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FIELD AND LABORATORY PERFORMANCE OF NOVEL INSECTICIDES AGAINST ARMYWORMS (LEPIDOPTERA: NOCTUIDAE)

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Abstract

Beet armyworm, *Spodoptera exigua* (Hübner), and fall armyworm, *Spodoptera frugiperda* (J. E. Smith), are occasional pests of cotton, *Gossypium hirsutum* (L.), and soybean, *Glycine max* (L.) Merrill. These insects can be difficult to control due to insecticide resistance and larval behavior on plants. The objectives of these studies were to determine the efficacy of selected insecticides against native infestations of beet armyworm in cotton and soybean and to generate baseline dose-mortality responses for beet armyworm and fall armyworm adults to indoxacarb and pyridalyl in the adult vial test. Indoxacarb, pyridalyl, spinosad, methoxyfenozide, and emamectin benzoate controlled beet armyworm infestations up to 10 d after treatment compared to the non-treated control. Thiodicarb reduced beet armyworm densities up to three d after treatment. The LC_{50} values of indoxacarb and pyridalyl for beet armyworm and fall armyworm exceeded the highest concentrations tested (100-200 µg/vial) in the adult vial test. Dose-mortality values of indoxacarb and pyridalyl were higher than discriminating concentrations of cypermethrin, methomyl, profenofos, and endosulfan used in the adult vial test for monitoring tobacco budworm, *Heliothis virescens* (F.), and bollworm, *Helicoverpa zea* (Boddie), susceptibility in Louisiana and Texas. These results indicate that the adult vial test may not be the most efficient test method for indoxacarb and pyridalyl in insecticide susceptibility monitoring programs.

Key Words: Beet armyworm, *Spodoptera exigua*, fall armyworm, *Spodoptera frugiperda*, cotton, *Gossypium hirsutum*, soybean, *Glycine max*, insecticides.

Resumen

El gusano trozador, *Spodoptera exigua* (Hübner), y el gusano cogollero, *Spodoptera frugiperda* (J. E. Smith), son plagas ocasionales de algodón, *Gossypium hirsutum* (L.), y soya, *Glycine max* (L.) Merrill. Estos insectos son dificiles de controlar debido a la resistencia hacia el insecticida y el comportamiento de las larvas en las plantas. Los objectivos de estos estudios fueron para determinar la eficacia de los insecticidas seleccionados contra las infestaciones nativas del gusano trozador en algodón y soya y para obtener respuestas de dosis-mortalidad basicas para los adultos de gusano trozador y de gusano cogollero al indoxacarb y pyridalyl en pruebas de adultos en viales de prueba. El indoxacarb, pyridalyl, spinosad, methoxyfenozide, y emamectin benzoate controlaron las infestaciones del gusano trozador hasta 10 dias después del tratamiento comparado al control sin tratamiento. El Thiodicarb redujó las densidades del gusano trozador hasta 3 dias después del tratamiento. Los valores del CL_{50} de indoxacarb y pyridalyl para el gusano trozador y el gusano cogollero excedieron las concentraciones mas altas probadas (100-200 µg/vial) en la prueba de los adultos en viales de prueba. Los valores de dosis-mortalidad de indoxacarb y pyridalyl fueron mas altas que las concentraciones discriminantes del cypermethrin, methomyl, profenofos, y endosulfan usados en pruebas de adultos en viales para monitorear la susceptibilidad del gusano del brote de tobaco, *Heliothis virescens* (F.), y el gusano del elote del maíz, *Helicoverpa zea* (Boddie), en Louisiana y Texas. Estos resultados indican que la prueba de los adultos en viales posiblemente no es el método de prueba más eficaz para indoxacarb y pyridalyl en programas para monitorear la susceptibilidad de insecticidas.

Beet armyworm, *Spodoptera exigua* (Hübner), and fall armyworm, *Spodoptera frugiperda* (J. E. Smith), are occasional pests of cotton, *Gossypium hirsutum* (L.), and soybean, *Glycine max* (L.) Merrill, in the mid-southern and southeastern United States. Beet armyworm larvae feed primarily on foliage in cotton (Smith 1989, Leser et al. 1996) and soybean (Baldwin 1994). Beet armyworm can be difficult to control, and for many years the only effective insecticides were thiodicarb and chlorpyrifos. Their performance has varied considerably against beet armyworm in the Mid-South and southeastern United States. Thiodicarb and chlorpyrifos provided >65% control of beet armyworm larvae in cotton in Texas (Smith 1985). In South Carolina, thiodicarb also provided 90% control of beet armyworm in cotton (Sullivan et al. 1991). Reed et al. (1994) reported <50% control of beet armyworm with both thiodicarb and chlorpyrifos in Mississippi cotton. In Louisiana, control of beet armyworm with thiodicarb and chlorpyrifos in cotton has been inconsistent (Burris et al. 1994; Graves et al. 1995; Mascarenhas et al. 1996). Spinosad (Dow Agrosciences, Indianapolis, IN), indoxacarb (E. I. DuPont de Nemours and Co., Wilmington, DE), and pyridalyl (Valent USA Corp., Walnut Creek, CA) are novel compounds that have demonstrated efficacy against many lepidopteran pests of cotton and soybean.

Fall armyworm larvae feed primarily on soybean foliage and are readily exposed to foliar insecticide applications (Baldwin 1994). In cotton, early instar fall armyworms occur in the lower portion of the plant canopy and feed on foliage (Ali et al. 1989, 1990). Therefore, control of early instar fall armyworms in cotton can be difficult because foliar insecticide applications generally do not penetrate the canopy sufficiently to reach the larvae. Older larvae move within the plant canopy to fruiting structures (Ali et al. 1990). These larger larvae feed inside fruiting structures which minimize their exposure to foliar insecticide applications. Fall armyworm larvae also become more tolerant to insecticides as larval size increases (Yu 1983; Mink & Luttrell 1989) making control even more difficult to achieve.

Insecticide resistance in key insect pests has become a significant problem in crop production. Surveying insect populations for changes in susceptibility to insecticides is an integral component of insecticide resistance management. Monitoring efforts should be initiated before a compound is widely used and while the frequency of resistant individuals is low (ffrench-Constant & Roush 1990). Determining the range of initial resistance frequencies among insect populations facilitates early detection of changes in susceptibility to an insecticide. Therefore, early establishment of resistance baselines are critical for successful implementation of insecticide resistance management strategies before field control failures become widespread. Baseline responses for laboratory and field strains of insects to novel compounds should be established to develop discriminating concentrations for monitoring programs and for historical reference values. Numerous states have implemented insecticide resistance monitoring programs for bollworm, *Helicoverpa zea* (Boddie), and tobacco budworm, *Heliothis virescens* (F.), in cotton. However, coordinated insecticide resistance monitoring programs in cotton have not been developed for beet armyworm and fall armyworm in the United States due to the sporadic occurrence of these pests in the Mid-South and southeastern United States.

The objectives of these studies were to evaluate the efficacy of selected insecticides against native infestations of beet armyworm in cotton and soybean, and to generate baseline dose-mortality responses for beet armyworm and fall armyworm adults to indoxacarb and pyridalyl in the adult vial test. These data will support insecticide recommendations and provide reference dose-mortality data for future monitoring programs.

Materials and Methods

Field Experiments

Field trials were conducted during 1998 and 2000 at the LSU Ag Center Macon Ridge Research Station (Franklin Parish, LA). Trials 1998 and 2000-B were conducted in cotton, while trial 2000-A was conducted in soybean. Plots were planted to the cotton varieties 'Stoneville LA 887' (Stoneville Pedigree Seed Co., Memphis, TN) and 'Phytogen 355' (Dow AgroSciences LLC, Indianapolis, IN) in 1998 and trial 2000-B, respectively. The soybean variety 'Pioneer 9631' (Pioneer Hi-Bred International, Inc., Des Moines, IA) was used in trial 2000-A. Plots were planted on 11 June 1998, 30 May in trial 2000-A, and on 28 June in trial 2000-B. Plots consisted of four rows on 1-m centers and 15.2 m long. Treatments were arranged in a randomized complete block design with four replications. Cultural practices recommended by the LSU AgCenter were followed to maintain plots in a consistent manner within each trial.

Insecticide treatments included the following: emamectin benzoate (Denim 0.16 Emulsifiable Concentrate (EC), 2.15% ai wt/wt, Syngenta Crop Protection, Greensboro, NC), indoxacarb (Steward 1.25 Suspension Concentrate (SC), 14.5% ai wt/wt, E. I. Du Pont de Nemours and Company, Wilmington, DE), methoxyfenozide (Intrepid 80 Wettable Powder (WP), 80% ai wt/wt, Dow AgroSciences LLC, Indianapolis, IN), pyridalyl (S-1812 4EC, 45% ai wt/wt, Valent USA Corporation, Walnut Creek, CA), Spinosad (Tracer 4SC, Dow AgroSciences LLC, Indianapolis, IN), and thiodicarb (Larvin 3.2 Flowable (F), 34% ai wt/wt, Bayer CropScience, Research Triangle Park, NC).

In 1998, treatments were applied on 14 and 17 August with a high-clearance sprayer and a CO_2-charged spray system calibrated to deliver 56.1 L per ha through TX-8 hollow cone nozzles (Spraying Systems Company, Wheaton, IL) (two per row) at 338 kPa. Treatments were applied on 11 and 14 Aug in trial 2000-A and trial 2000-B, respectively, with a high-clearance sprayer and a CO_2-charged spray system calibrated to deliver 56.1 L per ha through TX-8 hollow cone nozzles (two per row) at 359 kPa.

Treatment efficacy was determined 10 d after treatment (DAT), three and seven DAT, and two and seven DAT, respectively, in trials 1998, 2000-

A, and 2000-B. Larval density data were collected with a standard (38.1 cm) sweep net (25 sweeps per plot). Data for each trial were subjected to analysis of variance procedures and means separated according to Fisher's Protected Least Significant Difference (SAS Institute, 1990).

Laboratory Experiments

Insects tested were obtained from susceptible laboratory colonies maintained at the Louisiana State University Department of Entomology, Baton Rouge, LA. The beet armyworm colony was obtained from Ecogen, Inc. (Langhorne, PA) during 1994. This colony was originally established at the USDA-ARS Southern Insect Management Laboratory at Stoneville, MS before 1983. The fall armyworm colony was established in 1997 from collections in field corn, *Zea mays* L., and supplemented with additional individuals collected from field corn in 1999.

Larvae were fed an artificial wheat-germ and soybean protein diet described by King & Hartley (1985). Rearing conditions consisted of a 14:10 light-dark photoperiod, 23.9 to 29.4°C, and 80% relative humidity.

Samples of technical grade indoxacarb (E.I. DuPont de Nemours and Company, Wilmington, DE), pyridalyl (Valent USA Corporation, Walnut Creek, CA), spinosad (Dow AgroSciences, Indianapolis, IN), and cypermethrin (Chem Service, West Chester, PA) were used in adult vial tests. Procedures similar to those described by Plapp et al. (1987) for the adult vial test were used to evaluate the toxicity of indoxacarb, pyridalyl, and spinosad to beet armyworm and fall armyworm. Stock solutions of each compound were developed by dissolving technical grade insecticide in acetone. Dilutions from each stock solution were used to yield the desired concentrations. The interior surface of 20-ml scintillation vials was coated with insecticide by pipetting 0.5 ml of the appropriate insecticide solution into the vials. These vials were placed on a modified hot dog roller (heating element disconnected) until all of the acetone had evaporated. Vials were stored in a dark environment at ambient temperature (approximately 23.9°C) no longer than 21 d before being used in assays. All assays were conducted at ambient temperature (approximately 23.9°C). Washed (clean) non-treated vials were used as controls. Previous tests (J. B. Graves & B. R. Leonard, unpublished data) indicated no differences in mortality between washed non-treated vials and vials treated with acetone only.

Prior to testing, insects were segregated by sex based on dimorphic pupal characters. Pupae were placed into 3.78-L cardboard cartons containing a thin layer of vermiculite on the bottom. Newly eclosed adults were removed daily and placed into polypropylene cages (29.97 × 29.97 × 29.97 cm) (BugDorm, Megaview Science Education Services CO. Ltd., Taichung, Taiwan). Male and female moths were held in separate cages for ca. 24 h and provided 10% sugar water as a food source. Moths were placed into insecticide treated vials or control vials (1 moth per vial) and mortality was determined after 24 h of exposure. Moths were considered dead if they were incapable of sustained flight for at least 1.0 meter. The number and range of concentrations for each colony and compound combination are detailed in Table 1. Data were corrected for mortality in control vials (Abbott 1925) and analyzed by probit analysis with Polo PC (LeOra Software, Berkeley, CA). Differences were considered to be significant based upon non-overlap of the 95% confidence limits. Separate data analyses were conducted for males and females of the respective insect species for each compound. Data for males and females of the respective insect species for individual compounds were pooled when no significant differences were detected between sexes or LC_{50} or LC_{90} values exceeded the highest concentration tested. Data from adult vial tests are reported as µg of insecticide per vial.

TABLE 1. RANGE OF CONCENTRATIONS OF INDOXACARB, PYRIDALYL, SPINOSAD, AND CYPERMETHRIN TESTED AGAINST LABORATORY COLONIES OF INSECTS IN THE ADULT VIAL TEST.

Compound	Insect species	No. of concentrations	Concentration range (µg/vial)
Indoxacarb	Beet armyworm	7	10-200
	Fall armyworm	4	25-100
Pyridalyl	Beet armyworm	7	10-200
	Fall armyworm	4	25-100
Spinosad	Beet armyworm	15	1-100
	Fall armyworm	10	5-100
Cypermethrin	Beet armyworm	7	0.5-100
	Fall armyworm	5	5-100

Results and Discussion

Field Experiments

In trial 1998 (cotton), all insecticide treatments significantly reduced beet armyworm densities compared to the non-treated control at 10 DAT (Table 2). Beet armyworm densities were reduced by 5.6-fold, 5.7-fold, and 21.2-fold in plots treated with spinosad, indoxacarb, or pyridalyl, respectively, compared to those observed in the non-treated plots. In trial 2000-A (soybean), all insecticide treated plots had significantly lower densities of beet armyworm larvae compared to the non-treated plots at three DAT (Table 3). Plots treated with methoxyfenozide or emamectin benzoate had significantly fewer larvae compared to plots treated with indoxacarb, spinosad, or thiodicarb. Beet armyworm densities were 5.5-fold, 6.5-fold, and 17.9-fold lower in the indoxacarb, emamectin benzoate, and methoxyfenozide treated plots, respectively, compared to beet armyworm densities in the non-treated plots. At seven DAT, all insecticide treatments, except thiodicarb, significantly reduced beet armyworm densities compared to those observed in the non-treated control. In treated plots spinosad reduced beet armyworm densities 2.6-fold and indoxacarb reduced beet armyworms 4.8-fold compared to non-treated plots. No larvae were collected in plots treated with methoxyfenozide. In trial 2000-B (cotton), all insecticide treatments significantly reduced beet armyworm densities compared to those observed in the non-treated control at two DAT (Table 4). Plots treated with indoxacarb, spinosad, or emamectin benzoate had significantly fewer larvae than plots treated with methoxyfenozide. Beet armyworm densities in the spinosad and indoxacarb treated plots were 10.5-fold and 6.5-fold lower, respectively, compared to those in the non-treated plots. At seven DAT, all insecticide treatments significantly reduced larval densities compared to the non-treated control. Beet armyworm densities in the spinosad, indoxacarb, and methoxyfenozide treated plots were 30.2- fold, 11.9-fold, and 49.1-fold lower, respectively, compared to those in the non-treated plots.

Results of these studies are similar to those from Fitzpatrick et al. (1996); Terán-Vargas et al. (1997); Gore et al. (1999); Torrey et al. (1999) in which indoxacarb, spinosad, methoxyfenozide, and emamectin benzoate provided excellent control of beet armyworm infestations. Thiodicarb significantly reduced beet armyworm larval densities compared to the non-treated control at three DAT. At seven DAT, however, larval densities in the thiodicarb treated plots were not significantly different from those in the non-treated plots. These results for thiodicarb are similar to those reported by Mascarenhas et al. (1996) in which the performance of thiodicarb was inconsistent. Thiodicarb is no longer recommended for beet armyworm control in cotton in Mississippi and Louisiana (Bagwell et al. 2003; Layton 2004). The inconsistent performance of thiodicarb in these studies further supports its removal from insecticide recommendations for control of beet armyworm in cotton in Louisiana. Thiodicarb is recommended for use in soybeans against beet armyworm in Mississippi and Louisiana (Anonymous 2003; Baldwin et al. 2003) and for use in cotton and soybeans against beet armyworm in Arkansas (Johnson et al. 2002; Lorenz et al. 2002).

Laboratory Experiments

The LC_{50} values of indoxacarb and pyridalyl exceeded the highest concentration tested (200 µg per vial for indoxacarb and pyridalyl) for beet armyworm adults (Table 5). The LC_{50} values of spinosad (45.6 µg per vial) and cypermethrin (37.1 µg per vial) were not significantly different from each other. The LC_{90} values of indoxacarb, pyridalyl, spinosad, and cypermethrin for beet armyworm adults exceeded the highest concentrations tested

Table 2. Efficacy of selected insecticides against beet armyworm in cotton, 1998.

Treatment	Rate per ha (kg AI)	No. beet armyworm larvae per 25 sweeps 10 DAT (± SE)
Indoxacarb	0.101	6.3 b ± 0.9
Pyridalyl	0.14	1.8 b ± 1.7
Spinosad	0.073	6.8 b ± 1.6
Emamectin Benzoate	0.011	4.0 b ± 3.3
Non-Treated	—	38.3 a ± 5.2
F		87.1
df		4,12
$P > F$		<0.01

Means followed by a common letter are not significantly different ($P \leq 0.05$ Fisher's Protected Least Significant Difference).

TABLE 3. EFFICACY OF SELECTED INSECTICIDES AGAINST BEET ARMYWORM IN SOYBEAN (TRIAL 2000-A).

		No. beet armyworm larvae per 25 sweeps	
Treatment	Rate per ha (kg AI)	3 DAT (± SE)	7 DAT (± SE)
Indoxacarb	0.101	5.2 bc ± 3.0	2.4 bc ± 1.5
Spinosad	0.045	8.0 bc ± 1.9	4.4 b ± 2.1
Methoxyfenozide	0.224	1.6 c ± 1.5	0.0 c ± 0.0
Thiodicarb	0.504	12.2 b ± 10.3	8.4 a ± 4.1
Emamectin Benzoate	0.011	4.4 c ± 2.1	2.2 bc ± 1.5
Non-Treated	—	28.6 a ± 11.1	11.4 a ± 6.2
F		14.1	10.3
df		5,20	5,20
P > *F*		<0.01	<0.01

Means within columns followed by a common letter are not significantly different ($P \geq 0.05$ Fisher's Protected Least Significant Difference).

(200 µg per vial for indoxacarb and pyridalyl, 100 µg per vial for spinosad and cypermethrin). The LC_{50} values of indoxacarb and pyridalyl for fall armyworm adults exceeded 100 µg per vial (highest concentration tested) (Table 6). The LC_{50} value of cypermethrin (31.0 µg per vial) was significantly lower than that of spinosad (69.3 µg per vial) for fall armyworm adults. The LC_{90} values of indoxacarb, pyridalyl, spinosad, and cypermethrin for fall armyworm adults exceeded 100 µg per vial (highest concentration tested).

In these studies, the LC_{50} values of indoxacarb and pyridalyl for beet armyworm and fall armyworm from laboratory colonies exceeded 100 µg per vial. These values were significantly higher compared to the discriminating concentrations of cypermethrin (5-10 µg per vial) (Plapp et al. 1987; Graves et al. 1989), methomyl (2.5-10 µg per vial), profenofos (10-40 µg per vial), and endosulfan (3-10 µg per vial) (Kanga et al. 1995; Graves et al. 1994) for tobacco budworm and bollworm. Andaloro et al. (2000) reported LC_{50} values >100 ppm for bollworm, tobacco budworm, and beet armyworm larvae exposed to glass surfaces treated with indoxacarb indicating that contact exposure to residues is not a primary route of intoxication for indoxacarb. Additionally, Wing et al. (2000) reported that indoxacarb is inactive and is metabolically activated into toxic metabolites. These metabolites are extremely active and block sodium channels in the insect nervous system. Information regarding the route of intoxication of pyridalyl has not been released.

These data compare the relative toxicity of indoxacarb and pyridalyl to that of other common insecticides against two *Spodoptera* species and comprise initial efforts to develop baseline data. These data also demonstrate that the adult vial test is not an efficient test procedure for use with indoxacarb and pyridalyl in resistance monitoring efforts, as opposed to pyrethroids and spinosad, which generally perform well in the adult vial test. These studies indicate that discriminating concentrations for indoxacarb and pyridalyl for use in the adult vial test would be extremely high. Coordinated resistance monitoring efforts

TABLE 4. EFFICACY OF SELECTED INSECTICIDES AGAINST BEET ARMYWORM IN COTTON (TRIAL 2000-B).

		No. beet armyworm larvae per 25 sweeps	
Treatment	Rate per ha (kg AI)	2 DAT (± SE)	7 DAT (± SE)
Indoxacarb	0.101	6.5 c ± 3.4	3.3 b ± 3.3
Spinosad	0.101	4.0 c ± 3.6	1.3 b ± 1.3
Methoxyfenozide	0.168	23.5 b ± 8.3	0.8 b ± 1.0
Emamectin Benzoate	0.008	8.0 c ± 1.6	5.8b ± 2.5
Non-Treated	—	42.0 a ± 18.3	39.3 a ± 10.5
F		13.2	43.1
df		4,12	4,12
P > *F*		<0.01	<0.01

Means within columns followed by a common letter are not significantly different ($P \geq 0.05$ Fisher's Protected Least Significant Difference).

TABLE 5. RESPONSES OF LABORATORY REARED BEET ARMYWORM ADULTS TO INDOXACARB, PYRIDALYL, SPINOSAD, AND CYPERMETHRIN IN THE ADULT VIAL TEST.

	N	Slope ± SE	LC_{50}	95% C.L.	LC_{90}	95% C.L.	χ^2, *df*	Regression equations
Indoxacarb	350	0.72 ± 0.22	>200[1]	NA[2]	>200[1]	NA[2]	4.08,5	Y = 0.72x + -0.21
Pyridalyl	350	0.10 ± 0.25	>200[3]	NA[2]	>200[3]	NA[2]	21.15,5[6]	Y = 0.10x + -1.87
Spinosad	893	1.87 ± 0.17	45.6	39.9-52.5	>100[4]	NA[2]	10.06,13[6]	Y = 1.87x + -3.11
Cypermethrin	176	1.14 ± 0.21	37.1	17.7-124.5	>100[5]	NA[2]	8.52,5	Y = 1.14x + -1.79

Concentrations expressed in µg insecticide per vial.
[1]Values exceeded 200 µg per vial (highest concentration tested), 200 µg per vial concentration resulted in 39.0% mortality.
[2]Confidence limits could not be calculated.
[3]Values exceeded 200 µg per vial (highest concentration tested), 200 µg per vial concentration resulted in 16.0% mortality.
[4]Values exceeded 100 µg per vial (highest concentration tested), 100 µg per vial concentration resulted in 68.3% mortality.
[5]Values exceeded 100 µg per vial (highest concentration tested), 100 µg per vial concentration resulted in 65.0% mortality.
[6]Significant χ^2 ($P = 0.05$).

TABLE 6. RESPONSES OF LABORATORY REARED FALL ARMYWORM ADULTS TO INDOXACARB, PYRIDALYL, SPINOSAD, AND CYPERMETHRIN IN THE ADULT VIAL TEST.

	N	Slope ± SE	LC_{50}	95% C.L.	LC_{90}	95% C.L.	χ^2, *df*	Regression equations
Indoxacarb	329	0.63 ± 0.39	>100[1]	NA[2]	>100[1]	NA[2]	5.99,2	Y = 0.63x + -2.10
Pyridalyl	166	2.26 ± 0.72	>100[3]	NA[2]	>100[3]	NA[2]	3.57,2	Y = 2.26x + -5.17
Spinosad	859	1.70 ± 0.22	69.3	44.8-134.0	NA[4]	NA[2]	35.79,8[6]	Y = 1.70x + -3.13
Cypermethrin	174	2.09 ± 0.35	31.0	24.6-42.4	NA[5]	NA[2]	2.45,3	Y = 2.09x + -3.11

Concentrations expressed in µg insecticide per vial.
[1]Values exceeded 100 µg per vial (highest concentration tested), 100 µg per vial concentration resulted in 27.3% mortality.
[2]Confidence limits could not be calculated.
[3]Values exceeded 100 µg per vial (highest concentration tested), 100 µg per vial concentration resulted in 25.7% mortality.
[4]Values exceeded 100 µg per vial (highest concentration tested), 100 µg per vial concentration resulted in 70.0% mortality.
[5]Values exceeded 100 µg per vial (highest concentration tested), 100 µg per vial concentration resulted in 88.9% mortality.
[6]Significant χ^2 ($P = 0.05$).

generally test hundreds to thousands of insects of a particular species annually. The high discriminating concentrations of indoxacarb and pyridalyl in the adult vial test would dramatically increase the cost of monitoring efforts.

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