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Effect of soil application of imidacloprid on survival of adult green lacewing, *Chrysoperla carnea* (Neuroptera: Chrysopidae), used for biological control in greenhouse

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Abstract

In the greenhouse, survival of adult green lacewing, *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae), was reduced after feeding on flowers from plants treated with a soil application of imidacloprid (Marathon 1% G, label rate and twice label rate). Percent survival for *C. carnea* at 10 d was statistically different between treatments and controls: 79% for untreated flowers, 14% for label rate, and 6% for twice label rate. Trembling was observed in imidacloprid treatments, but not controls. A cold anthrone test showed that *C. carnea* were feeding equally from all treatments, confirming that lacewings were not starving to avoid feeding on treated flowers. In support of these data, a previous study in this system using residue analysis demonstrated that soil-applied imidacloprid was translocated to flower nectar. Consequently, plants treated with imidacloprid for the control of greenhouse pests will reduce populations of *C. carnea* and lower their efficacy as biological control agents.
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Keywords: Greenhouse IPM; Imidacloprid; Systemic insecticide; *Chrysoperla carnea*; Chrysopidae; Neuroptera

1. Introduction

Integrated pest management (IPM) depends on multi-faceted control measures. Consequently, it is important to know the potential side effects of using insecticides with augmentative and conservation biological control. Sales and use of neonicotinoid insecticides soar above organophosphates, carbamates, and pyrethroids for pest control (Matsuda et al., 2001). One of these, imidacloprid [1-(6-chloro-3-pyridylmethyl)-2-nitroimino-imidazolidine] 1-[(6-chloro-3-pyridinyl)methyl]-N-nitro-2-imidazolidinimine, is a systemic neonicotinoid insecticide applied to the soil to control many sucking and chewing insects. Imidacloprid acts upon the nervous system, causing blockage of postsynaptic acetylcholine receptors (Ware, 2000). Because of the systemic mode of action and low toxicity to humans, imidacloprid has become a popular insecticide worldwide for use in ornamentals, field crops, and vegetables (Ishaaya and Horowitz, 1998; Matsuda et al., 2001; Nauen and Denholm, 2005). Imidacloprid is registered in approximately 120 countries and is used on over 140 different agricultural crops (Buffin, 2005). It is marketed under many names depending on concentration and how it is administered. Trade names include Gaucho, Provado, Admire, Marathon, Merit, Imicide, Confidor, Intercept, Winner, Premier, and Premise.

The Koppert Biological System website is an important resource for IPM that lists compatibility between natural enemies and insecticides (Koppert, 2005). The website considers the use of foliar-applied imidacloprid harmful to beneficial insects, such as the green lacewing *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae); however, soil drenches of imidacloprid are listed as compatible with *C. carnea*. This recommendation is supported in a review of insecticides with novel modes of action (Ishaaya and Horowitz, 1998).

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According to the National Union of French Beekeepers (Apiservices, 2005) and Commissioners and Beekeepers of the European Union (Bonizzoni et al., 2006) imidacloprid should not be used due to its non-target effects on honey bees. Gaucho was banned in France from 1999 to 2006 (Anonymous, 2005). Some research has supported the claim by bee keepers of "mad bee disease". In the field, imidacloprid used as a seed treatment, (Gaucho, 40.7% AI, Bayer CropScience, Research Triangle Park, NC) is linked to alteration in foraging, recruitment, and mortality of honey bee, *Apis mellifera* (L.). In a review paper that used published data to estimate the exposure of honey bees to imidacloprid, it was found that honey bees were exposed to lethal and sublethal doses in fields that regularly used imidacloprid (Rortais et al., 2005). When honey bees were given 24 ppb imidacloprid in artificial nectar, they experienced decreased foraging activity (60%) and decreased activity in the hive (Decourtye et al., 2004). In corn, seed treatments of Gaucho resulted in 2.1 ppb imidaclopird in pollen (Bonmatin et al., 2005). In sunflowers, Gaucho when applied as a seed treatment resulted in 13 ppb in pollen (Laurent and Rathahoa, 2003).

Effects of foliar sprays of imidacloprid are documented. Bumble bees, *Bombus terrestris* (L.), showed 30% mortality in 24 h after imidacloprid was sprayed on cucumber plants (Incerti et al., 2003). After foliar applications of imidacloprid in cotton, the wasp parasitoid, *Microplitis croceipes* (Cresson), when fed on nectar, had 25% decrease in longevity and 77% reduction in host finding (Stapel et al., 2000). Survival for fifth instar nymphs of spined soldier bug, *Podisus maculiventris* (Say), was 50% when exposed topically to 70 ppb imidacloprid (De Cock et al., 1996).

For greenhouse, there are limited data on the effects of soil applications of imidacloprid on nectar feeding by biological control agents. *Bombus terricola occidentalis* (Greene) showed 96% mortality after foraging on tomato flowers from plants treated with a soil application of imidacloprid (Merit 75W, 75% AI, Bayer Environmental Science, Research Triangle Park, NC) (Al-Jabr, 1999). Mortality of the minute pirate bug, *Orius tristicolor* (White), increased when it pierced marigold leaves, *Tagetes erecta* (L.), treated with a soil drench of imidacloprid (Marathon 1% G, 1% AI, Olympic Horticultural Products, Mainland, PA) (Sclar et al., 1998). A soil drench of imidacloprid (Marathon 1% G) was translocated to flowers of sunflowers and caused 38% mortality in the pink lady beetle, *Coleomegilla maculata* (DeGeer), when confined to flowers for food (Smith and Krischik, 1999). The soil or irrigation applied formulation of imidacloprid, Intercept 60 WP (60% AI, Bayer CropScience, Calgary, Canada), states on the label that the product may result in adverse affects on pollinators and other beneficials in the greenhouse (Bayer, 2004).

The objective of this experiment was to investigate the effect of soil applications of imidacloprid on adult *C. carnea* used for biological control in greenhouse, since few studies evaluate the effects of soil-applied imidacloprid on nectar feeders. *C. carnea* larvae are generalist predators that attack eggs and soft-bodied insects, such as aphids, spider mites, whiteflies, and thrips. After feeding on insects, larvae turn into adults that feed on nectar and lay eggs. We evaluated whether adult *C. carnea* had reduced survival when fed flowers from buckwheat, *Fagopyrum esculentum* (Moench), and Mexican milkweed, *Asclepias curassavica* (L.), treated with soil-applied imidacloprid.

2. Materials and methods

2.1. Insect systems

Three thousand adult *C. carnea* were obtained from Rincon–Vitova Insectaries (Ventura, CA) 1 week before the start of each of three replicate experiments. This permitted *C. carnea* to feed before the experiment started and habituate to the food array and cages. Adult *C. carnea* arrived in paper containers and were distributed among nine mesh cages (30 cm × 30 cm × 30 cm) (BioQuip, Rancho Dominquez, CA) for the first replicate and twelve mesh cages for the second and third replicates. Upon release, cages were supplied with three 35 × 10 mm petri dishes smeared with commercial *C. carnea* diet (Rincon–Vitova), four tubes with water (Aquatube, Syndicate Sales, Kokomo, IN), four tubes with 20% honey–water, and two tubes with untreated flowers of *F. esculentum* and *A. curassavica*. The cages were cleaned and provisioned daily until the start of the experiment.

2.2. Plant systems

Fagopyrum esculentum and *A. curassavica* were used as nectar plants. *F. esculentum* is commonly used in organic production to provide shelter and nectar for beneficial insects, such as lady beetles, *Hippodamia convergens* (Guérin-Ménéville), minute pirate bugs, *Orius insidiousus* (Say), and adult *C. carnea* (Plotkin, 2005). *Asclepias curassavica* has small, open flowers comprising an umbel which produces large amounts of sucrose-rich nectar that attract beneficial insects (Wyatt and Broyles, 1994). Plants were grown in the greenhouse under 16:8 photoperiod at 20 °C daytime and 16 °C nighttime temperatures. Plugs of *A. curassavica* plants were obtained from North Creek Nurseries (Landenberg, PA) and seeds of *F. esculentum* were obtained from Johnny's Select Seeds (Winslow, ME). Multiple plants were grown in 15-cm pots containing Scott's Metro-Mix soilless media and 10 g Osmocote (Scotts Sierra Horticultural Products Company, Marysville, OH). Plants were fertilized weekly with a dilute drench of Peters 20-20-20 Fertilizer (Allentown, PA). At time of flowering, imidacloprid granules (Marathon 1% G) were applied to the soil surface (6 g, 1x, label rate and 12 g, 2x, twice label rate) at 3 weeks prior to feeding. The application rate was determined by extrapolation of soil volume for the recommended label rate of a 4-inch pot in which our preliminary studies were performed.

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