Diaprepes root weevil infestation can speed the decline of HLB-infected trees.

Entomopathogenic nematodes: root weevil management tool

By Larry Duncan

Citrus growers are recognized as early adopters of practices that enhance the biological control of arthropod pests. For more than a century, tactics such as the exploration and importation of predators and parasitoids or the reduced use of insecticides that disrupt biological control were increasingly employed against pests in the tree canopy. Beginning in the early 1990s, Florida's growers were also among the first to employ entomopathogenic nematodes (EPNs) to manage a subterranean insect pest of a major crop.

Diaprepes abbreviatus, the Diaprepes root weevil, became one of the most damaging pests to the state's citrus trees following its introduction from the Caribbean in the mid-1960s. The replacement of organochlorines with insecticides having short residual activity and the recognition that soil-applied pesticides pose a groundwater risk in Florida's sandy soils made effective control of the weevil difficult to achieve. In the absence of an effective soil-applied insecticide, EPNs were intensively studied and then recommended for control of the larvae feeding on the roots.

When used as recommended, the best EPN products were shown to reduce Diaprepes larvae in the soil by as much as 90 percent in the first week after application. Two annual applications consistently reduced the numbers of adult Diaprepes root weevil and blue green weevil (*Pachnaeus litus*) emerging from the soil to about half. It was also found that EPNs perform like a non-persistent insecticide. They kill larvae in the soil at the time of application, but only for a few days or weeks at most.

HISTORY OF EPN PRODUCTS

Unlike plant parasitic nematodes, EPNs provide a beneficial service to trees because they require insect prey for development and propagation. Native EPN species are active in all Florida citrus groves; they help maintain weevils at manageable levels in some locations, but not in others. Commercially produced EPN products can be used to supplement the beneficial activity of the native species, but the history of these products in Florida has been uneven.

When first developed, EPN products for management of Diaprepes root weevil were only marginally effective until a newly discovered species, *Steinernema riobrave*, was shown to be superior to other species in use at the time. A product featuring *S. riobrave* was soon on the market and widely used

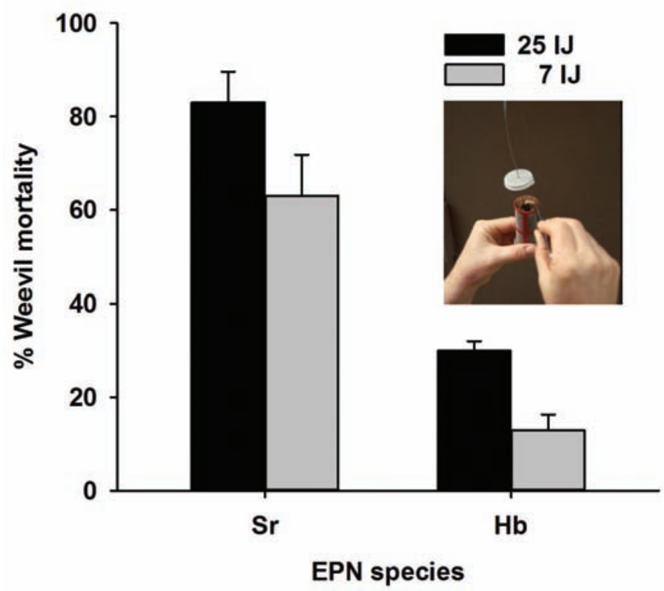

Figure 1. Mortality rate of caged, buried larvae of *Diaprepes abbreviatus* (inset photo) seven days after being treated with either *Steinernema riobrave* (Sr) or *Heterorhabditis bacteriophora* (Hb) at rates of seven or 25 infective juveniles (IJ) per cm² soil surface.

in the 1990s.

When that product was eventually acquired in a company merger and subsequently manufactured in a way that reduced the nematode viability, a steady reduction in use of EPNs resulted. A new *S. riobrave* formulation (BioVector 355, Becker Underwood) introduced in 2004 resolved the quality problem. However, the introduction of huanglongbing (HLB) in Florida eventually consumed growers' time and budgets, and BioVector 355 was discontinued in 2011 for lack of sales.

The discovery that HLB drastically reduces the citrus fibrous root system occurred concurrently with grower awareness that HLB-induced tree decline progresses faster in groves infested by root-damaging weevils. This observation has caused a renewed interest in EPN products for root weevil management. BASF responded by introducing Nemasys R in July 2016. Nemasys R contains *S. riobrave,* which is formulated using the same methods and facilities that produced BioVector 355. The product will be available during the months in which nematodes can be employed (March through November).

EFFECTIVE EPN USE

What do we need to know about EPNs to use them effectively? Key considerations affecting EPN efficacy include selecting the appropriate EPN species for the target insect, determining cost-effective application rates, understanding the most appropriate times of year for applications, and ensuring optimum soil moisture and temperature conditions. There are several EPN species commonly sold for pest control. Most of these products provide excellent control of the pests for which they are marketed, but have little effect against other insects. Currently, just one product containing *S. riobrave* is available. Therefore, it is the only EPN product recommended at this time for control of weevil larvae.

Figure 1 illustrates the relative difference in efficacy between *S. riobrave* (Sr) and another EPN species (*Heterorhabditis bacteriophora*) that is sold by several companies for control of a wide variety of grub species. In this field trial, caged Diaprepes root weevil larvae were buried at a depth of 12 inches, and the plots were sprayed with either species at rates of seven or 25 infective juvenile (IJ) EPNs per cm² surface area. The insects were recovered after seven days to determine the efficacy of each species and dose. The differences in Diaprepes mortality shown in Figure 1 are typical of a large number of studies and illustrate why application of *S. riobrave* at rates of approximately 25 IJs per cm² soil surface is recommended for weevil management.

Root weevil eggs are laid in clutches on the tree leaves. The newly hatched larvae fall to the soil, where they feed on roots for several months before pupating and then emerging from the soil as adults that typically lay eggs for about six weeks. Weevil adults emerge throughout the year, but peak emergence periods occur regularly in spring, early summer and often in autumn. Figure 2 illustrates these patterns for both Diaprepes and blue green weevils during a 4-year period in a grove near Alturas.

Figure 3 (page 14) shows the numbers of newly hatched (neonate) larvae

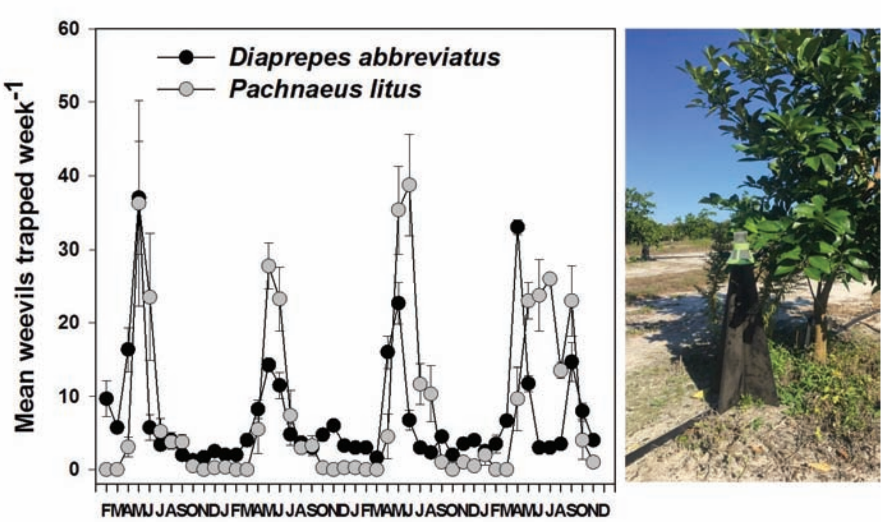

Figure 2. Average number of *Diaprepes abbreviatus* and *Pachnaeus litus* recovered from Tedder's traps (photo) during four years in a mature citrus grove.

caught in funnel traps during two years in the same Alturas grove. The figures illustrate regular, peak recruitment periods (mid-summer and mid-autumn) of neonate larvae into the soil that occur shortly after the peak emergence of adults. The patterns of adult emergence and larvae recruitment in soil suggest that EPN applications timed to occur four to six weeks following peak adult emergence from soil will present the infective juvenile EPNs with the largest number of weevil larvae targets. These periods are typically in mid-late summer and late autumn, but cost and weather variation can influence application decisions. Soil temperatures of 70°F and above facilitate EPN activity so that late-autumn applications are sometimes inappropriate. Applications to warm soil in spring can reduce the peak spring-summer adult emergence.

EPNs are most efficiently and effectively applied via microjet irrigation systems that can deliver the nematodes to pre-moistened soil and provide adequate water (ideally, an acre inch) during delivery. Microjet delivery also reduces the time during which the nematodes are exposed to harmful ultraviolet radiation.

Regardless of delivery method, filtration devices will trap the nematodes and must be removed before application. The irrigation system also affects the application costs because the amount of product used depends on the surface area of soil being wetted.

Figure 4 shows the mortality of weevil larvae beneath young trees on which jets were inverted to deliver the water to a small area around the base. Also in the grove were larger trees with jets in the normal position to spray a much larger area. Because the quantity of EPNs was adjusted to deliver approximately 25 IJ EPNs per cm^2 soil surface on young trees, fewer nematodes per surface area were deposited beneath larger trees.

Natural control by native EPNs was very high at this site, but the commercial *S. riobrave* killed four times more weevils beneath the small trees than the large ones, increasing the overall mortality to more than 90 percent. For EPNs, as for any non-persistent pesticide applied at the appropriate dosage, the net efficacy will largely depend on the treatment frequency. Since more EPNs are required to treat large trees at the appropriate rate, there is a tremendous opportunity to apply EPNs in young groves at greater frequency than in mature trees for the same annual cost.

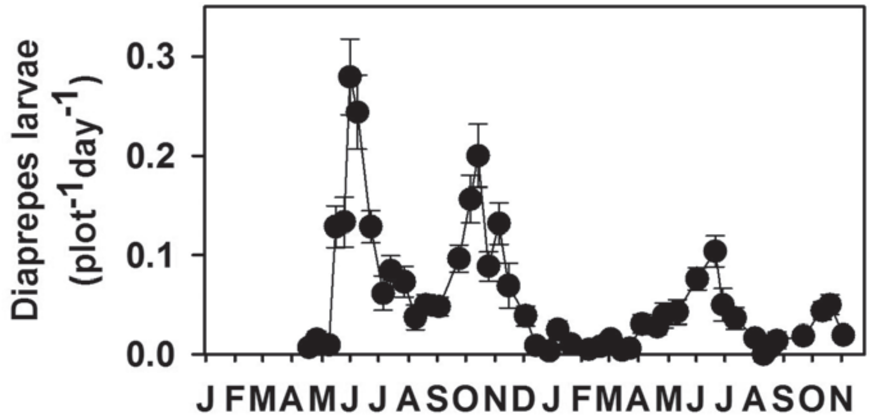

Figure 3. Numbers of *Diaprepes abbreviatus* neonate larvae recovered from funnel traps during two years beneath the canopies of mature citrus trees.

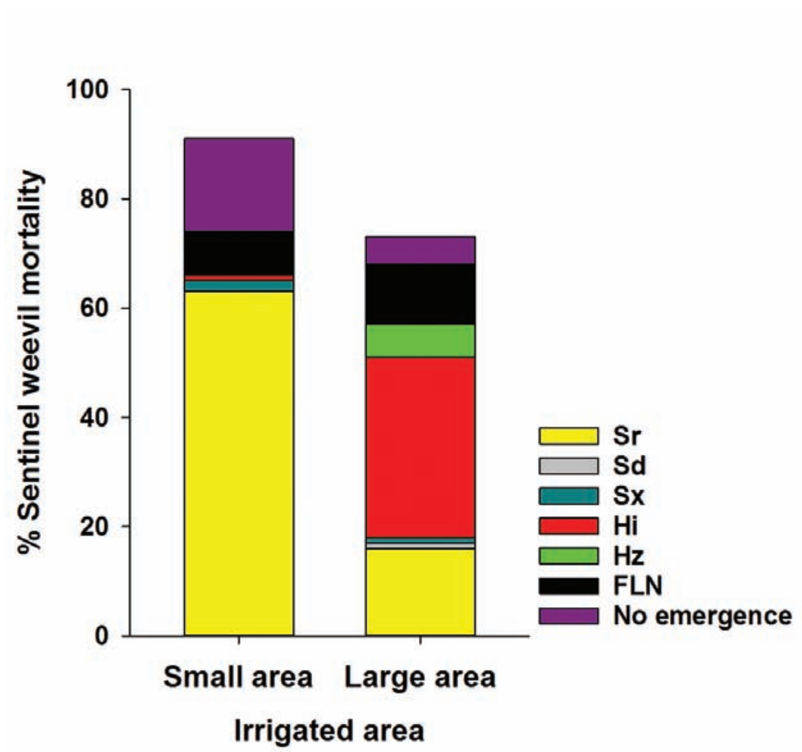

Figure 4. Mortality rate of caged, buried larvae of *Diaprepes abbreviatus* beneath young trees (small area with jet inverted) and mature trees (large area) seven days after being treated at different rates with *Steinernema riobrave.* Insect cadavers were examined to determine if they were colonized by *Steinernema riobrave* (Sr) or the native EPNs *S. diaprepesi* (Sd), *Steinernema* species (Sx), *Heterorhabditis indica* (Hi) and *H. zealandica* (Hz). Free-living competitors (FLN) of EPNs were also recovered.

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