ENTOMOPATHOGENIC NEMATODES FOR CONTROL OF OVERWINTERING NAVEL ORANGEWORM

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The navel orangeworm (NOW), *Amyelois transitella* (Walker), is a key pest of pistachios in California. NOW larvae overwinter in unharvested nuts and continue to develop throughout the winter as temperature permits. Overwintering larvae are unaffected by insecticides and are controlled by field sanitation. Entomopathogenic nematodes (EPNs) are effective in controlling a wide variety of insects in soil and cryptic habitats including those found in orchards. We evaluated the ability of two commercially available steinernematid species, *Steinernema carpocapsae* and *Steinernema feltiae*, to infect NOW larvae in pistachios on the berm, in order to determine if EPNs can play a role in orchard sanitation. We also evaluated the application rate and soil temperature necessary for success. In most trials, the berm was moistened for two hours using microsprinklers (6 gal/hour) before the nematodes were applied, and after application, water was applied again to facilitate EPN penetration.

Four trials employing 1-m^2 plots were conducted between February and July 2003 in Madera County, California (Table 1) to identify the best EPN candidate and demonstrate the feasibility of using nematodes. The nematodes were applied with a backpack sprayer at concentrations ranging from 200 million to four billion infective juveniles (IJs) per acre using 400 or 534 gallons of water per acre, followed by wetting the nematodes at the same rate 15-20 minutes after application. A total of 3,095 larvae were recovered from 18,390 laboratory-infested pistachios (16.8% average infestation). *S. carpocapsae* was more effective than *S. feltiae* and produced > 72% mortality at a concentration of 400 million IJs/acre when nighttime temperatures were above freezing. *S. carpocapsae* was equally effective in bare and leaf-covered plots and persisted longer in sandier soil (8 weeks) than *S. feltiae*. *S. carpocapsae* has the potential to multiply in the field because more than half of the cadavers recovered 21 days after application contained developing nematodes (Siegel *et al.* 2004).

Four new trials employing 1-m^2 plots were conducted between November 2003 and April 2004 in Madera and Kern County, California in order to determine if EPNs were effective using application rates closer to those an orchard manager would use. Nematodes were applied at a concentration of 400 million IJs per acre using application rates of 400 and 200 gallons of water per acre followed by water at the same rate 15-20 minutes after nematode application. A total of 7,880 larvae were recovered from 34,512 laboratory-infested pistachios (22.8% average infestation). *S. carpocapsae* was equally effective when applied at 200 gallons or 400 gallons per acre followed by wetting at 200 and 400 gallons per acre, respectively (Table 2). It did not matter whether the nematodes were applied before the nuts were moistened. Further research is needed to determine the minimum amount of water necessary for successful treatment.

Abiotic factors played a major role in determining the success of our treatments. The research conducted in 2003 demonstrated the deleterious effect of freezing temperatures, and the data from 2004 clearly demonstrate that high soil temperatures are also deleterious (Figure 1). These two applications were made in March, but at Belridge (Kern Co.) soil temperature exceeded 90° F within 3 hours after application, even though the soil had been previously moistened with microsprinklers. EPNs only caused 9.65% mortality and although this was significantly greater ($\underline{P} < 0.0001$) than the 1.5% Control mortality, we regard the experiment as a failure for NOW control. In contrast, soil temperature did not exceed 90° F at S&J Ranch (Madera Co.) and the treatment was successful (Table 2). Soil moisture also determined treatment success. Future research will concentrate on further quantifying the impact of temperature on treatment as well as determining the best time to apply EPNs after harvest.

Reference Cited

Siegel, J., L. A. Lacey, R. Fritts Jr., B. S. Higbee, and P. Noble. 2004. Use of steinernematid nematodes for post harvest control of navel orangeworm (Lepidoptera: Pyralidae, *Amyelois transitella*) in fallen pistachios. Biological Control 30 (2): 410-417.

Table 1. Percent mortality of navel orangeworm larvae after treatment with *Steinernema carpocapsae*. Dosage is million IJs per acre.

Trial	Species	Dosage	Mortality (±S.E.)[a]	N
February 2003, Block 1				
Bare + Leaves plots	Control		19.0 ± 2.3 a	384
Bare plot, 400 gal/acre	*S. carpocapsae*	400	31.2 ± 3.8 b	218
Leaves plot, 400 gal/acre	*S. carpocapsae*	400	36.7 ± 3.8 b	218
March 2003, Block 2				
Bare + Leaves combined	Control		8.9 ± 2.3 a	292
Bare plot, 534 gal/acre	*S. carpocapsae*	400	86.3 ± 6.0 b	51
Leaves plot, 534 gal/acre	*S. carpocapsae*	400	79.8 ± 5.4 b	54
Bare plot, 400 gal/acre	*S. carpocapsae*	400	72.2 ± 7.0 b	36
Leaves plot, 400 gal/acre	*S. carpocapsae*	400	78.5 ± 2.3 b	65
April 2003, Blocks 1 + 2				
Block 1+2 combined	Control		15.9 ± 2.6 a	452
Block 1 Leaves, 400 gal/acre	*S. carpocapsae*	400	80.6 ± 4.9 b	67
Block 2 Leaves, 400 gal/acre	*S. carpocapsae*	400	78.0 ± 3.2 b	164
Block 1 Leaves, 400 gal/acre	*S. carpocapsae*	200	68.2 ± 3.8 b	151
Block 2 Leaves, 400 gal/acre	*S. carpocapsae*	200	56.1 ± 3.8 c	173

[a]Means followed by the same letter within a trial are not significantly different at $\underline{P} < 0.05$, Fisher's protected LSD

Table 2. Percent mortality following treatment with *Steinernema carpocapsae* in March, 2004. All plots were bare and control plots were pooled. Asterisk denotes nuts that were wet first and then nematodes applied at 400 million/acre.

Block	Treatment	Percent Mortality
One		
	Control	1.4
	400 gal/acre	42.7
	200 gal/acre	41.0
	*200 gal/acre	44.5
Two		
	Control	1.4
	400 gal/acre	52.3[a]
	200 gal/acre	64.7
	*200 gal/acre	63.6

[a]Significantly different within a block at $\underline{P} < 0.05$, Fisher's protected LSD

Figure 1. Comparison of soil temperature at one inch depth between successful (S&J Ranch, Madera Co.) and failed (Belridge, Kern Co.) nematode application, March 2004. Nematodes were applied at a concentration of 400 million infective juveniles per acre.