Biocompatibility of OMRI listed insecticides on green lacewing (*Chrysoperla carnea*) larval mortality: implications for greenhouse vegetable production

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The availability of Organic Materials Review Institute (OMRI) listed insecticides has increased in recent years. Shorter pre-harvest intervals and residual activity have aided organic farmers with a low-risk option to chemically combat their pest populations (Sarkar et al., 2019). However, OMRI listed insecticides often have shorter residual activity resulting in repeated applications over a shorter time-period. This has raised concerns about the development of pest resistance as well as the non-target effects on natural enemy insect populations. In addition, while insecticides provide a short-term solution of managing damaging pest populations, a more sustainable approach for long-term management is still needed (Sarkar et al., 2019).

Combining chemical and biological control strategies offers a more sustainable long-term approach for pest management, as well as lowers the risk for development of pest resistance (Gentz et al., 2010). Using naturally occurring generalist predators that feed on an array of organisms throughout their life cycle has shown to increase predation rates of invasive pest species (Lee et al., 2019), thus lowering the frequency of chemical control in integrated pest management (IPM) systems. Generalist predators such as green lacewing (*Chrysoperla carnea*) (Neuroptera: Chrysopidae) are widely used in organic production to manage arthropod pest populations in a range of crops and environmental conditions (Senior and McEwen, 2001). The voracious consumption during their last larval stage has positioned green lacewing as a viable IPM tool in open-field and controlled environments for decades (Hoffmann and Frodsham ,1993). However, while green lacewing larvae are reported to have some resistance against once commonly used groups of synthetic insecticides (Pree et al., 1989), lethal effects have been reported on organic derivatives labeled as reduced risk to natural enemies (Amarasekare and Shearer, 2013; Lehnert, 2012).

The frequency of OMRI listed insecticide applications and the selectivity they have on non-target organisms has only begun to be understood in IPM programs. For example, Entrust® SC, an OMRI listed insecticide used for management of thrips on vegetables, has demonstrated acute toxicity to red-lipped green lacewing (*Chrysoperla rufilabris)* and minute pirate bug (*Orius insidiosus*) lasting between 3 and 7 days (Lee et al., 2019).

This study evaluated the residual effects of three OMRI listed insecticides, Azera®, Grandevo®, and M-Pede®, on the European green lacewing (*Chrysoperla carnea*), a generalist predator of soft-bodied insect pests commonly released in greenhouse settings. Commercial suppliers of beneficial organisms have indicated non-toxic and slightly-toxic side effects to green lacewing larvae with application of Azera and M-Pede, respectively; whereas Grandevo side effects are unknown. Therefore, our objectives were to 1) evaluate the lethal effects of these three OMRI listed insecticides on green lacewing survival, and 2) determine when growers can successfully integrate biological control agents (*C. carnea*) into their IPM programs.

Materials and Methods

Three commercially available OMRI listed insecticides were used in the laboratory bioassays, including Azera, Grandevo, and M-Pede (Table 1), at the University of Minnesota's St. Paul Campus in 2021. Green lacewing was tested with each insecticide treatment with an additional untreated control (deionized water) included for standardized mortality comparison. The bottom plate of 50 petri-dishes were sprayed with each treatment according to recommended rates in a spray chamber (Table 1). Plates remained enclosed in the chamber for two minutes while fans removed excess vapors before the lid placement. Petri-dishes were stored at room temperature for 4 hours for drying purposes.

Fresh shipments of green lacewing containing eggs, pupae, and larvae were obtained from Biobest Sustainable Crop Management (St. Paul, MN, USA), for each of the three rounds of the experiment (Fig. 1). Vials containing eggs, pupae, and larvae were isolated into separate petri-dishes with approximately 100 per dish to reduce cannibalism. Each petri dish received ¼ teaspoon of Nutrimac™ diet (Biobest Sustainable Crop Management) consisting of moth eggs. Larval stages were separated into sealed 40-ml plastic berry containers and given a pinch of diet in a controlled environment while treatments were applied to petri-dish assays (Fig. 2). Larva were then transferred to individual petri-dishes once treatment residue was dry. Each petri-dish was sprinkled with diet and given a small moistened cotton swab before being covered.

Table 1. List of active ingredients and rates associated with OMRI listed treatments in *Chrysoperla carnea* laboratory bioassays. All treatment rates mixed with 250 mL DI H20 for recommended concentrations listed on the manufacturer's label.

Active ingredient	Manufacturer	Rate	Trade name
Azadirachtin + Pyrethrins	Valent USA Corporation, Walnut Creek, CA	4.375 mL	Azera®
Chromobacterium subtsugae	Marrone Bio Innovations, Davis, CA	7.5 mL	Grandevo®
Potassium salts of fatty acids	Gowan Company, Yuma, Arizona	5.0 mL	M-Pede®

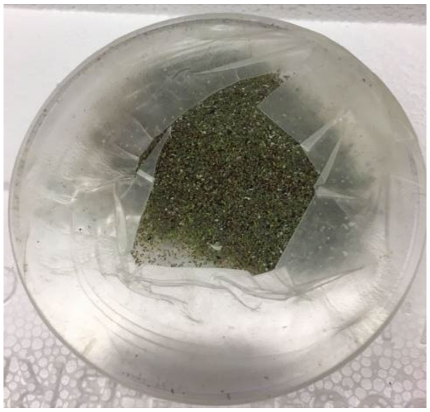

Figure 1. Fresh shipment of green lacewing eggs, pupae, and larvae before isolation.

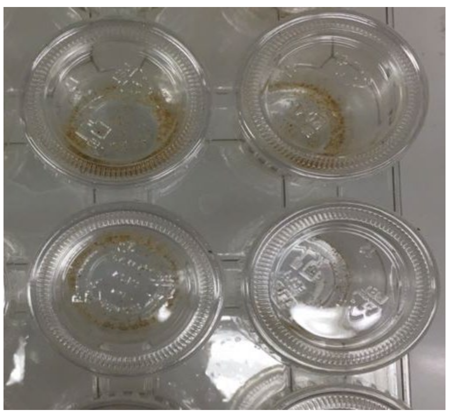

Figure 2. Green lacewing larvae given a pinch of diet and housed in a controlled environment before transfer to treated petri-dish assays.

Lethal and sub-lethal effects of OMRI listed insecticides were recorded at 1, 3, 5, and 7 days. Lethal effects were determined by probing the larvae and watching for body stimulus. Percent mortality was recorded and transformed to class ratings for each day(s) of exposure. Deceased green lacewing were recorded as Class 4 (>75% mortality= toxic) and discarded at the time of examination. Sub-lethal effects of insecticide treatments were defined as individuals being immobile but still alive, small instars or possessing abnormal behavior after probing such as curling or lying on their backs, or behaving normally, and were recorded as Class 3 (50-75% mortality = moderately toxic), Class 2 (25-50% mortality = slightly toxic), and Class 1 (< 25% mortality = non-toxic), respectively.

Each treatment was repeated five times, with 10 samples per replication, for a total of 50 petri dishes of larvae per treatment. Mortality percentage means were analyzed with repeated measures ANOVA using SAS PROC MIXED, and were separated with Tukey's HSD adjustment at $P < 0.05$. Days x treatment interaction of green lacewing larval mortality after 1, 3, 5, and 7 days of exposure were recorded.

Results

All treatment applications were given Class 1, non-toxic rating, to green lacewing larval mortality up to 7 days of exposure. Larval mortality was different by treatment ($P < 0.0001$), and survival decreased as days of exposure lengthened ($P < 0.05$). M-Pede had the highest mortality after 1 and 3-days of exposure (data not shown). Mortality increased in all treatments besides M-Pede from 3 to 5-days of exposure. Azera was the only treatment to increase in larval mortality after 5 days of exposure. Green lacewing larvae survival was highest with Grandevo and control treatments throughout the 7 days of exposure. Larval mortality was not affected by the interaction of days of exposure x treatment; therefore, mean treatment mortality was averaged over the 7 days (Table 2).

Table 2. Mean treatment toxicity of green lacewing (*Chrysoperla carnea*) larvae over 7 days of exposure. Mean mortality was reported at 5% increments.

Treatment[z]	**Mortality %**	**Class[y]**
Azera	< 15 b[x]	1
Grandevo	< 5 a	1
M-Pede	< 15 b	1
Control	< 5 a	1

[z] OMRI listed insecticides and their active ingredients; Azera® (Azadirachtin + Pyrethrins), Grandevo® (*Chromobacterium subtsugae*), M-Pede® (Potassium salts of fatty acids), and control (Deionized H_20).
[y] Class 1 indicated as <25% mortality = non-toxic.
[x] Means within column followed by the same letter are not different ($P \leq 0.05$) based on ANOVA for repeated measures with PROC Mixed (SAS 9.4), using Tukey's HSD adjustment.

Discussion

Insecticide toxicity to biological control agents is a major concern in IPM programs. It is well known that repeated insecticidal applications drastically reduce the fecundity of generalist predators, such as the green lacewing (Pree et al., 1989). Organic growers undergo an increased challenge with limited selection of insecticides approved for organic production, involuntarily forcing repeated applications to their crops. While new natural derivatives are constantly evolving, the impact of these emerging OMRI listed insecticides used in biological control programs have not been clearly understood.

We demonstrated that three OMRI-listed insecticides commonly used in greenhouse vegetable production were non-toxic to the larvae of the most recognized generalist predators, the green lacewing. This not only demonstrates that growers can safely release green lacewing larvae back into their crops due to low OMRI-residual activity, but also confirms *C. carnea*'s stability in greenhouse vegetable IPM programs.

Acknowledgments

Funding for [this Project or Publication] was made possible by the U.S Department of Agriculture's (USDA) Agricultural Marketing Service through grant No. AM190100XXXXG017. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA. We thank Biobest Sustainable Crop Management for supplying green lacewing throughout the study.

Reviewed by Erik Burkness,
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