Beneficial Nematodes vs. Fungi: Commercial Biocontrol Options for Managing Plum Curculio

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In the northeastern United States, the plum curculio (*Conotrachelus nenuphar*) completes only one generation per year. Overwintered adults emerge from wooded areas in late April to early May and begin oviposition shortly after petal fall. Eggs are deposited in young fruit, and the developing larvae cause premature fruit drop by June and July. Mature larvae exit dropped fruit to pupate in the soil, and new adults emerge in mid-July through August. These summer-generation adults feed on apples until September, and as day length shortens in early fall, they migrate to overwintering sites where they remain until the following spring.

Generally, management of overwintered adults with insecticide sprays during the petal-fall and early summer period is sufficient to prevent economic injury/ Summer-generation damage is considered to be minimal. However, in years of high population pressure or in orchards with severe injury, supplemental mid-season control may be warranted. Recent research has highlighted biological control agents such as entomopathogenic nematodes (EPNs) and entomopathogenic fungi (EPF) as promising alternatives. These organisms naturally occur in soil and can infect plum curculio larvae as they enter the ground to pupate, thereby reducing the emergence of summer adults. While the efficacy of EPNs in orchard soils has been repeatedly validated in field trials, results with EPF have been more variable.

This study was conducted to evaluate two commercially available products, the EPN *Steinernema carpocapsae* (BioSC) and he EPF *Beauveria bassiana* (BotaniGard ES), against plum curculio larvae. In Study 1, the objective was to determine larval mortality over time following treatment with each product at the label rate. In Study 2, the objective was to compare the rate of adult plum curculio emergence from treated soil when the products were applied at half-label, label, and double-label rates., relative to the recommended rate.

Materials & Methods

Experimental procedures. Field-collected soil was sterilized twice (to eliminate any existing pathogenic organisms) by autoclaving at 121 °C and 15 psi for 1 h on two consecutive days. After sterilization, the soil was air-dried completely for two days and then placed into 10.5-cm diameter plastic cups (100 g per cup).

In Study 1, treatments were applied at the label rate, whereas in Study 2, treatments were applied at the label rate, half-label rate, and double-label rate.For BioSC, the recommended field application rate is 250,000 infective juveniles (IJ) per m². Based on this rate, the corresponding rates were 2,200 IJ (label rate), 1,100 IJ (half-label rate), and 4,400 IJ (double-label rate) for the experimental units (cups) that were used for the experiment. For BotaniGard ES, the recommended field rate is 8 fl oz per 1,000 ft². Given that the product contains 1×10^9 viable conidia per mL, the calculated cup rates were 4.7×10^8 conidia (label rate), 2.4×10^8 conidia (half-label rate), and 9.4×10^8 conidia (double-label rate). All Treatments were applied by pipetting 2 mL of the prepared suspension evenly onto the soil surface in each cup.

Plum curculio larvae were obtained from prematurely dropped apples collected on June 19 from an unsprayed apple orchard in Belchertown, MA. The apples were placed on moist sand, and beginning one week after collection, the sand was rinsed daily to recover emerging larvae. Larval recovery continued until no additional larvae were obtained for three consecutive days. Recovered larvae were maintained on moist paper towels in plastic boxes and held in an environmental chamber at 25 °C with a 16:8 h (light:dark) photoperiod until used in the experiment. For the experiments, ten larvae were introduced into each prepared cup before the application of the treatments.

Data collection. In Study 1, soil from each cup was examined at 3, 7, and 10 days post-inoculation by emptying the contents onto a tray and recording larval mortality. All dead larvae were removed at each inspection. In Study 2, the soil was left undisturbed; cups were maintained until adult emergence, and the total number of emerging adults was recorded.

Results

Study 1. For the first question, regarding how long it took to kill plum curculio larvae following treatment with each product at the label rate, we found that the EPN BioSC killed about half of the larvae within 3 days, nearly 90% by day 7, and achieved complete mortality by day 10. In contrast, the EPF BotaniGard ES showed no difference compared with the untreated control (Figure 1).

Study 2. For the second question, comparing adult plum curculio emergence rates when the products were applied against the larvae at half-label, label, label rates, and double-label rates, we observed that the EPN BioSC completely suppressed adult emergence at all application rates, even at the half-label rate. In contrast, the EPF BotaniGard ES failed to suppress adult emergence, even when applied at double the label rate (Figure 2).

Conclusions

Our results clearly demonstrate that the commercial entomopathogenic nematode (EPN) *Steinernema carpocapsae* (BioSC) provides highly effective control of plum curculio, with the majority of adults killed within one week. In contrast, the entomopathogenic fungus (EPF) *Beauveria bassiana* (BotaniGard ES) failed to reduce plum curculio survival under our experimental conditions. Based on these findings, BioSC can be recommended as a promising biological tool for managing plum curculio when applied to the larval stage, whereas

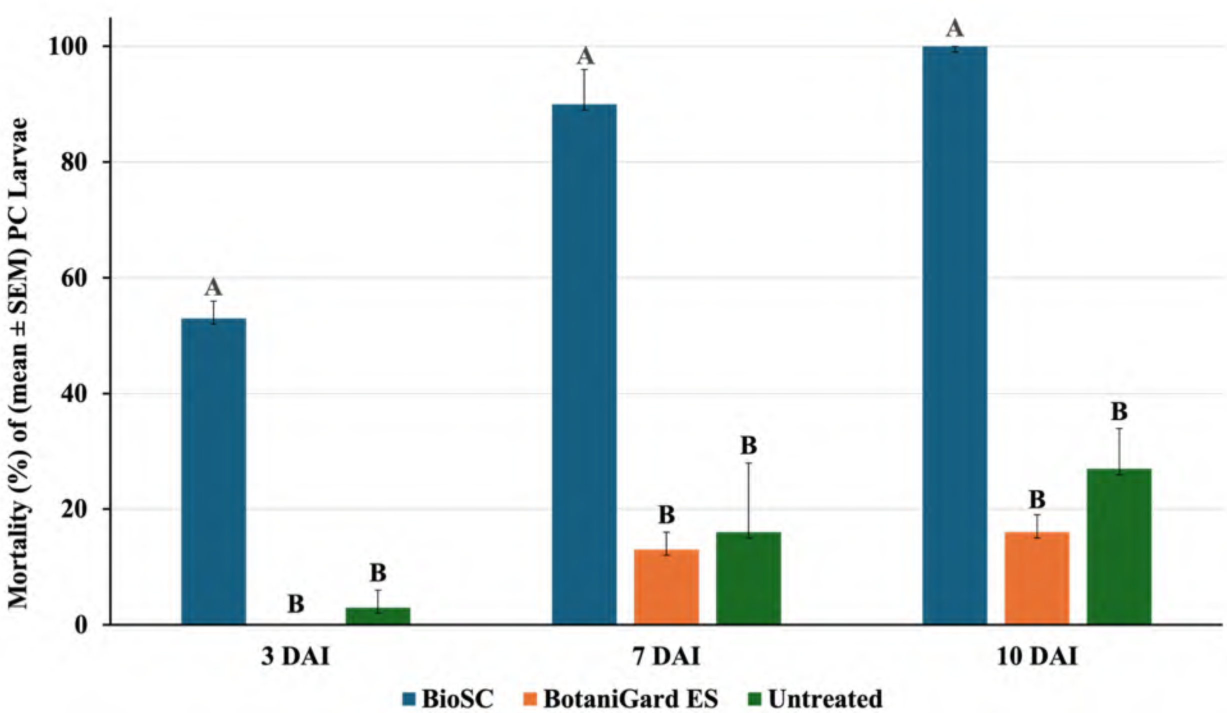

Figure 1. Mean (± SEM) mortality of plum curculio larvae (n = 10 per cup) at 3, 7, and 10 days after inoculation (DAI) with the entomopathogenic nematode *Steinernema carpocapsae* (BioSC), the entomopathogenic fungus *Beauveria bassiana* (BotaniGard ES), or water (untreated control). Within each DAI, bars with different lowercase letters (a, b) differ significantly ($P < 0.05$ means the odds are 1:19).

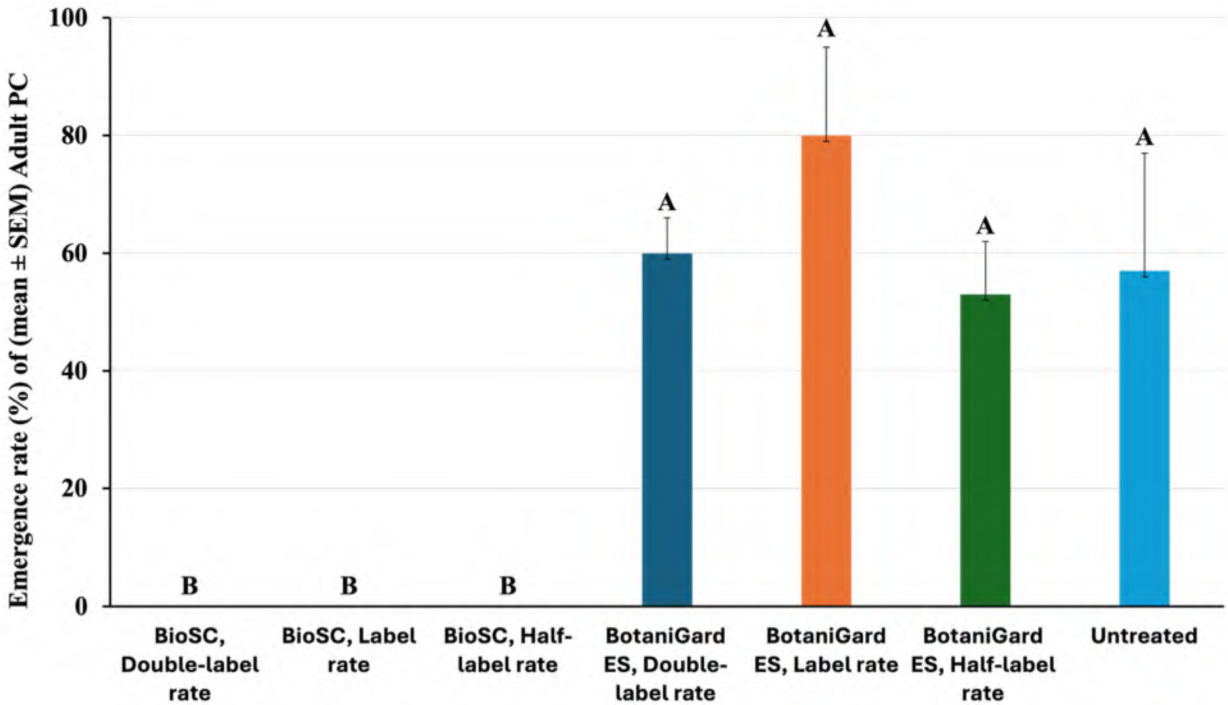

Figure 2. Mean (± SEM) adult emergence of plum curculio (PC) (n = 10 larvae per cup) after treatment with the entomopathogenic nematode *Steinernema carpocapsae* (BioSC), the entomopathogenic fungus *Beauveria bassiana* (BotaniGard ES) applied at half-, label-, or double-label rates, or water (untreated control). Bars with different letters differ significantly (P < 0.05).

BotaniGard ES should not be considered for this purpose until further research demonstrates efficacy. These results emphasize the need for research-based validation and Extension recommendations before new biological control products are adopted by growers.

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