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Authors: Studebaker, Glenn E., and Kring, Timothy J.

Source: Florida Entomologist, 86(2) : 178-185

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/0015-4040(2003)086[0178:EOIOOI]2.0.CO;2

EFFECTS OF INSECTICIDES ON *ORIUS INSIDIOSUS* (HEMIPTERA: ANTHOCORIDAE), MEASURED BY FIELD, GREENHOUSE AND PETRI DISH BIOASSAYS

GLENN E. STUDEBAKER[1] AND TIMOTHY J. KRING[2]
[1]Northeast Research & Extension Center, University of Arkansas, P.O. Box 48, Keiser, AR 72351

[2]Department of Entomology, University of Arkansas, Fayetteville, AR 72701

ABSTRACT

Orius insidiosus (Say) is an important predator of several economic pests in cotton. Laboratory-reared males, females and third instar nymphs were exposed to residues of nine insecticides applied to cotton plants in the field, in potted plants in the greenhouse and glass Petri dishes in the laboratory. Insects were exposed for 24-hours and then removed to determine mortality. Insecticides tested were spinosad, indoxacarb, imidacloprid, tebufenozide, methoxyfenozide, abamectin, emamectin benzoate, fipronil and λ-cyhalothrin. Differences were observed in mortality as measured by different methods. Spinosad, imidacloprid and indoxacarb induced significantly higher mortality with treated Petri dishes than on treated cotton plants in the field or greenhouse. No differences in mortality were observed between methods with fipronil or λ-cyhalothrin, and in only one instance with abamectin. Spinosad was not toxic in the field or greenhouse bioassays, but was highly toxic in the Petri dish bioassay. Imidacloprid was moderately toxic in the field and greenhouse, but was highly toxic in the Petri dish bioassay. Indoxacarb had variable toxicity, with low to moderate toxicity in the field and greenhouse, and high toxicity in the Petri dish bioassay. It is apparent that multiple testing methods should be used in evaluating the effects of pesticides on beneficial arthropods.

Key Words: insidious flower bug, pesticides, mortality

RESUMEN

Orius insidiosus (Say) es un depredador importante de diferentes plagas económicas en el algodón. Machos criados en el laboratorio, hembras y ninfas del tercer estádio fueron expuestos a residuos de nueve insecticidas aplicados a plantas de algodón en el campo, en plantas en masetas en el invernadero, y en platos de Petri de vidrio en el laboratorio. Los insectos fueron expuestos por 24-horas y después sacados para determinar la mortalidad. Los insecticidas probados fueron spinosad, indoxacarb, imidacloprid, tebufenozide, methoxyfenozide, abamectin, emamectin benzoate, fipronil λ-cyhalothrin. Se observaron diferencias en la mortalidad medida por métodos diferentes. Los spinosad, imidacloprid e indoxacarb inducian una mortalidad significativamente más alta en los platos tratados en los Petri tratados que en las plantas de algodón en el campo y en el invernadero. Ninguna diferencia en la mortalidad fué observada entre los métodos con fipronil λ-cyhalothrin, y solamente en una ocasión con abamectin. El spinosad no fue tóxico en los bioensayos del campo o del invernadero, pero fué altamente tóxico en el bioensayo en el plato Petri. Imidacloprid fué moderadamente tóxico en el campo y en el invernadero, pero fué altamente tóxico en el bioensayo en el plato de Petri. Indoxacarb tenia una tóxicidad variable, con una tóxicidad de baja a moderada en el campo y en el invernadero, y altamente tóxico en el bioensayo en el plato de Petri. Es evidente que se debe usar métodos de pruebas multiples para evaluar los efectos de pesticidas en artrópodos beneficos.

An increasing number of scientists are evaluating the toxicity of new pesticide chemistries on beneficial arthropods. Although a considerable number of studies have been published, it is sometimes difficult to compare results among researchers. The variety of methods used in bioassays is as varied as the number of individuals conducting the work. Scientists have used direct topical applications of the pesticide to the insect (Yu 1988; De Cock et al. 1996; Trisyono et al. 2000) or injected the insect with insecticide (Yu 1988), or fed treated prey (De Cock et al. 1996; Trisyono et al. 2000; Elzen 2001). These methods insure that a specific insecticide dose makes contact with the insect, either topically or internally, and will give an accurate indication of the actual toxicity of the pesticide to the insect in question. It is likely that if the insect species survives the topical or injection application, it will also survive any exposure in the field. However, the reverse

may not always be true. High mortality resulting from a topical or injection bioassay may not be related to mortality observed under field conditions.

Researchers commonly use an inert substrate such as glass vials, Petri dishes or slides to test the toxicity of various insecticide residues to predatory or parasitic insects (Plapp & Bull 1978; Mizell & Schiffhauer 1990; Bayoun et al. 1995; Oetting & Latimer 1995; De Cock et al. 1996) or may use treated plastic cups (Mizell & Schiffhauer 1990). There are several possible errors that could occur in using treated substances such as glass or plastic to evaluate the toxicity of any insecticide to an insect. While data from these bioassays will give an indication of the toxicity of a pesticide to an insect, relating this toxicity to that which may be encountered in the field is difficult. The activity of a pesticide may be affected by the substrate upon which it is deposited (Cogburn 1972; White 1982). Jain and Yadav (1989) found that some insecticides persisted much longer when applied to a plastic substrate as compared with glass or painted wood.

Potentially more realistic testing methods use treated excised leaves (Samsoe-Petersen 1985; Oetting & Latimer 1995; Jones et al. 1997; Elzen & Elzen 1999), or treated potted plants grown in the greenhouse (Brown & Shanks 1976; Pietrantonio & Benedict 1999). These methods should provide a more realistic picture of actual toxicity from contact with residues on a natural substrate. Environmental effects (e.g., solar radiation or insect movement within the plant canopy) which may effect actual toxicity are not addressed.

Numerous researchers have evaluated insecticide effects on beneficial arthropods by making evaluations in the field from treated field plots (Brown & Shanks 1976; Stoltz & Stern 1978; Young et al. 1997; Simmons & Jackson 2000). Generally, the results from field studies express toxicity as the resulting presence or absence of the insect from a treated plot in comparison with an untreated plot or with pretreatment counts. These data are often taken within a few days to a week after treatment, depending on the researcher and the experimental design. In many instances the studies were designed to evaluate mortality induced in the target pest, with beneficial arthropod counts being made as a secondary goal to the study. The test plots in this latter case are not designed to accurately evaluate the induced mortality in the beneficial arthropods naturally present in the study.

In evaluating the effects of pesticides on any insect, the method used may have an effect on the final results. Confounding factors include solar radiation, rainfall, substrate treated, temperature, etc. Under field conditions, the effectiveness of a properly-applied insecticide may be diminished by high temperatures, sunlight and rainfall events. Similarly, the same tests may underestimate mortality caused by those insecticides that are systemic in the plant tissue, particularly on plant feeding insects. Therefore, it would be important to compare these effects as measured through various methodologies.

Materials and Methods

Orius insidiosus (Say) were collected from host plants (crimson clover, vetch and corn) early in the season of each year and used to start a lab colony maintained on green bean pods and *Helicoverpa zea* (Boddie) eggs. *H. zea* pupae were obtained from a colony maintained at the University of Arkansas Agricultural Research and Extension Center, Fayetteville, AR. Once adult moths emerged, they were placed in aquariums covered with a layer of cheesecloth onto which the females could oviposit. Wild adult moths were also collected and added to the colony during the growing season when they were abundant. *O. insidiosus* were reared at a photoperiod of 14:10 (L:D) at 25°C in an illuminated incubator (Precision Scientific® model 818, Winchester, VA). Green bean pods were not only a source of food and moisture, but also served as a substrate into which females would readily oviposit. Green beans and *H. zea* eggs were replaced daily. Pods with *O. insidiosus* eggs were placed into separate containers to allow nymphs to hatch. Fresh bean pods and *H. zea* eggs were provided to nymphs as well.

Field Plots

Plots of SureGrow 125 cotton were planted at the University of Arkansas Northeast Research and Extension Center, Keiser, AR during the growing seasons of 2000 and 2001. Fertility and weed control recommendations outlined by the University of Arkansas Cooperative Extension Service were followed (Baldwin et al. 2001). No insecticides were applied to plots with the exception of the insecticide treatments outlined in this study (Table 1). Also, no in-furrow insecticides were applied at planting to insure insecticide-free plants. Plots were 4 rows by 7.6-m long arranged in a RCB design with 4 replications. Insecticides were applied using a CO_2 powered backpack sprayer. The sprayer was calibrated to deliver 10 gpa at a pressure of 40 psi through 2-TX8 hollow-cone nozzles per row. Water alone was applied to the untreated control plots. Only the center 2 rows of each plot were treated to give a buffer of 2 rows between each pair of treated rows. Treatments were applied early in the morning, just after sunrise, when wind conditions were negligible to avoid spray drift. The spray boom was cleaned between each treatment by rinsing with a water and bleach solution, followed by water.

O. insidiosus were caged on plants as soon as sprays had dried (approximately 1-h after applica-

TABLE 1. PERCENT MORTALITY IN *O. INSIDIOSUS* MALES MEASURED BY THREE METHODS IN 2000.

Insecticide	Rate kg ai/ha	Field[1]	Greenhouse[1]	Petri dish[1]
Untreated		21.3 cAB	12.5 dB	26.3 cA
Spinosad	0.09	18.8 cB	13.8 dB	98.8 aA
Spinosad	0.199	23.8 cB	21.3 dB	92.5 aA
Indoxacarb	0.078	25.0 cB	20.0 dB	100.0 aA
Indoxacarb	0.123	21.3 cB	16.3 dB	100.0 aA
Imidacloprid	0.027	42.5 bB	46.3 bcB	100.0 aA
Imidacloprid	0.053	53.8 bB	53.3 bB	100.0 aA
Methoxyfenozide	0.28	23.8 cA	18.8 dA	25.0 cA
Methoxyfenozide	0.84	27.5 cAB	36.3 cA	18.3 cB
Tebufenozide	0.14	23.8 cA	21.3 cA	28.8 cA
Tebufenozide	0.28	23.8 cA	23.8 cA	20.0 cA
Emamectin benzoate	0.005	100.0 aA	100.0 aA	91.3 aA
Emamectin benzoate	0.01	100.0 aA	100.0 aA	78.8 bB
Abamectin	0.01	100.0 aA	100.0 aA	100.0 aA
Abamectin	0.02	98.8 aA	100.0 aA	100.0 aA
Fipronil	0.042	100.0 aA	100.0 aA	100.0 aA
Fipronil	0.056	100.0 aA	100.0 aA	100.0 aA
λ-cyhalothrin	0.014	100.0 aA	100.0 aA	100.0 aA
λ-cyhalothrin	0.028	100.0 aA	100.0 aA	100.0 aA

Means within a column followed by the same lower case letter and means within a row followed by the same upper case letter do not significantly differ ($P \leq 0.05$, LSD).

[1]A total of 80 individuals were used per treatment.

tion). Cages were placed on the fourth leaf down from the plant's terminal. Insects were caged on the plants for 24 h and then removed to evaluate mortality. Cages were constructed from 11.5 cm hair clips that were bent to fit around 6 cm diameter polystyrene Petri dishes. Each cage was constructed of either 2 Petri dish bases or 2 Petri dish tops so that the edges would meet forming an enclosure. Strips of foam were glued to the edges of each dish so that a seal would form when the cage was closed. A hole 3.2-cm in diameter was cut in each side of the cage and a piece of organdy cloth was glued over the opening to allow for air flow through the cage. Males, females and third instar nymphs were evaluated separately to determine the effects on gender and insect stage. Data were arcsine transformed and means from all bioassays were subjected to analysis of variance and separated by least significant difference test (LSD, $P \leq 0.05$). Detransformed means are reported.

Greenhouse

SureGrow 125 cotton was grown in pots in the greenhouse at the University of Arkansas Northeast Research and Extension Center, Keiser, AR. Potted plants were treated in a DeVries model SB8 spray chamber. The chamber was calibrated to deliver 11.5 gpa through a single TX8 hollowcone nozzle. Potted plants were treated individually with insecticide and then placed back into the greenhouse. The spray chamber nozzle was cleaned between each treatment by rinsing with a water and bleach solution, followed by pure water. *O. insidiosus* were caged on plants as soon as sprays had dried (approximately 1 h after application). Insects were caged on the plants for 24 h and then removed to evaluate mortality. Cages were the same as those used in the field study (20 per replicate). Males, females and third instar nymphs were evaluated separately to determine the effects on gender and insect stage. Data were arcsine transformed and means from all bioassays were subjected to analysis of variance and separated by least significant difference test (LSD, $P \leq 0.05$). Detransformed means are reported.

Laboratory

Glass Petri dishes 6-cm in diameter were treated with the insecticides listed in Table 1. Dishes were treated in the same spray chamber as the potted plants at the same rate (20 dishes per replicate, 4 replications). Individual *O. insidiosus* were placed in each dish as soon as sprays had dried (approximately 1-h after application), which was then covered with a piece of parafilm to keep insects from escaping. Mortality was checked after 24 h. Data were arcsine transformed and means from all bioassays were subjected to analysis of variance and separated by least significant difference test (LSD, $P \leq 0.05$). Detransformed means are reported.

Results and Discussion

Abamectin, emamectin benzoate, fipronil and λ-cyhalothrin were consistently the most toxic of the tested insecticides to *O. insidiosus* as measured by all three methods during 2000 (Tables 1-3) and 2001 (Tables 4-6). Mortality from λ-cyhalothrin ranged from 95% to 100%, fipronil 77% to 100%, emamectin benzoate 61% to 100% and abamectin 56.3% to 100%. No differences in mortality were observed for any of the three methods with fipronil or λ-cyhalothrin.

In all instances, mortality induced by abamectin and emamectin benzoate was significantly higher than that in the untreated control. In three instances, the mortality measured after treatment with these two products using the Petri dish bioassay was significantly lower than that in the field and greenhouse bioassays. In two instances mortality measured in the Petri dish bioassay was significantly higher than that in the field bioassay. In all other instances mortality was not significantly different among methods with these two pesticides.

Mortality induced by tebufenozide and methoxyfenozide was not significantly different from that of the untreated control when measured by field or Petri dish bioassays. However, in a few instances, mortality was significantly higher with these two insecticides when measured by the greenhouse bioassay.

Differences in mortality measured between methods was most consistent with spinosad, imidacloprid and indoxacarb. In every instance, mortality was much higher in the Petri dish bioassay compared with both the field and greenhouse bioassays. This was most pronounced with spinosad. While no significant mortality was observed in the field and greenhouse bioassays, mortality was very high in the Petri dish bioassay with spinosad. Mortality was also quite high in the Petri dish bioassay with imidacloprid and indoxacarb, but the difference was not as great because mortality was approximately 50% in the field and greenhouse bioassays.

Overall, there were few differences in mortality as measured by the field and greenhouse bioassays. The majority of significant differences were between these two plant bioassays and the Petri dish bioassay. The field and greenhouse bioassays would be expected to be similar in the fact that both use the same substrate, treated cotton leaves. The only differences between the two would be environmental conditions (e.g., solar radiation, temperature, relative humidity).

Croft (1990) defines that mortality or sublethal effects of pesticides occur through three avenues: 1) direct contact with the insecticide, 2) residual uptake (contacting pesticide residues on another surface), and 3) food chain uptake (consuming prey or host plants containing the pesticide). In this study, obviously *O. insidiosus* could only take up pesticide through the residual uptake avenue in the Petri dish bioassay. However, because of this insect's omnivorous habit, the possible uptake on treated plants used in the field and green-

Table 2. Percent mortality in *O. insidiosus* females measured by three methods in 2000.

Insecticide	Rate kg ai/ha	Field[1]	Greenhouse[1]	Petri dish[1]
Untreated		15.0 dA	8.8 eA	11.3 dA
Spinosad	0.09	20.0 dB	15.0 eB	92.5 aA
Spinosad	0.199	17.5 dB	21.3 deB	100.0 aA
Indoxacarb	0.078	18.8 dB	16.3 deB	81.3 bcA
Indoxacarb	0.123	28.8 cdB	18.8 deB	92.5 aA
Imidacloprid	0.027	36.3 cB	36.3 bcB	100.0 aA
Imidacloprid	0.053	52.5 bB	46.3 bB	100.0 aA
Methoxyfenozide	0.28	20.0 dA	21.3 deA	23.8 dA
Methoxyfenozide	0.84	22.5 dA	17.5 deA	22.0 dA
Tebufenozide	0.14	13.8 dA	15.0 eA	18.8 dA
Tebufenozide	0.28	27.5 cdA	28.8 cdA	21.3 dA
Emamectin benzoate	0.005	100.0 aA	100.0 aA	68.8 cB
Emamectin benzoate	0.01	100.0 aA	100.0 aA	90.0 aA
Abamectin	0.01	100.0 aA	100.0 aA	81.3 bcB
Abamectin	0.02	97.5 aA	100.0 aA	87.5 abA
Fipronil	0.042	92.5 aA	97.5 aA	92.5 aA
Fipronil	0.056	96.3 aA	98.8 aA	96.3 aA
λ-cyhalothrin	0.014	95.0 aA	100.0 aA	100.0 aA
λ-cyhalothrin	0.028	100.0 aA	100.0 aA	100.0 aA

Means within a column followed by the same lower case letter and means within a row followed by the same upper case letter do not significantly differ ($P \leq 0.05$, LSD).

[1]A total of 80 individuals were used per treatment.

TABLE 3. PERCENT MORTALITY IN *O. insidiosus* NYMPHS MEASURED BY THREE METHODS IN 2000.

Insecticide	Rate kg ai/ha	Field[1]	Greenhouse[1]	Petri dish[1]
Untreated		20.0 dA	12.5 deA	25.0 bcA
Spinosad	0.09	21.3 dB	25.0 cdB	91.3 aA
Spinosad	0.199	30.0 dB	21.3 cdeB	95.0 aA
Indoxacarb	0.078	17.5 dB	16.3 deB	91.3 aA
Indoxacarb	0.123	23.8 dB	25.0 cdB	100.0 aA
Imidacloprid	0.027	23.8 dB	26.3 cdB	100.0 aA
Imidacloprid	0.053	52.5 cB	51.3 bB	100.0 aA
Methoxyfenozide	0.28	26.3 dA	32.5 cA	27.5 bcA
Methoxyfenozide	0.84	18.8 dA	16.3 deA	16.5 bcA
Tebufenozide	0.14	13.8 dB	8.8 eB	32.5 bA
Tebufenozide	0.28	20.0 dA	26.3 cdA	15.0 cA
Emamectin benzoate	0.005	100.0 aA	100.0 aA	93.8 aA
Emamectin benzoate	0.01	100.0 aA	100.0 aA	97.5 aA
Abamectin	0.01	100.0 aA	100.0 aA	98.8 aA
Abamectin	0.02	97.5 aA	98.8 aA	100.0 aA
Fipronil	0.042	100.0 aA	100.0 aA	100.0 aA
Fipronil	0.056	80.0 bB	95.0 aA	100.0 aA
λ-cyhalothrin	0.014	100.0 aA	100.0 aA	100.0 aA
λ-cyhalothrin	0.028	100.0 aA	100.0 aA	100.0 aA

Means within a column followed by the same lower case letter and means within a row followed by the same upper case letter do not significantly differ ($P \leq 0.05$, LSD).

[1]A total of 80 individuals were used per treatment.

house bioassays could be through residual uptake and/or food chain uptake. With uptake possibly occurring through two avenues, one would expect mortality to be higher in the greenhouse and field bioassays as compared with the Petri dish bioassay. Although this was not true in the majority of cases in this study. Imidacloprid, indoxacarb and spinosad had much higher mortality in the

TABLE 4. PERCENT MORTALITY IN *O. INSIDIOSUS* MALES MEASURED BY THREE METHODS IN 2001.

Insecticide	Rate kg ai/ha	Field[1]	Greenhouse[1]	Petri dish[1]
Untreated		12.5 dA	7.5 eA	16.3 cA
Spinosad	0.09	13.8 dB	15.0 eB	78.8 bA
Spinosad	0.199	27.5 dB	33.8 cB	80.0 abA
Indoxacarb	0.078	52.5 cB	67.5 bB	91.3 abA
Indoxacarb	0.123	47.5 cB	53.3 bcB	97.5 abA
Imidacloprid	0.027	48.8 cB	31.3 cdB	97.5 abA
Imidacloprid	0.053	51.3 cB	47.5 bcB	96.3 abA
Methoxyfenozide	0.28	7.5 dA	12.5 eA	11.3 cA
Methoxyfenozide	0.84	12.5 dA	10.0 eA	8.8 cA
Tebufenozide	0.14	8.8 dA	7.5 eA	8.8 cA
Tebufenozide	0.28	18.8 dA	22.5 deA	10.0 cA
Emamectin benzoate	0.005	82.5 abA	96.3 aA	97.5 abA
Emamectin benzoate	0.01	68.8 bcB	90.0 aA	97.5 abA
Abamectin	0.01	88.8 abA	96.3 aA	78.8 bA
Abamectin	0.02	90.0 aA	95.0 aA	86.3 abA
Fipronil	0.042	91.3 aA	90.0 aA	97.5 abA
Fipronil	0.056	93.8 aA	91.3 aA	98.8 abA
λ-cyhalothrin	0.014	100.0 aA	100.0 aA	100.0 aA
λ-cyhalothrin	0.028	100.0 aA	100.0 aA	100.0 aA

Means within a column followed by the same lower case letter and means within a row followed by the same upper case letter do not significantly differ ($P \leq 0.05$, LSD).

[1]A total of 80 individuals were used per treatment.

TABLE 5. PERCENT MORTALITY IN *O. INSIDIOSUS* FEMALES MEASURED BY THREE METHODS IN 2001.

Insecticide	Rate kg ai/ha	Field[1]	Greenhouse[1]	Petri dish[1]
Untreated		16.3 gA	8.8 eA	15.0 dA
Spinosad	0.089	12.5 gB	11.3 eB	67.5 bcA
Spinosad	0.178	11.3 gB	12.5 eB	92.5 abA
Indoxacarb	0.07	43.8 efB	53.8 bB	82.5 abA
Indoxacarb	0.11	18.8 fgB	26.3 cdeB	88.8 abA
Imidacloprid	0.024	53.8 eB	38.8 bcdB	92.5 abA
Imidacloprid	0.047	58.8 cdeB	48.8 bcB	95.0 aA
Methoxyfenozide	0.25	20.0 fgAB	31.3 b-eA	5.0 dB
Methoxyfenozide	0.75	17.5 gA	17.5 deA	15.0 dA
Tebufenozide	0.125	20.0 fgA	15.0 deA	7.5 dA
Tebufenozide	0.25	22.5 fgA	20.0 deA	12.5 dA
Emamectin benzoate	0.0045	61.3 cdeB	82.5 aA	88.8 abA
Emamectin benzoate	0.009	82.5 abcA	91.3 aA	81.3 abcA
Abamectin	0.009	70.0 bcdA	85.0 aA	56.3 cA
Abamectin	0.018	85.0 abA	91.3 aA	75.0 abcA
Fipronil	0.038	83.8 abcA	90.0 aA	91.3 abA
Fipronil	0.05	78.8 a-dA	86.3 aA	77.5 abcA
λ-cyhalothrin	0.012	95.0 ab	97.5 aA	97.5 aA
λ-cyhalothrin	0.025	100.0 aA	98.8 aA	100.0 aA

Means within a column followed by the same lower case letter and means within a row followed by the same upper case letter do not significantly differ ($P \leq 0.05$, LSD).

[1]A total of 80 individuals were used per treatment.

Petri dish bioassay. Possibly, *O. insidiosus* did not receive a toxic dose in every instance in the treated plant bioassays (field and greenhouse) by not feeding on the treated plant during the 24-h exposure time used in this study. Another explanation offered is that the plant surface somehow altered or bound the pesticide deposits making them less available for uptake by the test insects.

TABLE 6. PERCENT MORTALITY IN *O. INSIDIOSUS* NYMPHS MEASURED BY THREE METHODS IN 2001.

Insecticide	Rate kg ai/ha	Field[1]	Greenhouse[1]	Petri dish[1]
Untreated		13.8 cA	17.0 cdA	12.5 cA
Spinosad	0.09	16.3 cB	26.3 cdB	85.0 abA
Spinosad	0.199	15.0 cB	23.8 cdB	75.0 bA
Indoxacarb	0.078	26.3 cB	42.5 bcB	70.0 bA
Indoxacarb	0.123	27.5 cB	40.0 bcB	93.8 abA
Imidacloprid	0.027	61.3 bB	31.3 bcC	100.0 aA
Imidacloprid	0.053	77.5 abA	48.8 bB	97.5 abA
Methoxyfenozide	0.28	22.5 cA	31.3 bcA	17.5 cA
Methoxyfenozide	0.84	18.8 cA	13.8 dA	12.5 cA
Tebufenozide	0.14	17.5 cA	22.5 cdA	13.8 cA
Tebufenozide	0.28	17.5 cA	18.8 cdA	25.0 cA
Emamectin benzoate	0.005	85.0 aA	93.8 aA	96.3 abA
Emamectin benzoate	0.01	90.0 aA	95.0 aA	100.0 aA
Abamectin	0.01	86.3 aA	97.5 aA	78.8 abA
Abamectin	0.02	87.5 aA	90.0 aA	96.3 abA
Fipronil	0.042	87.5 aA	93.8 aA	98.8 aA
Fipronil	0.056	95.0 aA	90.0 aA	100.0 aA
λ-cyhalothrin	0.014	100.0 aA	100.0 aA	98.8 aA
λ-cyhalothrin	0.028	100.0 aA	100.0 aA	100.0 aA

Means within a column followed by the same lower case letter and means within a row followed by the same upper case letter do not significantly differ ($P \leq 0.05$, LSD).

[1]A total of 80 individuals were used per treatment.

Imidacloprid and indoxacarb are known to have good translaminar movement into the leaf and would therefore move the pesticide away from direct contact to the insect in the plant bioassays. Because glass is an inert substance, it is not likely that the pesticide deposits would be altered or somehow bound to the substrate, leaving them free for uptake by an insect. Also, the entire inside surface of the dish was treated, making the parafilm cover the only area in which the insects could avoid the pesticide. In this study, test insects were observed on the inside of the parafilm cover only occasionally. In both the field and greenhouse bioassays, the clip cages offered a greater surface area on which the insects could avoid the pesticide. Even if the insect was not attempting to avoid the pesticide deposits, the chances of picking up a lethal dose would have been greater in the Petri dish. The most interesting results from this study were with spinosad. In both the field and greenhouse bioassays, mortality was not significantly different from that found in the untreated control, indicating that this pesticide is not toxic to *O. insidiosus*. However, mortality was very high in the Petri dish bioassay with this pesticide (100% in some instances). This leads one to think that the plant surface somehow makes this compound unavailable to this insect. Although spinosad is reported to have some translaminar movement into the leaf (Bret et al. 1997), this does not adequately explain the low toxicity in the plant bioassays.

Obviously, experimental design can have a pronounced effect on the outcome of a study and may offer some explanation on the disparity of results sometimes observed in the literature. In this study, particularly with spinosad, one would come to the conclusion that this pesticide would not be a good fit in a cotton IPM program with *O. insidiosus* when looking at the Petri dish bioassay alone. However, no effects were observed in the caged field and greenhouse studies, leading one to the opposite conclusion. It is apparent that merely evaluating mortality of pesticides on beneficial arthropods by only one method does not give an accurate depiction on how those pesticides would fit into IPM programs. This study concurs with Banken and Stark (1998) and Croft (1990) in that multiple testing methods should be used in evaluating pesticide effects on beneficial arthropods. However, this may not always be feasible. Often, lab studies utilizing an artificial substrate, are the quickest and least expensive means of obtaining data. However, particularly when working with omnivorous predators such as *O. insidiosus*, utilizing field studies or potted plants grown in the greenhouse would be the preferred method for bioassays. Bioassays utilizing artificial substrates, while providing important information, should not be the sole means of evaluating the effects of pesticides on beneficial arthropods.

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