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Entomopathogenic nematodes and neonicotinoids for remedial control of oriental beetle, *Anomala orientalis* (Coleoptera: Scarabaeidae), in highbush blueberry

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Abstract

A series of greenhouse and field assays evaluated two entomopathogenic nematode species and two neonicotinoid insecticides for remedial control of third-instar oriental beetle, *Anomala* (= *Exomala*) *orientalis* (Waterhouse), in highbush blueberry. In two greenhouse and two field assays, *Steinernema scarabaei* Stock & Koppenhöfer provided 50–95% control, the effect of imidacloprid varied from no effect to 60% control, and *Heterorhabditis bacteriophora* Poinar and thiamethoxam were ineffective. The combination of imidacloprid with *S. scarabaei* or *H. bacteriophora* was not more effective than the better of imidacloprid or nematode alone. *S. scarabaei*, should it become commercially available, could be an effective and economic alternative to preventive control with imidacloprid.

Keywords: *Anomala orientalis*; Entomopathogenic nematodes; *Steinernema*; *Heterorhabditis*; Neonicotinoid; Imidacloprid

1. Introduction

The root-feeding larvae of the oriental beetle, *Anomala* (= *Exomala*) *orientalis* (Waterhouse) (Coleoptera: Scarabaeidae), are a major pest of blueberries, *Vaccinium corymbosum* L., ornamental nurseries, and turfgrass in the northeastern USA (Polavarapu, 1996; Polavarapu et al., 2002). In New Jersey, *A. orientalis* is the most important white grub species infesting blueberries, nursery stock, and turfgrass with the Asiatic garden beetle, *Maladera castanea* (Arrow), and the Japanese beetle, *Popillia japonica* Newman, being distant second and third in importance (Polavarapu, 1996; Koppenhöfer, unpublished data). *A. orientalis* is thought to be native to the Philippines and was first discovered in the continental USA in 1920 in Connecticut. Presently, its range extends from Massachusetts south to the Carolinas and west to Ohio and Tennessee but it is most common in southern New England, southeastern New York, New Jersey, and eastern Pennsylvania (Potter, 1998; Alm et al., 1999; Vittum et al., 1999). A major route of long-distance dispersal of this species has been the shipment of infested nursery stock (Alm et al., 1999).

The 1-year life cycle of *A. orientalis* is similar to that of *P. japonica*. In New Jersey, adult emergence starts in early to mid-June and peaks in late June to early July (Polavarapu, 1996). After mating, females lay eggs singly in the soil, which hatch after 2–3 weeks (Vittum et al., 1999). Most larvae reach the third instar by mid-September (Polavarapu, 1996). The larvae move downward in the soil as temperatures drop and remain there throughout the winter. In early spring, with warming soil temperatures, the larvae move upward, feed for another 4–6 weeks, pupate in the soil around late May, and emerge as adults in June/July (Polavarapu, 1996; Polavarapu et al., 2002).

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Blueberries are a major component of the southern New Jersey economy ($47 million annual value in 2003) and are grown on approximately 3000 ha, mainly in the ecologically sensitive pine barrens of New Jersey (NJASS, 2003). Extensive feeding by white grubs like *A. orientalis* can lead to the destruction of the root-system of the host plant. Blueberry bushes with sustained damage to the roots show reduced vigor, are twiggy, have smaller leaves, and support fewer berries than uninfested bushes of the same age. Presently, the only effective control option for white grubs in blueberries is the neonicotinoid insecticide imidacloprid (Polavarapu et al., 1998). However, imidacloprid is expensive, particularly because it is most effective when applied against the first-instar grubs (Potter, 1998) and therefore used in a preventive approach. There is a dire need for alternative control options, particularly control options that are effective as curative treatments against the later larval stages.

Entomopathogenic nematodes (Heterorhabditidae and Steinernematidae) are used for the biological control of insect pests (Grewal et al., 2005a), primarily against soil insects and in an inundative approach. These nematodes may offer an environmentally safe and IPM compatible option for curative white grub control (Grewal et al., 2005b). Several species of entomopathogenic nematodes in the genera *Steinernema* and *Heterorhabditis* were evaluated against *A. orientalis* larvae in the laboratory and in turfgrass greenhouse and field trials (Yeh and Alm, 1995; Grewal et al., 2002; Lee et al., 2002). Overall, the most virulent species in the laboratory and the most effective in turfgrass trials for control of *A. orientalis* larvae has been *Steinernema scarabaei* Stock & Koppenhöfer (Grewal et al., 2005b) which has outperformed *Steinernema glaseri* (Steiner), *Heterorhabditis zealandica* Poinar and several strains of *Heterorhabditis bacteriophora* Poinar (Koppenhöfer and Fuzy, 2003; Koppenhöfer et al., 2006).

There is also increasing evidence from turfgrass trials that imidacloprid and another neonicotinoid, thiamethoxam, may be as effective as the carbamate carbaryl and the organophosphate trichlorfon for curative control of late second- and early third-instar white grubs (Grewal et al., 2001) including *A. orientalis* (Koppenhöfer, unpublished data). In addition, combinations of neonicotinoid insecticides, particularly imidacloprid, and entomopathogenic nematodes, particularly *H. bacteriophora*, have interacted synergistically on the mortality of third-instar *A. orientalis* in the turfgrass system (Koppenhöfer et al., 2002; Koppenhöfer and Fuzy, 2003).

All of the above observations were done in turfgrass, a system with continuous ground-cover, relatively shallow roots with white grubs feeding primarily in the top 0–5 cm of soil, and typically neutral to slightly acidic soils (Potter, 1998; Vittum et al., 1999). Conditions under which highbush blueberries are grown are very different with non-continuous ground-cover, deeper roots with white grubs feeding at depths to 30 cm (Polavarapu, Koppenhöfer, personal observations), and typically sandy and highly acidic soils. Particularly the low pH value of blueberry soils could have a negative impact on the performance of entomopathogenic nematodes (Koppenhöfer and Fuzy, 2006).

The objective of this study was therefore to determine the potential of the entomopathogenic nematode *S. scarabaei*, the neonicotinoids imidacloprid and thiamethoxam, and combinations of the nematodes *S. scarabaei* or *H. bacteriophora* with imidacloprid for curative control of late-instar *A. orientalis* under conditions typical for blueberry culture.

2. Material and methods

2.1. General methods

Third-instar *A. orientalis* were collected each year from turf areas at the Rutgers University Research Farm in Adelphia, NJ, in early September for the field trials and late September/early October or late april for the greenhouse trials. The larvae were kept individually in the cells of 24-well plates in sandy loam at 15 °C for short-term storage and at 10 °C for long-term storage (1–20 weeks). The larvae were warmed up at room temperature (21–25 °C) for 24 h before use in experiments.

H. bacteriophora (TF strain) was cultured in late-instar greater wax moth larvae, *Galleria mellonella* (L.) (Lepidoptera: Pyralidae) (Kaya and Stock, 1997). *S. scarabaei* was cultured in *P. japonica* and *A. orientalis* larvae because its production in wax moth larvae was unreliable. It should be noted that the use of a different host for rearing may have affected to a limited degree the relative virulence of the two nematode species (see Section 4). The infective juvenile stage nematodes (IJs) emerging from infected larvae were harvested from emergence traps over 7 days and stored in water at 10 °C for 7–30 days (Kaya and Stock, 1997).

The soils used in the experiments were typically acidic blueberry sand (92–94% sand, 6–8% silt, 0% clay, 4–5% organic matter, pH 3.9–4.1). For the greenhouse experiments the soil had been air-dried for at least 3 weeks before use. In the field experiments there was no ground cover near any of the blueberry bushes. Imidacloprid was obtained as a flowable liquid with 21.4% active ingredient (AI) (Admire 2F; Bayer CropScience, Research Triangle Park, NC) and thiamethoxam as a suspension concentrate with 21.6%AI (Platinum 2SC; Syngenta, Greensboro, NC).

2.2. Greenhouse experiments

Greenhouse experiments were conducted in 111 pots with one 2-year-old blueberry plant of the variety 'Bluecrop' per pot planted in acidic blueberry sand. Average temperature was 21 °C and photoperiod was 12:12 light to dark. The pots were seeded with *A. orientalis* 4 days before treatment application by placing the larvae individually in holes (1 cm in diameter, 5 cm in depth) made evenly on the