Using mulches to improve the efficacy and persistence of insect specific nematodes for control of overwintering codling moth

L. A. Lacey[1], D. Granatstein[2], H. L. Headrick[1], R. Fritts, Jr.[3] and S. Arthurs[1]

[1]USDA-ARS, Yakima Agricultural Research Laboratory, Wapato, WA, [2]Washington State University, TFREC, Wenatchee, WA, [3]Certis USA, Clovis, CA

Codling moth, *Cydia pomonella*, is the most serious insect pest of apple in the Pacific Northwest. In conventional orchards, the traditional method for controlling this pest is through the routine application of broad spectrum insecticides. Options for codling moth control for organic growers have been limited to methods such as oils, trapping, mating disruption, and manual removal of infested fruit. The recent registration of commercial formulations of the granulovirus of *C. pomonella* in the USA and their approval by the Organic Materials Review Institute (OMRI) expands the options for control of newly hatched larvae in organic orchards and provides a biological alternative for conventional growers. In addition, entomopathogenic nematodes (EPNs) targeted for overwintering stages of the moth offer the potential for a double-pronged strategy for controlling this pest. The overwintering stage of codling moth, cocooned larvae within hibernacula, is a difficult stage to kill using most conventional approaches. In the fall and winter, this stage represents the entire population and is virtually a captive audience if an effective means of control could be harnessed against it. The elimination or reduction of the codling moth at this time would provide significant protection to fruit early in the following growing season. EPNs are capable of controlling overwintering cocooned larvae of codling moth when moisture is maintained and temperatures are 60ºF and above. Preliminary research with nematodes and mulches indicates that nematodes will persist longer in moist mulch than on bare ground and provide extended control of cocooned codling larvae.

Since 1997 the USDA-ARS-Yakima Agricultural Research Laboratory has conducted several trials of EPNs to determine their most effective application strategy to control overwintering codling moth. We have found EPNs to be effective in controlling overwintering cocooned larvae of codling moth at applications rates ranging from 0.4 to 1 billion infective juvenile nematodes (IJs) per acre when the habitat is kept moist for 6 to 8 hours and temperatures are 60ºF and above (Lacey et al., 2000; Unruh and Lacey, 2001). Maintenance of moisture after application of the nematodes using irrigation in orchards has been especially successful in trellised apple orchards and older pear orchards. Sustained moisture that was favorable for nematode survival is enhanced in orchards where mulch (shredded paper, hay, wood chips, or clover) is placed beneath trees. Mulching and crop residue have facilitated prolonged survival of EPNs in other cropping systems and enhanced their insect parasitic activity. In orchard agroecosystems mulching has been used for weed control and nutrient management. Our objectives in this studies were to: develop evaluation methods for assessing impact of different mulch types on the larvicidal activity and persistence of insect parasitic nematodes; evaluate EPNs in several mulch types using sentinel cocooned codling moth larvae; and to assess the persistence and recycling potential of candidate EPNs in apple agroecosystems with wood chip mulch.

METHODS:

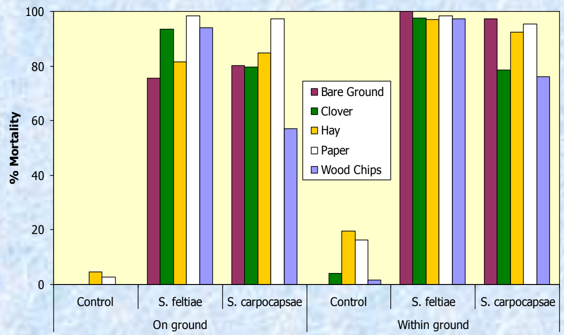
Experimental orchard trials. Randomized and replicated study plots were set up within the Wenatchee Community College orchard in East Wenatchee. Applications of infective juveniles (IJs) of two commercially available species of nematodes, *Steinernema carpocapsae* and *S. feltiae, were* be made using a back pack sprayer. Mulch treatments in the first trial (fall, 2003) consisted of four ground cover types (shredded paper, clover, wood chips and hay) with conventionally maintained bare ground used as a non-mulched control. Untreated mulched plots were set up to monitor background mortality of both codling moth and non-targets. Five replicate plots of each mulch type were used for each nematode species, and control. Sentinel cocooned larvae in cardboard strips were placed on the surface of the ground and in crevices in the ground beneath the mulch as well as in the bare ground plots. Prior to application of nematodes the irrigation was run for 30 min. After application of nematodes (1 billion infective nematodes/hectare= 0.4 billion/acre) the irrigation was turned on for 2 hours. Sentinels were collected 48 hours after spraying and incubated at 75˚F for one week before assessing mortality.

The second through fourth trials took place in the spring, summer and fall of 2004. Plots were mulched with wood chips only and five replicate plots were set up for each nematode species and untreated control.. Sentinel larvae in cardboard strips were placed on the surface of the ground and covered with 2 cm of mulch. Five bare ground plots were also set up for each treatment and control with cocooned sentinel larvae placed on the surface of the ground. In the spring and fall, plots were treated with 0.4 billion nematodes/acre. In the fall trial, 1 billion nematodes/acre were applied. Sentinels were collected and incubated as before. During the fall trial, 3 days after application of nematodes, 30 diapausing larvae were released into each of 3 arenas/plot (30 cm in diameter). The arenas were constructed of stove pipe sunk into the soil of each plot (treated and controls, mulched and bare) prior to application of nematodes to minimize disturbance of the treated mulch. 5 empty cardboard strips were placed 2.5 under the mulch of mulch plots or on the surface of bare soil plots to provide locations in which to spin cocoons. The cardboard strips in the bare plots and all of the mulch within the arenas of the mulched plots were retrieved 5 days after releasing larvae. Samples were kept at 50˚F until assessed for larval mortality. Using this approach we will be able to monitor the initial efficacy of nematode applications against codling moth *in situ* as well as the overall persistence and recycling potential against further larvae migrating into treated areas as the season progresses.

Results and Discussion

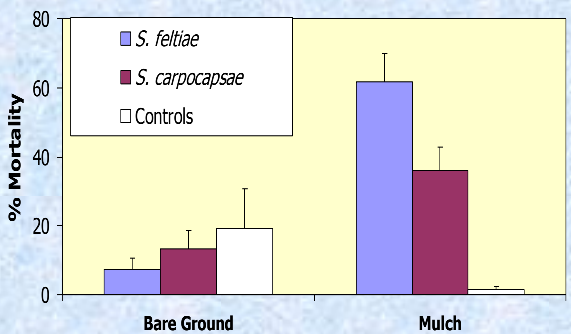
Both nematode species performed well against larvae that were placed in grooves within the soil (Figure 1). Nematode infection and mortality in control sentinels in grooves revealed the presence of native entomopathogenic nematodes (*Heterorhabditis* spp.). The on ground larvae in mulched were well controlled by both nematodes under the paper mulch, but variable responses were observed for the other mulches. *S. carpocapsae* was less effective under wood chips. S. feltiae performed better in plots with paper, wood chip and clover mulches than it did on bare ground.

Fig. 1. Evaluation of *Steinernema carpocapsae* and *S. feltiae* (0.4 billion IJs/acre) on bare ground, within ground and in plots with 4 types of mulch. September 2003.



The same dosage of *S. feltiae* in the spring trials resulted in lower mortality of codling moth larvae in the mulch plots than in the fall of 2003 ostensibly due to lower temperatures (Fig. 2). Mortality in mulch plots was significantly better than that in the bare ground plots. As in the fall 2003 trials, *S. carpocapsae* produced significantly lower mortality in codling moth larvae in mulch plots than *S. feltiae*.

Fig. 2. Evaluation of *Steinernema carpocapsae* and *S. feltiae* (0.4 billion IJs/acre) on bare ground and in plots with wood chip mulch, Spring 2004.



The results of applications in mid July 2004 are presented in Figure 3. The majority of the larvae in all of the bare ground plots died from causes other than nematode infection making a comparison between mulch and bare ground plots impossible. *S. carpocapsae* performed surprisingly better than *S. feltiae* in these plots, probably because *S. feltiae* is better adapted to cooler temperatures. The maximum temperatures recorded following application of IJs (92-96˚F) were apparently detrimental to this species.

Fig. 3. Evaluation of *Steinernema carpocapsae* and *S. feltiae* (0.4 billion IJs/acre) on bare ground and in plots with wood chip mulch, Summer 2004.

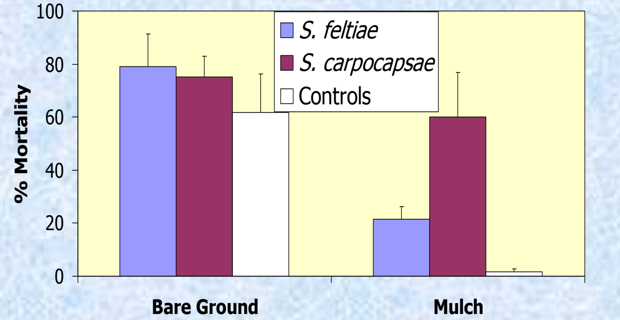
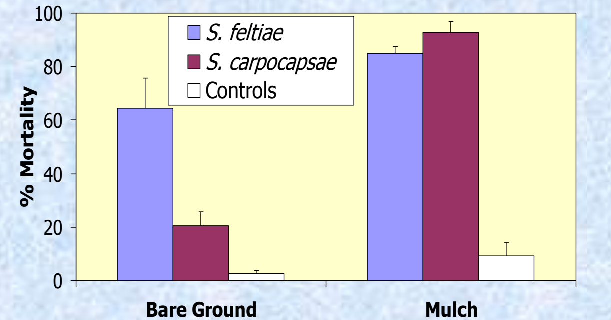


Fig. 4. Evaluation of *Steinernema carpocapsae* and *S. feltiae* (1 billion IJs/acre) on bare ground and in plots with wood chip mulch, Fall 2004.



Application of the higher concentrations of IJs in the fall of 2004 resulted in fair control of codling moth larvae by *S. feltiae* in the bare ground plots ostensibly due to its host-seeking ability. Control by *S. carpocapsae*, however, was considerably reduced. In the mulch plots on the other hand both EPN species produced significant higher mortality in codling moth larvae. Fairly low mortality (12-14%) due to both species nematodes was observed in larvae that were added to mulched plots 3 days after application of IJs. Cocooned larvae tended to be clumped in groups of 4-5 within the arenas and infection of one larva per clump could ultimately result in the infection of nearby larvae due to recycling of IJs.

EPNs offer potential for control of overwintering cocooned larvae and mulches can extent the persistence and help to facilitate maintenance of moisture necessary for their activity. Control of the overwintering stage of codling moth will decrease the initial oviposition pressure the following spring. Nematodes used in combination with the codling moth virus and mating disruption have the potential for effective and conventional pesticide-free control of various stages of codling moth. Because of their specificity for insects, entomopathogens are ideal candidates for incorporation into IPM where their effects on natural enemies will be minimal as compared to most presently used chemical pesticides.