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Toxicity and Field Efficacy of Acetamiprid on Asparagus Beetle

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Abstract

The asparagus beetle, *Crioceris asparagi* L., is a major pest of asparagus in the United States. Commercial growers typically apply a foliar insecticide in the spring to kill adults before they can oviposit on asparagus spears. However, very few new insecticides have been registered on the crop in the last twenty years, and many chemicals have lost their registrations due to enactment of the Food Quality Protection Act. Laboratory and field experiments were conducted to evaluate the efficacy of a novel neonicotinoid insecticide, acetamiprid, to control all life stages of the asparagus beetle. Laboratory toxicity assays revealed that acetamiprid is highly toxic to asparagus beetle eggs and larvae. LC_{50} levels were 8.95 mg ai/liter for eggs and 0.012 mg ai/liter for larvae. Field efficacy trials in Virginia showed that acetamiprid applied at 0.112 kg ai/ha significantly reduced the numbers of asparagus beetle adults, eggs, and larvae on asparagus equal to or greater than that of the insecticide standard, methomyl. Acetamiprid also provided excellent control of aphids on spears, equal to or greater than that of methomyl.

Introduction

The asparagus beetle, *Crioceris asparagi* L. (Coleoptera: Chrysomelidae) (Fig. 1), is found throughout North America and is a major pest of asparagus. Three generations of the insect usually occur throughout most of its range in the U.S. (1,8). In Virginia, overwintered adults usually emerge from field debris in April or May and feed on the tender growing tips of newly-sprouted spears of asparagus (4). Feeding injury appears as pits and gouges and/or brownish discoloration of the plant tissue, which often render spears unmarketable (1) (Fig. 2). Adult females also oviposit conspicuous dark brown eggs on spears, which cannot be removed by washing and are considered contaminants that also may render the crop unmarketable (Fig. 3). Asparagus beetle larvae feed on spears, buds, and foliage which can seriously stunt plant growth (Fig. 4). In addition, this feeding can also prevent proper root development, which can cause a decrease in the size and quality of the crop in subsequent years.

Fig. 1. Asparagus beetle adult (photo courtesy of University of Minnesota).

Fig. 2. Asparagus beetle damage (photo courtesy of University of Minnesota).

Fig. 3. Asparagus beetle eggs on asparagus spear (photo courtesy of University of Minnesota).

Fig. 4. Asparagus beetle larva (photo courtesy of University of Minnesota).

Natural enemies of the asparagus beetle include the parasitoid, *Tetrastichus asparagi* Crawford (Hymenoptera: Eulophidae), which can kill over 50% of eggs and larvae (2), and numerous arthropod predators such as coccinellids and predatory bugs (1). These organisms contribute to the overall mortality of asparagus beetle, but they are usually not a reliable source of economic control. Consequently, in order to protect spears from feeding injury or egg-laying, most commercial asparagus growers apply insecticides when asparagus beetle adults appear in the spring. Insecticide applications are also made to asparagus ferns during the summer and fall months to reduce asparagus beetle densities before adults can overwinter (4).

In the last two decades there have been very few insecticides labeled on asparagus. Growers rely largely on older carbamates, organophosphates, or pyrethroids (Table 1), which are broad-spectrum toxicants that negatively impact non-target organisms. Moreover, many of these insecticides are currently under review by the U.S. EPAs Food Quality Protection Act. Spinosad is a reduced-risk insecticide that was recently registered on asparagus, but is labeled for postharvest protection of ferns only. Acetamiprid (Assail, Cerexagri Inc., King of Prussia, PA) is a relatively new neonicotinoid insecticide that is registered for use on some vegetable crops, but not asparagus. The chemical has ovicidal, larvicidal, and adulticidal activity against numerous beetles and sucking insects while having reduced impact on beneficial insects (3). To our knowledge, there is no published information on the toxicity of acetamiprid or any other neonicotinoid insecticide on asparagus beetle. Thus, the objective of this study was to evaluate the laboratory toxicity and field efficacy of acetamiprid on all stages of the asparagus beetle.

Table 1. Commercial insecticides labeled for asparagus beetle control in Virginia in 2005.

Insecticide (active ingredient)	**Insecticide class** (IRAC Mode of Action Category)	**Products**
Carbaryl	Carbamate (1A)	Carbaryl 4L, Sevin 4F, Sevin 80S, Sevin XLR Plus
Dimethoate	Organophosphate (1B)	Dimethoate 400, Dimethoate 4EC
Kaolin	N/A	Surround WP
Methomyl	Carbamate (1A)	Lannate LV, Lannate SP
Permethrin	Pyrethroid (3)	Ambush 25W, Perm-up 25WP, Perm-up 3.2EC, Permethrin 3.2AG, Permethrin 3.2EC, Pounce 25WP, Pounce 3.2EC
Pyrethins	Pyrethrins (3)	Evergreen EC60, Pyganic EC
Pyrethrins + rotenone	Pyrethrins (3) + Rotenone (21)	Pyrellin EC
*Spinosad	Spinosyns (5)	SpinTor 2SC, Entrust 70WP

* Labeled for postharvest protection of ferns only.

Laboratory Toxicity Assays of Acetamiprid on Asparagus Beetle Eggs and Larvae

Laboratory assays were conducted on beetle eggs and larvae collected from a 15 year old asparagus stand of 24 beds (each ~60.96 m long on 1.83 m row centers) located near Painter, VA and comprised of a mix of 'Jersey' asparagus hybrids. The stand was maintained over the years according to standard commercial production practice, including annual harvesting of spears in April and May every two to three days for a period of 8 weeks. No insecticides were applied to the beds. In May 2004 and 2005, approximately 300 asparagus beetle eggs and larvae were collected from the asparagus stand. Sections of spears or ferns containing the insects were cut from plants in the field and placed in rearing containers in the laboratory. Insects were assayed within 24 h of their collection from the field. For egg toxicity assays, serial dilution concentrations of acetamiprid at 0, 0.0001, 0.001, 0.01, and 0.1 mg ai/ml solution were mixed in 500 ml of de-ionized water. Seven replicates of each concentration were tested in a single experiment. The test unit included a 5- to 8-cm-long section of asparagus stem or fern, which contained 8 to 12 fresh asparagus beetle eggs. The plant section was dipped for 10 s in the solution, held vertically to allow excess solution to drip off, placed in a drying rack in a fume exhaust hood to air dry for 2 h, and then placed into a 9-cm diameter plastic Petri dish containing a moistened cotton ball. Petri dishes were maintained at 27 ± 2°C, 40 to 70% RH, and a photoperiod of 14:10 (L:D). Percentage egg hatch was determined after 1 week by counting numbers of larvae in the Petri dish.

For larval toxicity assays, the same experimental protocol was followed with the exception of the following: (i) there was one additional acetamiprid concentration of 0.00001 mg ai/ml; (ii) there were 5 replicates for each concentration; (iii) 10 asparagus beetle larvae (2 to 4 instars) were placed in each dish; and (iv) larval mortality was determined after 48 h of exposure. Larvae were considered dead if they did not move when prodded. Both egg and larval toxicity experiments were conducted twice. Data were pooled and toxicity curves including LC_{50} and 95% fiducial limits were constructed and calculated using Polo Plus toxicity data software (PoloPlus version 1.0, Probit and Logit Analysis, 2002-2003 LeOra Software, Berkeley, Calif.).

Results indicated that acetamiprid was highly toxic to asparagus beetle eggs and larvae. Concentrations of 1 mg ai/liter killed 62 to 84% of eggs and 100 mg ai/liter killed 100% of eggs (Table 2). For asparagus beetle larvae, concentrations of 0.1 mg ai/liter or higher resulted in greater than 90% mortality (Table 2). The LC_{50} level was calculated to be 8.95 mg ai/liter for asparagus beetle eggs and 0.012 mg ai/liter for larvae (Table 3). These LC_{50}

levels of acetamiprid are substantially lower than that of a typical field-rate concentration of the insecticide (5,750 mg ai/liter) that would be applied on other vegetable crops (Table 3).

Table 2. Mortality of field-collected asparagus beetle eggs and larvae* on asparagus dipped into various acetamiprid solutions and allowed to dry for 2 h.

Rate (mg ai/liter)	**% egg mortality** (5 DAT)		**% larval mortality** (48 h)	
	Trial 1	**Trial 2**	**Trial 1**	**Trial 2**
0	52.9	15.7	2.0	23.3
0.01	–	–	44.0	38.3
0.1	–	–	94.0	91.7
1	84.3	62.9	100.0	96.7
10	85.7	92.9	100.0	100.0
100	100.0	100.0	100.0	100.0

* 8 to 12 specimens per Petri dish; 5 or 7 reps per treatment per experimental trial.

Table 3. Lab toxicity of leaf-dip solutions of acetamiprid to asparagus beetle eggs and larvae collected from Painter, VA.

Asparagus beetle life stage	**n**	**LC_{50}** (mg AI/liter)	**95% fiducial limits***	**Slope ± SE**	**Proportion of the LC_{50} to the actual field spray concentration***
Eggs	42	8.95	0.43-26.67	1.186 ± 0.264	0.002
Larvae	55	0.012	0.007-0.018	1.723 ± 0.320	0.0000002

* Based on a typical application rate of 0.05 lb per acre on other vegetable crops (3) and a spray volume of 355 liters per hectare.

Field Efficacy Trials of Acetamiprid on Asparagus Beetle

Two field trials were conducted at the Virginia Tech Eastern Shore Agricultural Research and Extension Center (ESAREC), near Painter, VA (75° 49'W, 37°35'N; elevation ≈ 12 m). Experiments were performed on the same 15 year old asparagus stand of 24 beds mentioned previously. Trial 1 was conducted in spring 2005, and consisted of three treatments arranged in a completely randomized design: (i) acetamiprid (Assail 30SG, Cerexagri); (ii) methomyl (Lannate LV, Dupont Inc., Des Moines, IA); and (iii) an untreated check. At 50 random locations among the asparagus beds for each treatment (150 total locations), a 1.52-m long plot was flagged along the beds. Each individual plot was isolated from each other by at least 1.8 m. On 5 May, within each plot, one asparagus spear (> 12.7 cm long) containing asparagus beetle eggs, and one spear without eggs were marked with flagging tape and all other spears were harvested. Asparagus plots were sprayed with insecticides one time using a backpack sprayer equipped with a three-nozzle flat fan boom that delivered 113.56 liter/0.40 ha.

At 4 days after treatment (DAT), all marked asparagus spears that previously had no asparagus beetle eggs were inspected for eggs and any other insect pests such as aphids. All spears that previously contained asparagus beetle eggs were collected and brought back to the laboratory to assess egg hatch. Sections of the spears containing the eggs were held in Petri dishes at room temperature for 5 days. The total number of eggs and number hatched (indicated by the presence of larvae) were recorded for each Petri dish and percentage egg hatch calculated. The same experiment was repeated on 13 May (Trial 2) on a fresh batch of newly emerging asparagus spears.

Data on numbers of asparagus beetle eggs and aphids on spears 4 DAT, and percentage mortality of asparagus beetle eggs after insecticide treatment were analyzed using one-way ANOVA. Proportion data were arc-sine sqrt transformed prior to analysis. Means were separated using Fisher's Protected LSD at the $P < 0.05$ level of significance.

Another field efficacy experiment was conducted in June at the same Painter, VA location. This experiment tested the efficacy of acetamiprid against asparagus beetle larvae and adults. The experiment consisted of the same three aforementioned treatments acetamiprid, methomyl, and an untreated check arranged in a completely randomized design. At 10 random locations among the asparagus beds (separate from those used for egg efficacy trials) for each treatment (30 total locations), a single asparagus fern was flagged along the beds. On 19 June, asparagus ferns in the plots were sprayed with a Solo backpack sprayer equipped with a single-nozzle flat fan boom that delivered 75.71 liters/0.40 ha. To evaluate efficacy, at 3 DAT, asparagus ferns were inspected for live asparagus beetle larvae and adults. Numbers of each were recorded for each fern. Data were analyzed using one-way ANOVA. Means were separated using Fisher's Protected LSD at the $P < 0.05$ level of significance.

Results showed that there was a significant treatment effect on the percentage of asparagus beetle eggs hatching for Trial 1 (F = 31.7; df = 2, 112; $P < 0.0001$) and Trial 2 (F = 101.0; df = 2, 84; $P < 0.0001$). In both trials, egg hatch in the untreated control was significantly higher than the methomyl or acetamiprid treatments (Table 4). There was also a significant treatment effect on numbers of new asparagus beetle eggs on spears for Trial 1 (F = 6.0; df = 2, 156; $P < 0.0031$) and Trial 2 (F = 8.8; df = 2, 156; $P < 0.0002$). Acetamiprid and methomyl plots had significantly fewer new eggs than the untreated control in both trials (Fig. 5). In addition to asparagus beetles, aphids were also occasionally found on spears. Though we did not identify the aphid species, to the best of our knowledge it appeared to us to be English grain aphid, *Sitobion avenae* (Fabr.), migrating from surrounding wheat plots. There was a significant treatment effect on numbers of aphids on spears in Trial 1 (F = 3.6; df = 2, 156; $P < 0.029$) and nearly a significant treatment effect in Trial 2 (F = 2.9; df = 2, 156; $P < 0.059$). Acetamiprid plots had fewer aphids than the untreated control, and methomyl was not different than either (Fig. 6).

Table 4. Percentage of asparagus beetle eggs hatching after foliar insecticide applications to asparagus; ESAREC, Painter, VA, 2005.

		% of eggs hatching	
Treatment	**Rate** (lb ai/acre)	**Experiment 1** (May 5)	**Experiment 2** (May 13)
Acetamiprid	0.10	6.0 ± 2.0 b	0.4 ± 0.4 c
Methomyl	0.45	12.5 ± 4.0 b	8.3 ± 2.5 b
Untreated control	–	44.8 ± 4.9 a	47.7 ± 3.9 a

Numbers within a column followed by a letter in common are not significantly different according to ANOVA followed by Fisher's Protected LSD at the $P < 0.05$ level of significance.

Table 5. Numbers of asparagus beetle larvae and adults (mean ± SEM) on asparagus ferns 3 days after insecticide applications; ESAREC, Painter, VA, 2005.

		No. of live asparagus beetles per fern	
Treatment	**Rate** (lb ai/acre)	**Larvae**	**Adults**
Acetamiprid	0.10	0.0 ± 0.0 b	0.0 ± 0.0 b
Methomyl	0.45	0.0 ± 0.0 b	1.2 ± 0.6 ab
Untreated control	–	4.6 ± 1.1 a	2.8 ± 1.1 a

Numbers within a column followed by a letter in common are not significantly different according to ANOVA followed by Fisher's Protected LSD at the $P < 0.05$ level of significance.

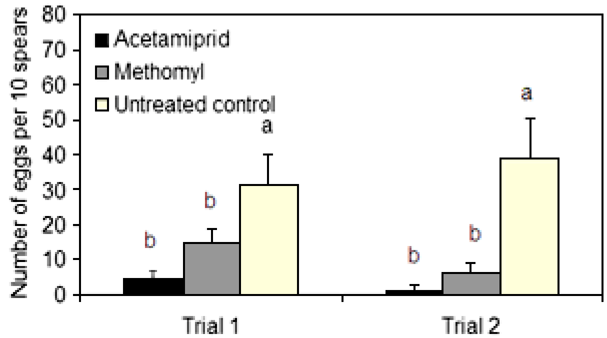

Fig. 5. Asparagus beetle eggs (mean + SEM) on asparagus spears 4-days after application; Painter, VA, May 2005. Bars within the same trial with a letter in common are not significantly different (*P* < 0.05).

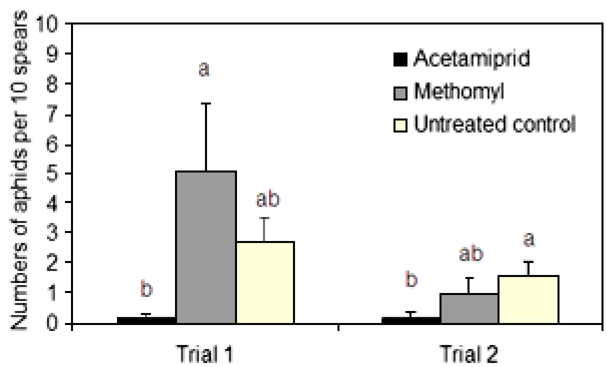

Fig. 6. Numbers of aphids (mean + SEM) on asparagus spears 4-days after spraying; Painter, VA, May 2005. Bars within the same trial with a letter in common are not significantly different (*P* < 0.05).

In the second field experiment, there was a significant treatment effect on numbers of asparagus beetle larvae (F = 17.9; df = 2, 27; *P* < 0.0001) and adults (F = 3.8; df = 2, 27; *P* < 0.0359) at 3 DAT. No live larvae were found in the acetamiprid or methomyl plots compared with 4.6 larvae per fern in the untreated control (Table 2). In addition, no asparagus beetle adults were found in the acetamiprid plots, which was significantly less than the untreated control (Table 5). Methomyl was intermediate and not significantly different than either treatment.

Summary

The neonicotinoid insecticide, acetamiprid, has been shown to be efficacious against certain Coleopteran pests such as Colorado potato beetle, flea beetles, cucumber beetle, and Japanese beetle (3,5,6,7). Results of our field and laboratory experiments indicate that acetamiprid is highly toxic to asparagus beetle eggs and larvae and is very effective at controlling the pest on asparagus in the field. Historically, control of asparagus beetle has been achieved with carbamates, organophosphates, or pyrethroids, all of which are broad-spectrum toxicants that entail greater health risk for the user and also kill non-target organisms such as natural enemies that can help reduce asparagus beetle populations (1,2). Acetamiprid is profiled as a reduced-risk pesticide by the EPA and is less toxic to natural enemies than currently-registered products (3). These attributes make it a relevant choice in the spectrum of an integrated pest management program. Acetamiprid also provides excellent control of aphids and other sucking insects. Our data indicate that acetamiprid or perhaps a similar neonicotinoid insecticide, would be an excellent integrated pest management tool for asparagus growers if registered.

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