Remember Diaprepes? It's still a problem

Diaprepes adult

By Larry W. Duncan, Megan Dewdney and James H. Graham

In the huanglongbing (HLB) era in Florida, attention to other pests and diseases has diminished as growers and scientists urgently search for sustainable ways to manage the bacterium *Candidatus* Liberibacter asiaticus.

However, the *Diaprepes* root weevil (*Diaprepes abbreviatus*) has been a serious pest throughout much of Florida's citrus industry since its arrival in the mid-1970s and remains so for many growers.

Unlike most insect pests of citrus, *Diaprepes* is uniquely difficult to manage because the larval stages live in the soil where they develop by feeding on the citrus root system, whereas the egg and adult stages reside above ground in the foliage of citrus and many other plants. Newly formed adult weevils emerge from the soil, and newly hatched weevil larvae fall from leaves to enter the soil during all but the coldest months of the year.

Because most methods to kill adults, eggs or larvae are of relatively short duration, significant windows of time can remain when new adults emerge from the soil to replace those killed in the canopy, or new larvae fall to the soil replacing those killed using biological control. For this reason, it is noteworthy that the recent emphasis on managing the insect vector of HLB by using low-volume sprays to reduce costs and permit more frequent applications of insecticides may have the added benefit of providing better control of *Diaprepes* adults by reducing the intervals between insecticide sprays. Whether or not this is the case, intensive use of insecticides is unlikely to be sustainable for many reasons familiar to growers.

Diaprepes management will continue to rely on the integration of tactics currently available and those developed through ongoing and future research. Effective use of these tactics requires understanding the ecology of *Diaprepes* and other soil-borne organisms that interact with the weevil in important ways.

SOILS AND THE DIAPREPES FOOD WEB

Feeding by *Diaprepes* larvae can result in extensive damage to the cortex of major citrus roots (Figure 1). The damage is compounded, however, when the wounded roots are colonized by either *Phytophthora nicotianae* or *Phytophthora palmivora*. This *Diaprepes-Phytophthora* pest-disease complex can kill trees and rapidly make entire orchards unprofitable.

Figure 1. *Damage to the cortex of the major structural roots of citrus trees by older stages of Diaprepes larvae impairs root function and allows greater infection by species of Phytophthora.*

Photo courtesy of Robin Stuart

Soil conditions, especially poor drainage, that favor root infection by the aquatic, motile spores of *Phytophthora* are major factors that contribute to the severity of the *Diaprepes-Phytophthora* complex. In turn, they dictate the level and type of management required to reduce economic losses.

Soils also affect *Diaprepes* in the absence of *Phytophthora* and may also affect the tree response to larval feeding. The average numbers of *Diaprepes* adults trapped during three years in three Central Ridge orchards on deep sandy soils were only 20 percent of those trapped in three orchards in the coastal and inland flatwoods regions. In these regions, shallower, finer textured soils are often bedded to improve drainage and increase the available rooting depth.

The causes for regional variation in *Diaprepes* pressure are poorly understood. Some flatwoods sites support fewer species and numbers of native entomopathogenic nematodes that are very effective in killing *Diaprepes* larvae. During a two-year period in a Central Ridge orchard with modest numbers of *Diaprepes*, up to 80 percent of larvae buried monthly beneath trees died within a week, most killed by native nematodes belonging to one of three species. By contrast, between 3 percent and 20 percent of buried larvae died in a flatwoods orchard that was highly infested by weevils, but supported just a single entomopathogenic nematode species.

Whether local differences in nematode abundance are due mainly to direct effects of physical soil properties or the suitability of different soils for natural enemies of nematodes is currently being studied. The goal of the project is to modify soil properties to favor biological control of weevils. For example, the use of composted animal manure as a mulch suppressed several fungal species that actively prey on nematodes while increasing the numbers of buried weevil larvae killed by nematodes (Figures 2 and 3). Nevertheless, despite major differences between some groves, the role of biological control in regulating the abundance of weevils is not clear-cut. This is because entomopathogenic nematodes are abundant in some groves with significant weevil damage to trees. Such observations demonstrate the need to better understand how soil conditions may affect *Diaprepes* development directly, as well as the abundance of nematodes and many other natural enemies of the weevil.

Soils may also affect the tree response to weevil-feeding damage. In ongoing research, citrus seedlings planted in coarse sand from the Central Ridge (97 percent sand) suffered less root loss by weevil feeding than seedlings planted in fine sand (89 percent), or sandy loam (59 percent) soils from the flatwoods (Figure 4A). Despite care taken not to overwater the finer soils, seedlings not exposed to weevils grew better in the coarse sand than in the other soils, suggesting that an unidentified stress to trees in the finer soils predisposed them to greater damage by weevils. Nematodes that were used in some of the experimental treatments to manage the weevil larvae

Figure 2. *Fungi are among a number of organisms in soil that kill nematodes. At left is an entomopathogenic nematode trapped by a fungus species that employs adhesive branches seen extending from the sides of the threadlike fungus mycelia. At right is a nematode filled with round fungal sporangia that produce and release hundreds of motile spores that swim through moist soil to locate, infect and kill other nematodes.*

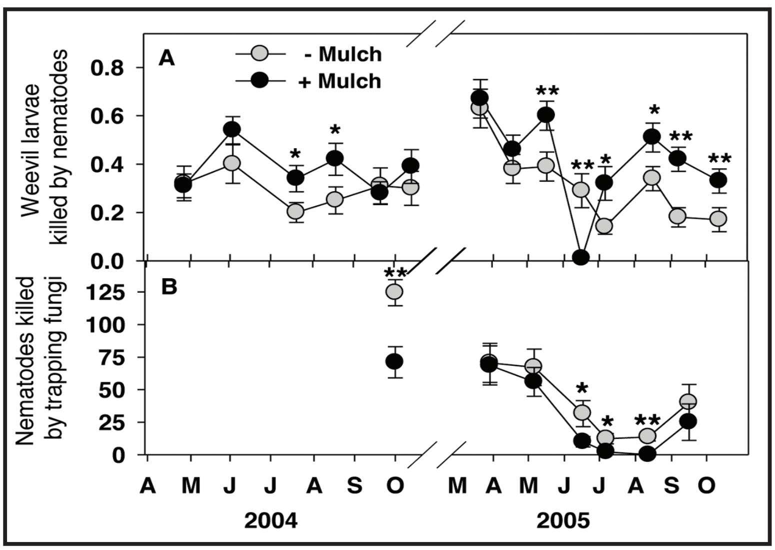

Figure 3. *The use of composted animal manure mulches beneath mature citrus trees increased the numbers of Diaprepes root weevil larvae killed by naturally occurring entomopathogenic nematodes. The mulches also reduced the abundance of some fungal species that trap nematodes, suggesting a possible cause for some of the increase in nematode activity.*

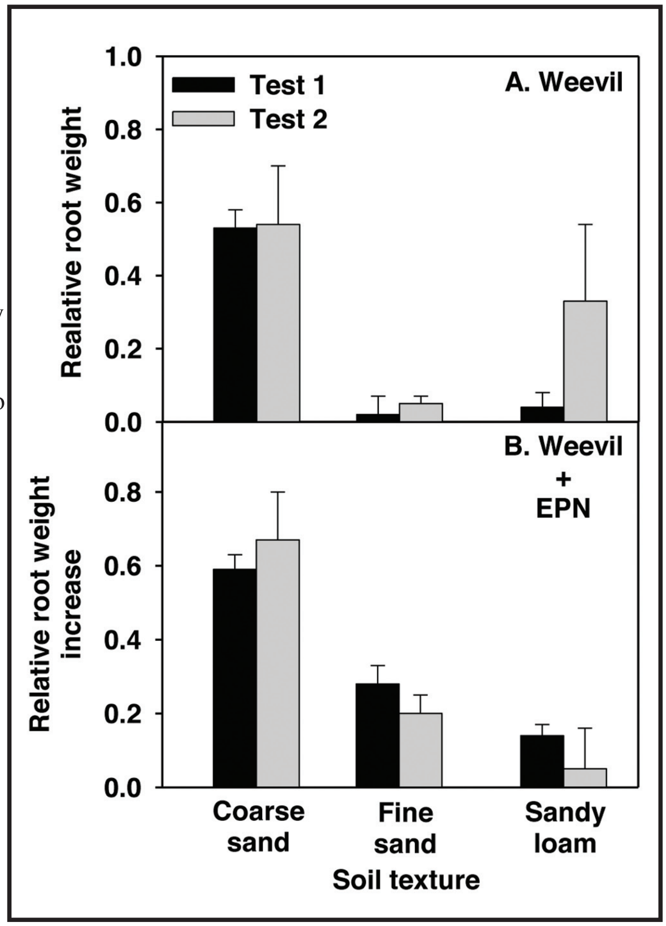

Figure 4. *The roots of potted citrus seedlings grown with weevil larvae in coarse sand weighed about half as much as those of seedlings grown without weevils (relative weight is the proportion compared to plants with no weevils). However, when seedlings were grown in two finer-textured soils, weevils caused much greater reduction in root weights (Panel A). Entomopathogenic nematodes added to pots with weevils prevented root loss from weevil feeding better in the coarse sand than in the other soils (Panel B).*

Figure 6. Aerial view of a grove in the central flatwoods showing greater effect of Diaprepes on tree size (and health) in a low, wet area of the orchard shown in the lower left-hand portion of the photograph. Buried Diaprepes larvae survived better and were attacked by fewer entomopathogenic nematodes in the low area compared to drier portions of the grove at higher elevation.

protected roots better in the coarse sand, despite evidence that they provided similar levels of weevil control in all soils (Figure 4B).

Clearly, the economic impact of *Diaprepes* on Florida citrus orchards involves complex interactions between the insect, its plant host and numerous other organisms in the soil food web, all of which are modulated in important ways by physical properties of soils. Cost-effective management of *Diaprepes* will profit from a better understanding of the food web dynamics; however, our current knowledge provides some basis for site specific IPM.

MANAGING THE DIAPREPES-PHYTOPHTHORA COMPLEX

IFAS guidelines for managing *Diaprepes* can be found at the Diaprepes Task Force Web site located in the Extension section of the Citrus Research and Education Center Web page (www.crec.ifas.ufl.edu).

The Web site also contains general information about the insect and PDF files of most *Diaprepes* research published since 1970. Following are some general guidelines based on regional differences in soils likely to affect the ecology of *Diaprepes*.

Because numbers of *Diaprepes* tend to be lower on the Central Ridge and *Phytophthora* problems occur less frequently in well-drained soils, Ridge growers may have less immediate need to manage the pest-disease complex than in the flatwoods. Many groves in

Figure 5. *Callused wounds caused by weevil larvae to major structural roots of a mature citrus tree in a grove on the Central Ridge. Although few adult weevils were encountered in the grove, damage to the root system has accumulated over the years.*

this region remain productive in the absence of *Diaprepes* management. Nevertheless, the damage to the root cortex by larval feeding is cumulative and over time can cause tree decline, even when adults are not readily evident (Figure 5). The greater abundance of *Diaprepes* and *Phytophthora* in flatwoods soils and the greater likelihood of tree stress from other causes such as poor drainage make monitoring and management of the pest-disease complex more important in regions with those soils.

Rootstock selection is the most critical decision in managing *Diaprepes* due to the interaction between weevils and *Phytophthora*. As a general rule, use of *Phytophthora*-resistant rootstocks such as Swingle citrumelo and C-35 are appropriate choices if soil conditions are suitable for their use. An exception to this rule occurs for groves on finer textured, wetter soils in which *P. palmivora* (rather than the more common *P. nicotianae*) is encountered. Trifoliate-derived rootstocks such as Swingle and C-35 perform poorly in the presence of *P. palmivora*. Rather, rootstocks from mandarin or pummelo parents (e.g., Cleopatra mandarin and newly released USDA rootstocks US-802 and US-897) perform better than other commercial varieties when attacked by the weevil and *P. palmivora*.

Regardless of which *Phytophthora* species occurs in a region, groves should be engineered to achieve the best possible water drainage to minimize tree stress. The importance of drainage is readily apparent in groves on poorly drained soils where damage by the weevil is most evident in the wettest sections of the grove (Figure 6).

Management of the above-ground

adult and egg weevil stages is an important IPM component in groves with significant weevil infestations. In a 9-year field study conducted in a flatwoods grove heavily infested with *Diaprepes*, trees on the *Phytophthora*-resistant rootstock C35 yielded 2.6 times more fruit than trees on Cleopatra mandarin in the absence of pesticides. Fruit yield on C35 rootstock increased an additional 3.2-fold when pesticides with activity against the egg and adult stages of *Diaprepes* were applied twice during the peak emergence of weevils from soil during the spring and early summer.

Soil-borne larvae are best managed with biological control using commercially available entomopathogenic nematodes to supplement native nematode communities. Nematodes are applied through microjet irrigation systems or using herbicide booms on pre-moistened soil. Two applications per year (early spring/summer and late summer) have been shown to reduce the numbers of adults by approximately 50 percent in trials on the Central Ridge. Nematodes should only be applied when soil temperatures are well above 70°F, and irrigation should occur during and immediately following application.

Use of a fungicide for *Phytophthora* control in soil should be unnecessary in well-drained soils, especially when appropriate rootstocks are planted. Fungicides may be warranted in poorly drained soil, or when soil pH or calcium carbonate are high and

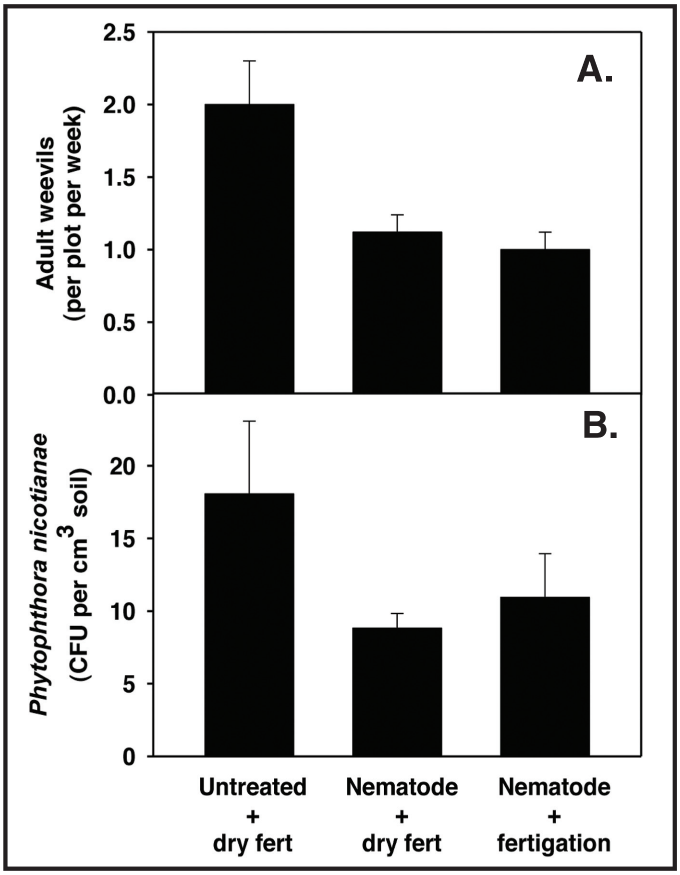

Figure 7. *The application of commercial entomopathogenic nematodes to soil twice per year for four years reduced the numbers of adult weevils trapped weekly by about half in an orchard on the Central Ridge (A). Managing weevil larvae with nematodes also reduced the availability of infection sites on roots, thereby reducing the abundance of Phytophthora in soil samples (B). The figure shows the overall average of data collected during the four-year trial.*

Phytophthora populations exceed damaging levels (10-20 propagules per cm^3 soil for either *P. nicotianae* or *P. palmivora*). It is critical that adult and/or larval weevil control is effective before implementing *Phytophthora* control. The effect on *Phytophthora* of weevil management using entomopathogenic nematodes during four years in a commercial orchard (Figure 7) illustrates the importance of disrupting the pest-disease interaction for effective control of the pathogen.

Larry W. Duncan and James H. Graham are professors and Megan Dewdney is an assistant professor, all at the University of Florida-IFAS's Citrus Research and Education Center, Lake Alfred.