigation systems are used to deliver EPNs into pre-moistened soil. Approximately one acre inch of water should also be applied immediately following application of EPNs. Microsprinkler systems designed to deliver water uniformly will deposit nematodes evenly across a grove, except for the last 1-2 sprinklers at the end of

each poly-line. Back-flow of water at the ends of lines typically result in about half as many nematodes being delivered from the last emitters. EPNs should not be applied with drip irrigation systems because they quickly settle out of suspension. Differences in the effectiveness of ground equipment and microsprinkler irrigation systems for EPN delivery have not been reported, but the question requires further study. Sunlight is harmful to these nematodes and application late in the day allows them time to move into the soil during darkness.

Research is ongoing to evaluate the profitability of using EPNs as part of a program to manage root weevils, but no such estimates are yet available. Several published and ongoing studies suggest that the recommended dosages of EPNs can result in very high mortality of weevil larvae beneath young or small trees in the field (80-95%), but that efficacy is lower (0-60%) when applied to larger mature trees. The discrepancy in effectiveness occurs partly because recommended dosages are based on acreage rather than on the surface area within an acre that is actually treated. A ten-fold increase in EPNs/acre is required to achieve the same number of nematodes per square foot beneath the canopy of mature trees compared to young trees. Unless improvements in EPN production technology can be found to reduce the cost of the material, it may prove difficult to achieve a high degree of insect control using EPNs in mature groves.

Each of Florida's variable soils favor persistence and efficacy of certain EPN species more than others. Although the commercially available nematode species perform well in coarse sandy soils, they have shown no efficacy in heavily textured soil. Research is ongoing to better define those soil textures in which the nematodes are likely to provide effective control.

A third common cause of variation in the effectiveness of EPNs is inconsistent quality of commercial material. The viability of commercially formulated EPNs is estimated by nematode motility after formulation. Marked variation in the motility of batches of EPNs produced using fermentation has been reported during the past several years and corresponds to variability in the effectiveness of these nematodes in ongoing field research.

Despite encouraging results from earlier studies, EPNs were withdrawn from the Florida Citrus Pest Management Guide in June 2000.

Natural control of Diaprepes root weevils by native EPNs are already reducing the impact of Diaprepes root weevils on citrus trees in Florida. Commercially formulated EPNs are providing additional control in some situations. However, additional research is required to increase the usefulness of these organisms for management of Diaprepes root weevils.

Chemical Soil Barriers -- Larvae

Traditionally, the chlorinated hydrocarbon insecticides such as DDT, aldrin, dieldrin and chlordane were used by Florida citrus growers for soil insect control, particularly the neonate stage of important citrus root weevil species. Because of their excellent persistence in the soil, a single application was effective for at least one year. Application was simple, a granular formulation was added to the fertilizer mix at the appropriate rate. When the chlorinated hydrocarbons were banned for environmental reasons, less persistent compounds were evaluated against weevils. Finding a commercial replacement for these banned products that has all the required activity characteristics but being non-water soluble so as not to move into the groundwater has been challenging. Controls that fail to act at the soil surface will allow for larval invasion of the rhizosphere. As stated earlier, chemicals that will move down to the root zone could also move into the groundwater.

The synthetic pyrethroid, bifenthrin, is effective as a soil barrier treatment. When this insecticide is applied beneath the tree using a herbicide applicator to achieve uniform coverage, the compound will persist at the point of application by drying on soil particles. It is not systemic. Formulated and marketed as Capture[®] 2EC, this compound is recommended for Diaprepes weevil control under an EPA Section 18 specific exemption label. It may be applied at the rate of 1 quart per treated acre only once per year in the May-June or September-October period based on adult activity. The soil surface needs to be relatively litter and weed free. In experimental trials, bifenthrin persistence has varied from 4 to 10 weeks depending

on the weather and reduces neonate populations entering the soil from 80-100%. Bifenthrin is also a control for fire ants that often prey on weevil larvae. Experimental field trials show, however, that ant populations can recover within 3 to 4 weeks and native ants become more common during this period as predators due to lack of fire ant competition. Other soil surface applied chemical insecticides are not recommended at this time.

Adult Weevils

(See current Florida Citrus Pest Management Guide for products and rates.) Adults feeding on the foliage of host plants may be killed by applying recommended pesticides. There are several problems associated with this approach:

1. Adults emerge over a prolonged period of time. Those emerging after the applications escape by feeding on flush that has come out since treatment. This necessitates multiple applications.
2. Pesticides (especially Carbaryl) require high rates to give both initial kill and residual activity. Growers are currently using multiple applications at reduced rates to cut costs with questionable results. No more than two applications per season at recommended rates should be utilized. Timing should be at visual sighting of high numbers of adults which usually occurs during the May-June and/or September-October periods.
3. Both the above scenarios risk reduction of natural enemies for other pests of citrus, which may result in pest flare-ups.

Petroleum spray oil, approved for use on citrus, when applied to citrus flush discourages egg deposition on treated surfaces and interferes with the cementing of leaves together leaving the egg mass vulnerable to environmental effects and predation.

Micromite[®], an insect growth regulator, can be mixed with petroleum spray oil and applied to the canopy of the trees. With this product, dose is critical. If an adult female weevil, feeding on treated foliage, ingests enough toxin, the eggs she produces will be

infertile. If she moves off treated foliage and feeds for 7-10 days, the eggs will again be fertile and hatch. Eggs deposited on treated foliage will absorb the active ingredient from the leaf surface and will not hatch. Petroleum spray oil appears to enhance this adsorption.

Biological Control

Diaprepes root weevil eggs are fed upon by numerous predators including several species of ants, mites and spiders. The larval stage is attacked by the red imported fire ant, native ant species and earwigs before it can escape into the soil.

No native egg parasitoids have been detected; however, two species of exotic egg parasitic wasps have been reared and released. These are *Ceratogramma etiennei* and *Quadrastichus haitiensis*. Their establishment and effectiveness are currently under investigation.

Several species and isolates of entomopathogenic fungi have been evaluated for effects on both larvae and adults. To date, none look commercially effective but naturally occurring strains can reduce populations.

Regulatory

The Florida Department of Agriculture and Consumer Services, Division of Plant Industry, regulates the movement of all nursery stock originating from nurseries known to be infested with Diaprepes root weevils.

Infested nurseries are required to be under a compliance agreement that enables the nursery stock to move from the nursery once all the conditions in the agreement are met. These conditions may include removal of plants from growing media, shipping plants bare-root, or the application of approved chemical treatment.

Anyone needing more specific information concerning these regulations should contact The Florida Department of Agriculture and Consumer Services, Division of Plant Industry office at (352) 372-3505.

Sanitation

Movement of equipment and materials that might spread the pest from infested to noninfested areas should be restricted. All stages of Diaprepes root weevils may harbor in soils, plants, leaves, grass, sod and stump wood.

Recommendations to Slow Spread

Production

- Eliminate soil and leaf litter before equipment enters and exits groves.
- Access to blocks with known infestations should be limited.

Harvesting

- Eliminate soil and leaf litter as equipment enters and exits groves.
- Clean all picking sacks and personal items.
- Prevent leaf litter from being loaded onto semi trailers.
- Install slatted sides on loaders instead of solid walls.
- Process fruit harvested within a known infested area in that same area if possible.

Packinghouse - Processing Plants

- Remove all leaf debris from pallets coming from areas of known infestation.
- Clean semi trailers to eliminate leaf debris.
- Burn or compost leaf debris at plant site or haul to an approved sanitary landfill using covered transport.