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Toxicity Of Selected Insecticides Against Immature And Adult Stages Of Beet Armyworm (Lepidoptera: Noctuidae)

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ABSTRACT

Laboratory studies were conducted to test the toxicity of methomyl, bifenthrin, emamectin benzoate and chlorfenapyr against immature and adult beet armyworm, *Spodoptera exigua* (Hübner). Bifenthrin and emamectin benzoate showed greater efficacy against third instar larvae compared to chlorfenapyr. Methomyl showed the least efficicacy for killing the larvae among the four insecticides tested. Emamectin benzoate and chlorfenapyr had delayed efficacy against the larvae compared to bifenthrin and methomyl. Against beet armyworm male adults, the order of toxicity of the insecticides was: bifenthrin > methomyl > emamactin benzoate > chlorfenapyr. Also, ememactin benzoate and chlorfenapyr had delayed effect in killing the adults. Potential role of the novel insecticides emamectin benzoate and chlorfenapyr in integrated beet armyworm management programs is discussed.

RESUMEN

Estudios in laboratorio fueron conducidos para probar la toxicidad de methomyl, bifenthrin, emamectin benzoate y chlorfenapyr en contra de formas juveniles y adultas del gusano soldado de la remolacha, *Spodoptera exigua* (Hubner). Bifenthrin y emamectin benzoate mostraron ser más eficaces en contra del tercer estadío larvario comparado con chlorfenapyr. Entre todos los insecticidas provados, methomyl mostró la menor eficacia para matar larvas de este insecto. Emamectin benzoate y chlorfenapyr tuvieron una eficacia retardada en contra de larvas comparado con bifenthrin y methomyl. El orden de eficacia de estos cuatro insecticidas fue: bifenthrin > methomyl > emamectin benzoate > chlorfenapyr. Tambíen, emamectin benzoate y chlorfenapyr tuvieron efectos retardados en contra de los adultos. El uso potencial de emamectin benzoate y chlorfenapyr en programas de control integrado es discutido en este artículo.

Additional index words. Toxicity, insecticides, beet armyworm, integrated pest management

The beet armyworm, *Spodoptera exigua* (Hübner), is an important lepidopterous insect pest of many agricultural and horticultural crops primarily in tropical and subtropical regions (Brown and Dehaust 1975). In California, this pest attacks cotton, strawberries, alfalfa, tomatoes, celery, lettuce, sugar beets and many other crops causing serious economic damage (Mitchell 1979, Smits et al. 1987). Although predators and parasites have been used to control this pest with variable efficacy, the use of chemical insecticides still remains the most effective way to suppress the pest populations on various crops (Yee and Toscano 1998, Liburd et al. 2000). In California, growers heavily rely on conventional insecticides, such as methomyl (carbamate), to control beet armyworm (Byrne and Toscano 2001). Repeated applications of same insecticide exert tremendous selective pressure on pest populations, resulting in increased potential for development of resistance (Brewer and Trumble 1989, 1994, Brewer et al. 1990).

In the past decade, several novel insecticides with different modes of action have been developed for management of lepidopterous insect pests. The avermectins are a group of macrocyclic lactones isolated from fermentation of the soil microorganism *Streptomyces avermitilis*. They have high binding affinity to the neuronal membrane and act as agonists for GABA-gated chloride channels (Deng and Casida 1992, Fischer and Mrozik, 1989). Emamectin benzoate is an avermectin derivative acting specifically on lepidopteran pests and is relatively non-toxic to beneficial insects (Cox et al. 1995, Hoy and Cave 1985). Chlorfenapyr belongs to the pyrrole class of insecticides and is a pro-insecticide that is activated by mixed function oxidases to its N-dealkylated analog (Black et al. 1994). This metabolite uncouples oxidative phosphorylation in mitochondrial membranes, resulting in cell death and the death of the organism (Black et al. 1994). It has been suggested that resistance due to changes in target sites of other insecticides would not result in cross-resistance to chlorfenapyr and strains resistance to other insecticides might have increased sensitivity to this chemistry (Scott et al. 2004). The addition of these two novel chemicals with different modes of action to current integrated beet armyworm management programs in California should enable the development of a management strategy to minimize the threat of insecticide resistance.

The objective of the present study was to compare the toxicity of these insecticides with the conventional insecticides methomyl and bifenthrin against immature and adult beet armyworm in the laboratory.

MATERIALS AND METHODS

Insects and insecticides. Beet armyworm used in the bioassay was from a susceptible colony collected from Orange County, California, and was maintained at the University of California at Riverside. The colony was subjected to periodic infusion of wild insects. Larvae were maintained on an artificial diet as described by Patana (1985). Insecticides used in the experiment were as follows: bifenthrin (FMC, Philadelphia, PA), methomyl (DuPont, Wilmington, DE), emamectin benzoate (Syngenta, Greensboro, NC), and chlorfenapyr (Olympic Hort. Products, Mainland, PA). These chemicals were diluted in acetone for different concentrations.

Bioassays. Third instar larval and adult male beet armyworm were used to test the toxicity of the insecticides. The mean larval weight was 7.5 mg and the mean weight of adults was 37.0 mg. There were no significant differences among initial weights of the larvae or adults used in the experiment ($P < 0.05$). For test purposes, 0.5 μl and 1 μl of each concentration of diluted insecticides or acetone control were delivered to the thoracic dorsum of larva and adult, respectively, with an Arnold microapplicator (Burkard, Rickmansworth, England). The concentrations (μg AI/μl) of each insecticide used in the test against larvae were as follows, methomyl: 0.212, 0.425, 0.850, 1.700, 3.400, 6.800, and 13.600; bifenthrin: 0.003, 0.006, 0.0120, 0.024, 0.048, 0.080, and 0.100; ememectin benzoate: 0.002, 0.005, 0.010, 0.02, 0.050, and 0.080; chlorphenapyr: 0.100,0.200, 0.400, 0.800, 1.200, 1.600, 2.400, and 4.800. The concentrations (μg AI/μl) of each insecticide used in the test against adults were:methomyl, 0.026, 0.053, 0.160, 0.212, 0.320, and 0.425; bifenthrin, 0.010, 0.0125, 0.020, 0.030, 0.040, and 0.050; emamectin benzoate, 0.08, 0.160, 0.320, 0.640, 1.280, 2.560, and 5.120; chlorfenapyr, 0.200, 0.400, 0.800, 1.600, 2.400, 4.800, and 9.600. Those concentrations of each insecticide covered 5-95% mortality of the tested insects. A minimum of twenty larvae or adults was treated with each concentration of each insecticide. Each larva was held in a 30-ml plastic cup filled with artificial diet. Beet armyworm adults were incubated in groups of 10 moths per oviposition cage with 10% sugar solution for nourishment. Mortality of insects for each dosage of the insecticides was recorded at 24 h intervals up to 96 h after application. Insects were considered dead if they did not move when prodded with a dissecting needle.

Data analysis. The resulting data were corrected for control mortality (Abbott, 1925) and analyzed by probit analysis using POLO-PC (LeOra Software 1987). LD_{50} and LD_{90} for each insecticide were determined for each 24 h interval (24, 48, 72, 96 h) after the treatment. Differences in LD_{50s} and LD_{90s} were considered significantly different if their respective 95% CL did not overlap.

Table 1. Toxicity of selected insecticides to beet armyworm third instar larvae.

Insecticides	Hours after application	n	Slope ± SE	LD_{50}[a] (95% CL)	LD_{90}[a] (95% CL)
Methomyl	24	275	1.04 ± 0.16	53.33 a (19.27-93.05)	904.38 a (404.49-6724.87)
	48	275	1.12 ± 0.17	42.14 a (17.50-69.76)	581.73 a (308.82-2125.37)
	72	275	1.06 ± 0.17	31.34 a (10.35-55.52)	512.40 a (268.15-1997.42)
	96	275	1.07 ± 0.17	29.21 a (7.90-54.46)	466.19 a (237.57-2092.69)
Bifenthrin	24	250	1.50 ± 0.24	0.64 a (0.40-0.89)	3.74 a (2.66-14.20)
	48	250	1.57 ± 0.24	0.57 a (0.33-0.81)	3.74 a (2.23-11.62)
	72	250	1.71 ± 0.25	0.56 a (0.33-0.79)	3.13 a (1.94-8.68)
	96	250	1.71 ± 0.25	0.56 a (0.33-0.79)	3.13 a (1.94-8.68)
Emamectin benzoate	24	275	1.56 ± 0.18	0.91 a (0.53-1.60)	6.05 a (2.90-35.92)
	48	275	1.59 ± 0.19	0.36 b (0.22-0.52)	2.29 ab (1.45-5.00)
	72	275	1.62 ± 0.20	0.24 b (0.14-0.33)	1.45 b (0.98-2.64)
	96	275	1.97 ± 0.24	0.19 b (0.07-0.31)	0.85 b (0.51-2.37)
Chlorfenapyr	24	275	1.57 ± 0.20	24.64 a (14.57-36.68)	160.65 a (91.36-522.15)
	48	275	1.92 ± 0.21	18.93 a (10.58-28.15)	88.14 a (55.34-214.04)
	72	275	2.07 ± 0.22	17.92 a (11.13-25.24)	74.48 a (50.33-144.11)
	96	275	2.15 ± 0.23	17.58 a (11.06-24.58)	69.28 a (47.47-129.19)

[a] μg AI g^{-1} larva body weight, column values within an insecticide and a lethal concentration followed by different letters are significantly different (non-overlap of 95% CL).

RESULTS

Different insecticides had different efficacies against the beet armyworm based on the results of LD_{50} in the 24 to 96 h test period (Tables 1 and 2). Bifenthrin and emamectin benzoate showed greater efficacy against third instar larvae with low LD_{50} values (0.64 to 0.56 µg g^{-1} larva for bifenthrin, and 0.91 to 0.19 µg g^{-1} larva for emamectin benzoate from 24 to 96 h post treatment) compared to chlorfenapyr where the LD_{50}s ranged from 26.44 to 17.58 µg g^{-1} larva (Table 1). Methomyl showed the highest LD_{50} values (53.33 to 29.21 µg g^{-1} larva) among the four insecticides tested (Table 1). Emamectin benzoate and chlorfenapyr had delayed efficacy to the larvae compared to bifenthrin and methomyl, due to the sharp decreases of the LD_{50} values from 24 to 96 h after being applied (Table 1). LD_{90} values of these insecticides for the third instars followed the same order as the LD_{50}s (Table 1). Against beet armyworm male adults, the order of LD_{50} values of the insecticides were: bifenthrin (0.97 to 0.53 µg g^{-1} larva), methomyl (4.29 to 2.95 µg g^{-1} larva), emamectin benzoate (257.31 to 4.44 µg g^{-1} larva), and chlorfenapyr (579.41 to 10.17 µg g^{-1} larva) (Table 2). LD_{90}s for the adults were: bifenthrin (1.99 to 1.30 µg g^{-1} adult), methomyl (12.25 to 12.13 µg g^{-1} adult), emamectin benzoate (957.45 to 18.71 µg g^{-1} adult), and chlorfenapyr (2226.23 to 63.35 µg g^{-1} adult) (Table 2). Also, emamectin benzoate and chlorfenapyr had delayed effect in killing the adults (Table 2).

DISCUSSION

Our results indicate that emamectin benzoate is a powerful toxicant against the larval beet armyworm, and the efficacy is comparable to that of bifenthrin and far superior to that of methomyl (Table 1). Apparent toxicity is several days delayed compared to that of bifenthrin or methomyl due to their different modes of action (Table 1). The contact efficacy of emamectin benzoate against adult beet armyworm is comparable to that of methomyl (Table 2). These results generally agree with previous reports (Jansson et al. 1996, Dunbar et al. 1996, Ishaaya et al. 2001). Emamectin benzoate is extremely selective at killing lepidopterous pests, while conserving natural enemies, thus is compatible with IPM goals (Hoy and Cave, 1985, Jansson et al. 1996, Ishaaya et al. 2001).

Our results also show that chlorfenapyr is a potent insecticide against immature beet armyworm (Table 1), consistent with previous report (Wier et al. 1994). The efficacy was greater than that of methomyl but lower than that of bifenthrin, agreeing with results of our field tests on lettuce (Table 1, Toscano et al. unpublished data). Chlorfenapyr is in the pyrrole class of

Table 2. Toxicity of selected insecticides to beet armyworm adults

Insecticides	H after application	n	Slope ± SE	LD_{50}[a] (95% CL)	LD_{90}[a] (95% CL)
Methomyl	24	340	2.81 ± 0.26	4.29 a (3.18-5.86)	12.25 a (8.33-25.37)
	48	340	2.66 ± 0.24	3.98 a (2.94-5.44)	11.92 a (8.15-25.07)
	72	340	2.51 ± 0.23	3.62 a (2.70-4.86)	11.73 a (7.99-23.24)
	96	340	2.09 ± 0.21	2.95 a (2.16-3.96)	12.13 a (8.03-25.17)
Bifenthrin	24	320	4.08 ± 0.53	0.97 a (0.84-1.14)	1.99 a (1.57-3.05)
	48	320	4.16 ± 0.55	0.76 ab (0.65-0.86)	1.54 a (1.27-2.12
	72	320	3.37 ± 0.52	0.64 b (0.49-0.76)	1.53 a (1.22-2.28)
	96	320	3.26 ± 0.51	0.53 b (0.38-0.65)	1.30 a (1.04-1.89)
Emamectin benzoate	24	320	2.25 ± 0.51	257.31 a (140.24-402.72)	957.45 a (552.32-5881.87)
	48	320	1.48 ± 0.18	26.31 b (18.40-36.74)	192.38 b (115.89-443.57)
	72	320	2.28 ± 0.33	9.15 c (6.19-11.98)	33.46 c (25.73-48.58)
	96	320	2.05 ± 0.28	4.44 d (2.82-6.08)	18.71 c (14.12-26.99)
Chlorfenapyr	24	340	2.19 ± 0.48	579.41a (412.04-1147.76)	2226.23 a (1130.85-13541.33)
	48	340	2.22 ± 0.33	129.71 b (77.64-193.11)	490.98 ab (300.77-1522.27)
	72	340	1.91 ± 0.23	32.08 c (13.43-53.30)	150.84 bc (89.14-406.27)
	96	275	1.61 ± 0.21	10.17 c (4.05-17.26)	63.35 c (37.97-147.06)

[a] µg AI g^{-1} larva body weight, column values within an insecticide and a lethal concentration followed by different letters are significantly different (non-overlap of 95% CL).

insecticides with a novel mode of action. Insect resistance to other insecticides may not result in cross-resistance to this insecticide and strains resistant to other insecticides might be more sensitivive to this chemistry (Scott et al. 2004). Therefore, chlorfenapyr is potentially a potent component in IPM programs to control the beet armyworm (Wier et al. 1994). Chemical control is still an important component of IPM systems. In California, growers rely on conventional insecticides such as methomyl, chlorpyrifos and pyrethroids to control the beet armyworm on various crops. Widespread tolerance to some of these compounds has been reported in California and other areas (Brewer and Trumble 1989, 1994, Brewer et al. 1990; Mascarenhas et al. 1998). Introducing and alternating emamectin benzoate and chlorfenapyr into the current beet armyworm management programs will be strategic to alleviate the risk of insecticide resistance. The results of this study can also serve as baselines for resistance monitoring programs.

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