Effects of Various Insecticide Residues in Cotton on Gender and Developmental Stage of the Insidious Flower Bug (Hemiptera: Anthocoridae)[1]

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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 field residues of nine insecticides applied to cotton plants. Insects were caged for 24 h and then removed to determine mortality from 0, 1, 2, 3, and 7-day-old insecticide residues. Insecticides and rates (kg ai/ha) tested were spinosad (0.09, 0.199), indoxacarb (0.78, 0.123), imidacloprid (0.027, 0.053), tebufenozide (0.14, 0.28), methoxyfenozide (0.28, 0.84), abamectin (0.01, 0.02), emamectin benzoate (0.005, 0.01), fipronil (0.042, 0.056), and λ-cyhalothrin (0.014, 0.028). Fipronil and λ-cyhalothrin were the most toxic, causing a significant reduction in survival (up to 3-day-old residues). Abamectin and emamectin benzoate caused significant mortality in predators exposed shortly after application, but survival tended to increase as residues aged. Imidacloprid and indoxacarb were intermediate, causing approximately 50% mortality in this insect. Survival was good in all treatments with 7-day-old residues with the exception of λ-cyhalothrin. Males tended to by more sensitive with lower survival than females.

Key Words *Orius insidiosus,* insidious flower bug, insecticide residues, cotton, survival, developmental stage, gender

The main tenet of IPM is to integrate natural, cultural and chemical controls to manage pest populations in an agricultural setting. However, insect control in agriculture in the past, as well as today, has relied predominantly on chemical controls. Many insecticides have been blamed for secondary outbreaks of pests such as aphids, whiteflies, beet armyworms and spider mites (Ridgway et al. 1966, Dinkins et al. 1971, Eveleens et al. 1973, Stoltz and Stern 1978). These outbreaks are believed to be the result of broad spectrum insecticides removing many or all of the predatory and parasitic arthropods from the agro-ecosystem. With older chemistries being eliminated due to more stringent labeling requirements, agricultural chemical companies have begun to search for new, more environmentally-friendly pesticides. Many of these pesticides are touted as being less toxic to non-target beneficial arthropods in the agricultural system. Several insecticides including spinosad, indoxacarb, tebufenozide, and methoxyfenozide make claims on their labels on having reduced effects on a broad range of predatory arthropods.

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Data on pesticide effects on predatory and parasitic arthropods in the literature sometimes seem to be contradictory. Elzen et al. (1998) found 62% survival in *Orius insidiosus* (Say) treated with oxamyl at 280 gm ai/ha, while England et al. (1997) found only 5% survival of the same insect at the same rate of oxamyl. Duffie et al. (1998) found a significant reduction in coccinellids with spinosad at 99.8 gm ai/ha, while Elzen et al. (1998) and Tillman and Mulrooney (2000) observed little or no mortality from the same insecticide. However, the time frame in which the data were collected may have a significant effect on the outcome of the test. Much of the data collected on predatory and parasitic arthropods arise as secondary counts from studies designed to evaluate pest species. Data are taken at various times, often from a few days to a week after treatment depending on the researcher and the experimental design. Reported reduced effects may be the result of the insecticide either having no toxicity to the arthropod or by the insecticide delivering a sublethal dose to the arthropod through reduced exposure. The lack of lethal effects may be the result of the insecticide having a short residual time of activity on the plant surface. This short residual may be the result of the compound rapidly breaking down or by movement of the compound to an area of the plant unavailable to the arthropod in question. Many of the newer chemistries have some form of systemic activity. Moving either freely throughout the plant or, more commonly, moving into the plant at the point of contact (e.g., translaminar movement of imidacloprid from the leaf surface into the leaf interior). Some compounds such as abamectin have a very short half-life on the leaf surface (Chukwudebe et al. 1997) but move rapidly into the treated plant through translaminar movement (Jansson and Dybas 1998). While this does remove the insecticide from the arena used by many predatory and parasitic arthropods, it may not reduce exposure to those that are also omnivorous in habit by feeding on the plant on which they also search for prey. In effect, those insecticides with systemic or translaminar movement may indeed have little, or no, effects on predators that are not omnivorous, but may well cause significant effects on those that are. Therefore, it would be beneficial to measure the toxicity effects on beneficial arthropods over a range of aged residues, particularly those insecticides with some systemic activity and those insects that are omnivorous (e.g., many predatory Heteroptera).

Oruis insidiosus is an important predator found in cotton, where it preys on thrips, Lepidoptera eggs (Nuessly and Sterling 1994, Sansone et al. 1997), spider mites and whiteflies (Knutson and Ruberson 1996). It has also been reported to feed upon leafhoppers and plant bugs (Barber 1936, Deitz et al. 1980). McGriff and Ruberson (1999) reported this insect, along with *O. tristicolor* (White) and *Geocoris* spp., to be the most important predators in cotton. *Orius insidiosus* is also considered to be omnivorous (Coll and Izraylevich 1997), feeding on plant tissue. It is easily reared in the lab and lends well to handling with little mortality. Because of its importance as a biological control agent and omnivorous feeding habit, it was chosen for evaluation of the effects of insecticide residues on this predator.

Materials and Methods

Orius insidiosus were collected by sweeping wild host plants (crimson clover and vetch) with a 0.38-m diam sweepnet. Later, bugs were also collected from corn by aspirating individuals from within whorls. These were used to start a lab colony that was maintained on green bean pods and *Helicoverpa zea* (Boddie) eggs. *Helicoverpa zea* pupae were obtained from a colony maintained at the University of Arkansas

Table 1. Percentage survival of *O. insidiosus* after exposure to insecticide residues in the field in 1999

Treatment	Rate kg ai/ha	Males*			Females*			Nymphs*		
		0 DAT	1 DAT	2 DAT	0 DAT	1 DAT	2 DAT	0 DAT	1 DAT	2 DAT
untreated		87.5 a	85.0 a	73.8 ab	90.0 a	78.8 a	86.2 a	87.5 ab	83.8 ab	81.2 a
spinosad	0.09	75.0 abc	77.5 abc	70.0 abc	80.0 ab	80.0 a	75.0 a	90.0 a	85.0 ab	77.5 a
spinosad	0.199	60.0 bc	75.0 abc	85.0 a	85.0 ab	70.0 ab	81.2 a	71.2 ab	90.0 a	83.8 a
indoxacarb	0.078	81.2 ab	70.0 abc	51.2 bc	90.0 a	80.0 a	77.5 a	86.2 ab	67.5 b	73.8 a
indoxacarb	0.123	92.5 a	68.8 bc	63.8 bc	90.0 a	71.2 ab	76.2 a	77.5 ab	77.5 ab	63.8 a
imidacloprid	0.027	75.0 abc	71.2 abc	51.2 bc	60.0 bc	75.0 ab	47.5 b	80.0 ab	72.5 b	73.8 a
imidacloprid	0.053	50.0 c	63.8 c	48.8 c	50.0 c	62.5 ab	53.8 b	55.0 b	71.2 b	75.0 a
methoxyfenozide	0.28	95.0 a	76.2 abc	71.2 abc	87.5 ab	56.2 b	82.5 a	88.8 a	85.0 ab	73.8 a
methoxyfenozide	0.84	81.2 ab	80.0 ab	72.5 abc	95.0 a	82.5 a	78.8 a	91.2 a	86.2 ab	75.0 a
fipronil	0.042	0.0 d	0.0 d	2.5 e	10.0 d	6.2 c	16.2 c	16.2 c	25.0 c	30.0 b
fipronil	0.056	0.0 d	0.0 d	1.2 e	0.0 d	0.0 c	10.0 c	2.5 c	0.0 d	18.8 b
λ-cyhalothrin	0.014	0.0 d	0.0 d	20.0 d	20.0 d	8.8 c	22.5 c	0.0 c	0.0 d	0.0 c
λ-cyhalothrin	0.028	0.0 d	0.0 d	10.0 de	0.0 d	0.0 c	10.0 c	0.0 c	0.0 d	0.0 c

Means within a column followed by the same letter do not differ significantly ($P < 0.05$, LSD).

* A total of 80 individuals were used per treatment.

Table 2. Percent survival of *O. insidiosus* males after exposure to insecticide residues in the field in 2000

Treatment	Rate kg ai/ha	Days after treatment*				
		0	1	2	3	7
untreated		78.8 a	83.8 ab	73.8 abc	80.0 a	75.0 abc
spinosad	0.09	81.2 a	81.2 ab	87.5 a	77.5 a	82.5 ab
spinosad	0.199	76.2 a	76.2 ab	81.2 ab	78.7 a	78.8 ab
indoxacarb	0.078	75.0 a	90.0 a	40.0 c-f	63.8 ab	66.2 bc
indoxacarb	0.123	78.8 a	80.0 ab	51.2 a-e	56.2 ab	58.8 c
imidacloprid	0.027	57.5 b	56.2 bc	55.0 a-d	66.2 ab	63.8 bc
imidacloprid	0.053	46.2 b	42.5 cd	46.8 b-e	43.8 bc	63.8 bc
methoxyfenozide	0.28	76.2 a	78.8 ab	81.2 ab	73.8 ab	75.0 abc
methoxyfenozide	0.84	72.5 a	82.5 ab	80.0 ab	76.2 a	90.0 a
tebufenozide	0.14	76.2 a	78.8 ab	82.5 ab	70.0 ab	81.2 ab
tebufenozide	0.28	76.2 a	88.8 a	80.0 ab	75.0 ab	73.8 abc
emamectin benzoate	0.005	0.0 c	28.8 de	25.0 d-g	21.2 d	77.5 abc
emamectin benzoate	0.01	0.0 c	25.0 de	52.5 b-e	58.8 ab	72.5 bc
abamectin	0.01	0.0 c	8.8 ef	15.0 fg	63.8 ab	80.0 ab
abamectin	0.02	1.2 c	15.0 ef	10.0 g	61.2 ab	72.5 bc
fipronil	0.042	0.0 c	0.0 f	7.5 fg	7.5 d	66.2 bc
fipronil	0.056	0.0 c	0.0 f	0.0 g	15.0 d	58.8 c
λ-cyhalothrin	0.014	0.0 c	0.0 f	17.5 efg	21.2 cd	68.8 bc
λ-cyhalothrin	0.028	0.0 c	0.0 f	0.0 g	8.8 d	58.8 c

Means within a column followed by the same letter do not differ significantly ($P < 0.05$, LSD).
* Total of 80 individuals were used per treatment.

Agricultural Research and Extension Center, Fayetteville, AR. Once *H. zea* adults had emerged, they were placed in glass containers (95 × 21.5 × 26 cm) covered with a layer of cheesecloth onto which the females could oviposit. Wild adults were also collected and added to the colony during the growing season when they were abundant. *Orius insidiosus* were reared at a 14:10 L:D photoperiod at 25°C in a Precision Scientific® (Winchester, VA) model 818 illuminated incubator. Green bean pods were not only a source of food and moisture, but were also a substrate into which females would readily oviposit. Green beans and 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.

Plots of SureGrow 125 cotton were planted at the University of Arkansas Northeast Research and Extension Center, Keiser, AR, during the growing seasons of 1999, 2000 and 2001. Fertility and weed control recommendations outlined by the University of Arkansas Cooperative Extension Service (Baldwin et al. 1998) were followed. No insecticides were applied to plots with the exception of the insecticide treatments outlined in this study. In the first year of the study, tebufenozide, emamectin benzoate, and abamectin were not included, but were added in 2000 and 2001. 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

Table 3. Percent survival of *O. insidiosus* females after exposure to insecticide residues in the field in 2000

Treatment	Rate kg ai/ha	Days after treatment*				
		0	1	2	3	7
untreated		85.0 a	78.8 abc	77.5 ab	78.8 ab	81.2 a
spinosad	0.09	80.0 ab	83.8 ab	75.0 ab	87.5 a	78.8 a
spinosad	0.199	82.5 ab	75.0 a-d	77.5 ab	78.8 ab	80.0 a
indoxacarb	0.078	81.2 ab	86.2 a	57.5 abc	85.0 a	71.2 a
indoxacarb	0.123	71.2 ab	86.2 a	76.2 ab	67.5 abc	75.0 a
imidacloprid	0.027	63.8 bc	52.5 cde	43.8 bcd	45.0 cd	65.0 a
imidacloprid	0.053	47.5 c	32.5 e	35.0 cde	63.8 abc	46.2 a
methoxyfenozide	0.28	80.0 ab	77.5 a-d	77.5 ab	80.0 ab	78.8 a
methoxyfenozide	0.84	77.5 ab	73.8 a-d	80.0 a	77.5 ab	63.8 a
tebufenozide	0.14	86.2 a	75.0 a-d	80.0 a	77.5 ab	67.5 a
tebufenozide	0.28	72.5 ab	76.2 a-d	80.0 a	70.0 abc	73.8 a
emamectin benzoate	0.005	0.0 d	48.8 de	28.8 cde	43.8 cd	67.5 a
emamectin benzoate	0.01	0.0 d	56.2 b-e	58.8 abc	52.5 bc	70.0 a
abamectin	0.01	0.0 d	11.2 f	17.5 def	77.5 ab	73.8 a
abamectin	0.02	2.5 d	0.0 f	0.0 f	72.5 abc	82.5 a
fipronil	0.042	7.5 d	5.0 f	21.2 de	17.5 e	66.2 a
fipronil	0.056	3.8 d	0.0 f	18.8 def	10.0 e	68.8 a
λ-cyhalothrin	0.014	5.0 d	5.0 f	21.2 def	52.5 bc	71.2 a
λ-cyhalothrin	0.028	0.0 d	0.0 f	11.2 ef	23.8 de	65.0 a

Means within a column followed by the same letter do not differ significantly ($P < 0.05$, LSD).
* Total of 80 individuals were used per treatment.

were applied using a CO_2 powered backpack sprayer. The sprayer was calibrated to deliver 93.5 L per ha at a pressure of 0.27 MPa through 2-TX8 hollowcone nozzles per row. Water alone was applied to the untreated control plots before insecticides were applied to other 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 alone.

Orius insidiosus were caged on plants at 0 (as soon as sprays had dried, which was approximately 1 h after application), 1 and 2 days after treatment in 1999. In 2000 and 2001, insects were caged at these intervals and also at 3 and 7 days after treatment. Cages were placed on the fourth leaf from the plant 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 bent to fit around 6-cm diam 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 3.2-cm diam hole 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. Insects were caged individually

Table 4. Percent survival of *O. insidiosus* nymphs after exposure to insecticide residues in the field in 2000

Treatment	Rate kg ai/ha	Days after treatment* 0	1	2	3	7
untreated		80.0 a	82.5 a	78.8 a	75.0 abc	73.8 a
spinosad	0.09	78.8 a	73.8 ab	73.8 a	70.0 abc	82.5 a
spinosad	0.199	70.0 a	75.0 ab	68.8 a	63.8 abc	78.8 a
indoxacarb	0.078	82.5 a	68.8 ab	67.5 a	67.5 abc	73.8 a
indoxacarb	0.123	76.2 a	66.2 ab	51.2 a	78.8 ab	61.2 a
imidacloprid	0.027	76.2 a	57.5 ab	58.8 a	51.2 c	58.8 a
imidacloprid	0.053	50.0 b	48.8 b	63.8 a	56.2 bc	68.8 a
methoxyfenozide	0.28	73.8 a	81.2 a	77.5 a	83.8 a	71.2 a
methoxyfenozide	0.84	81.2 a	80.0 a	70.0 a	78.8 ab	76.2 a
tebufenozide	0.14	86.2 a	73.8 ab	76.2 a	82.5 a	67.5 a
tebufenozide	0.28	80.0 a	78.8 a	70.0 a	71.2 abc	77.5 a
emamectin benzoate	0.005	0.0 d	0.0 c	11.2 b	8.8 d	67.5 a
emamectin benzoate	0.01	0.0 d	2.5 c	8.8 b	10.0 d	71.2 a
abamectin	0.01	0.0 d	0.0 c	1.2 b	71.2 abc	81.2 a
abamectin	0.02	2.5 d	0.0 c	0.0 c	68.8 abc	82.5 a
fipronil	0.042	0.0 d	7.5 c	8.8 bc	3.8 d	43.8 a
fipronil	0.056	20.0 c	0.0 c	2.5 bc	6.2 d	55.0 a
λ-cyhalothrin	0.014	0.0 d	0.0 c	0.0 c	2.5 d	68.8 a
λ-cyhalothrin	0.028	0.0 d	0.0 c	0.0 c	1.2 d	51.2 a

Means within a column followed by the same letter do not differ significantly ($P < 0.05$, LSD).
* Total of 80 individuals were used per treatment.

and gender recorded using 20 cages per replicate. Males, females, and third-instar nymphs (20 each per replicate) were evaluated separately to determine pesticide effects on gender and insect stage. Data were arcsine transformed before being subjected to analysis of variance and separated by least significant difference test (LSD, $P < 0.05$). Detransformed means are reported.

Results and Discussion

Survival of *O. insidiosus* males, females, and third-instar nymphs after exposure to various insecticide residues is reported in Tables 1-7. Fipronil and λ-cyhalothrin were consistently the most toxic, resulting in significantly lower survival than the untreated control on up to 3-day-old residues. Toxicity significantly decreased by 7 days except in 2001 when λ-cyhalothrin resulted in significant mortality in nymphs at both rates and males and females at the high rate (Tables 5-7). Residues of abamectin and emamectin benzoate were also highly toxic just after drying, but survival tended to increase as residues aged. Imidacloprid and indoxacarb were moderately toxic with approximately 50% survival, which was significantly lower than the untreated control in some instances and significantly higher than fipronil and cyhalothrin. This contradicts the findings of Elzen et al. (1998) who found very low mortality from exposure to

Table 5. Percent survival of *O. insidiosus* males after exposure to insecticide residues in the field in 2001

Treatment	Rate kg ai/ha	Days after treatment*				
		0	1	2	3	7
untreated		87.5 a	93.8 a	77.5 a	81.2 ab	81.2 ab
spinosad	0.09	86.2 ab	80.0 abc	72.5 ab	80.0 ab	82.5 ab
spinosad	0.199	72.5 a-d	70.0 a-d	27.5 cde	76.2 abc	78.8 ab
indoxacarb	0.078	47.5 de	92.5 a	47.5 a-d	58.8 bc	73.8 abc
indoxacarb	0.123	52.5 b-e	87.5 ab	57.5 a-d	2.5 fg	80.0 a
imidacloprid	0.027	51.2 cde	52.5 b-e	26.2 def	7.5 efg	80.0 ab
imidacloprid	0.053	48.8 de	7.5 f	10.0 efg	23.8 ef	83.8 a
methoxyfenozide	0.28	92.5 a	93.8 a	60.0 abc	83.8 ab	85.0 a
methoxyfenozide	0.84	82.5 a-d	92.5 a	61.2 ab	87.5 ab	83.8 a
tebufenozide	0.14	91.2 a	86.2 ab	76.2 a	90.0 a	90.0 a
tebufenozide	0.28	81.2 abc	91.2 a	77.5 a	85.0 ab	87.5 a
emamectin benzoate	0.005	17.5 fg	48.8 cde	48.8 a-d	18.8 efg	57.5 bc
emamectin benzoate	0.01	31.2 ef	53.8 b-e	42.5 bcd	27.5 de	52.5 c
abamectin	0.01	11.2 fg	76.2 abc	47.5 a-d	66.2 abc	83.8 a
abamectin	0.02	10.0 fg	60.0 bcd	41.2 bcd	31.2 de	83.8 a
fipronil	0.042	8.8 fg	42.5 de	3.8 g	47.5 cd	81.2 ab
fipronil	0.056	6.2 fg	31.2 ef	12.5 fg	0.0 g	85.0 a
λ-cyhalothrin	0.014	0.0 g	6.2 f	5.0 g	1.2 fg	73.8 abc
λ-cyhalothrin	0.028	0.0 g	6.2 f	2.5 g	0.0 g	26.2 d

Means within a column followed by the same letter do not differ significantly ($P < 0.05$, LSD).
* Total of 80 individuals were used per treatment.

30-min residues of imidacloprid. Spinosad, tebufenozide and methoxyfenozide showed no toxicity. These findings agree with those of Pietrantonio and Benedict (1999) who also found low toxicity with spinosad and tebufenozide and high toxicity from λ-cyhalothrin with fresh and 1-day-old residues. However, they did not look at residues beyond 1 day. Ruberson and Tillman (1999) also examined the effects of fresh, 1 and 3-day-old residues on cotton with somewhat different results, finding lower survival at 1 hour and 3-day-old residues of spinosad (51.7% and 55%, respectively).

Until this study, little data were available on the effects of 7-day-old insecticide residues on this insect in cotton with these compounds, as were any data separating the effects of residues on mortality between sex or developmental stage. Few differences in survival were observed between sex or developmental stage, particularly when looking at data generated within the same year. Differences were observed between years of the study. In 2001, survival was significantly lower than the untreated control in both sexes and nymphs with the high rate of spinosad (Tables 3, 5, and 7). However, no significant differences were observed with this compound in other years of the study (Tables 1, 2, 4, and 6). A similar difference was observed with indoxacarb having lower survival in 1999 and 2001 on 2 and 3-day-old residues with all individuals and stages and with 0-day residues in males and females, but not in

Table 6. Percent survival of *O. insidiosus* females after exposure to insecticide residues in the field in 2001

Treatment	Rate kg ai/ha	Days after treatment* 0	1	2	3	7
untreated		93.8 a	97.5 a	83.8 ab	88.8 a	88.8 a
spinosad	0.09	87.5 ab	92.5 ab	86.2 a	86.2 ab	91.2 a
spinosad	0.199	88.8 a	87.5 ab	46.2 efg	88.8 a	85.0 ab
indoxacarb	0.078	56.2 bcd	91.2 ab	58.8 b-g	43.8 cd	67.5 bc
indoxacarb	0.123	81.2 ab	93.8 ab	75.0 a-e	17.5 def	91.2 a
imidacloprid	0.027	52.5 b-e	17.5 ef	52.5 d-g	32.5 c-f	82.5 ab
imidacloprid	0.053	41.2 c-f	7.5 f	62.5 a-g	15.0 ef	95.0 a
methoxyfenozide	0.28	80.0 abc	91.2 ab	86.2 abc	95.0 a	90.0 a
methoxyfenozide	0.84	82.5 ab	91.2 ab	86.2 abc	88.8 a	90.0 a
tebufenozide	0.14	80.0 abc	83.8 ab	80.0 a-d	86.2 ab	85.0 ab
tebufenozide	0.28	77.5 abc	85.0 ab	86.2 a	82.5 ab	83.8 ab
emamectin benzoate	0.005	38.8 d-g	73.8 abc	68.8 a-f	36.2 cde	83.8 ab
emamectin benzoate	0.01	17.5 fgh	66.2 bcd	68.8 a-f	23.8 def	86.2 ab
abamectin	0.01	30.0 efg	76.2 abc	42.5 fg	81.2 ab	90.0 a
abamectin	0.02	15.0 gh	67.5 bcd	57.5 c-g	60.0 bc	81.2 ab
fipronil	0.042	16.2 fgh	40.0 de	36.2 g	33.8 cde	92.5 a
fipronil	0.056	21.2 fgh	43.8 cd	37.5 g	53.8 c	80.0 ab
λ-cyhalothrin	0.014	5.0 gh	8.8 ef	10.0 h	10.0 fg	78.8 ab
λ-cyhalothrin	0.028	0.0 h	0.0 f	0.0 h	0.0 g	53.8 c

Means within a column followed by the same letter do not differ significantly ($P < 0.05$, LSD).
* Total of 80 individuals were used per treatment.

nymphs. This variability from year to year may explain different results observed between different researchers. Pietrantonio and Benedict (1999) and Ruberson and Tillman (1999) obtained conflicting results with spinosad, but their studies were based on one year's data. In contrast, the bulk of this study was conducted over a 3-yr period. While the majority of the data agree with Pietrantonio and Benedict (1999), the 2001 data do show some similarity to that of Ruberson and Tillman (1999). While studying another insect, *Geocoris punctipes* (Say), Ruberson et al. (2001) did observe variation between populations when examining diapause. Variability may, therefore, also occur between populations of *O. insidiosus* and may have an effect on their response to pesticides. However, this effect was not observed with all pesticides tested in this study. Croft (1990) suggests that variability in the substrates used in testing procedures may affect the results, particularly when working with natural or living substrates (e.g., differences in leaf hairiness, cuticular waxes, leaf veins, etc.). Buchholz and Nauen (2001) also found differences in foliar penetration rates with imidacloprid when applied to cotton and cabbage leaves with approximately 40% of the material moving into the cotton leaf in 24 h while 77% had penetrated a cabbage leaf in the same time frame. This may offer some explanation to the differences obtained by various researchers working with the same insect and the same insecticides. Croft (1990) also alludes to effects of environmental conditions on the sus-

Table 7. Percent survival of *O. insidiosus* nymphs after exposure to insecticide residues in the field in 2001

Treatment	Rate kg ai/ha	Days after treatment* 0	1	2	3	7
untreated		86.2 a	87.5 a	86.2 a	93.8 a	85.0 ab
spinosad	0.09	83.8 a	87.5 a	78.8 ab	82.5 ab	90.0 a
spinosad	0.199	85.0 a	72.5 abc	51.2 bc	82.5 ab	85.0 ab
indoxacarb	0.078	73.8 a	83.8 ab	33.8 cd	52.5 bc	71.2 bc
indoxacarb	0.123	72.5 a	86.2 a	47.5 bc	6.2 f	86.2 ab
imidacloprid	0.027	38.8 b	50.0 bcd	20.0 de	15.0 ef	87.5 ab
imidacloprid	0.053	22.5 bc	7.5 fg	26.2 cd	17.5 def	87.5 a
methoxyfenozide	0.28	77.5 a	88.8 a	52.5 bc	90.0 a	86.2 ab
methoxyfenozide	0.84	81.3 a	85.0 a	60.0 ab	81.2 ab	83.8 ab
tebufenozide	0.14	82.5 a	90.0 a	73.8 ab	91.2 a	81.2 ab
tebufenozide	0.28	82.5 a	87.5 a	63.8 ab	87.5 a	77.5 abc
emamectin benzoate	0.005	15.0 cd	31.2 def	66.2 ab	18.8 def	80.0 ab
emamectin benzoate	0.01	10.0 cd	31.2 def	68.8 ab	11.2 f	60.0 cd
abamectin	0.01	13.8 cd	48.8 bcd	66.2 ab	40.0 cd	85.0 ab
abamectin	0.02	12.5 cd	45.0 cd	67.5 ab	41.2 cde	77.5 abc
fipronil	0.042	12.5 cd	37.5 de	17.5 de	58.8 bc	82.5 ab
fipronil	0.056	5.0 cd	12.5 efg	8.8 def	2.5 f	85.0 ab
λ-cyhalothrin	0.014	0.0 d	3.8 fg	2.5 ef	0.0 f	57.5 cd
λ-cyhalothrin	0.028	0.0 d	0.0 g	0.0 f	0.0 f	50.0 d

Means within a column followed by the same letter do not differ significantly ($P < 0.05$, LSD).
* Total of 80 individuals were used per treatment.

ceptibility of the insect. In our study, test insects were caged on the leaves in the field sometimes under rather high temperatures. Ruberson and Tillman (1999) and Pietrantonio and Benedict (1999) also used field weathered residues, but brought excised leaves indoors from either the field or from potted plants kept outdoors, and exposed insects to these leaves in the lab under more constant environmental conditions.

These data provided some explanation of the variability among and within previous studies. This study also indicates the importance of not only testing the effects of pesticides on predatory insects by various methods as reported by Banken and Stark (1998) and Croft (1990), but also suggests the importance of testing over multiple years or at least with different populations of the same species.

In our studies, spinosad, tebufenozide and methoxyfenozide had little effect on mortality in *O. insidiosus* and should fit well into IPM programs designed to conserve populations of this predator. Also, it appears that indoxacarb and imidacloprid could also have some fit to a lesser extent, but would give better conservation than that of fipronil or λ-cyhalothrin. Abamectin and emamectin benzoate, while causing high mortality initially, did appear to have short-lived residues and would be beneficial in instances where predators could re-establish from untreated areas of the field or other nearby habitat.

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