RESPONSE OF THE BOLLWORM (NOCTUIIDAE: LEPIDOPTERA) TO INSECTICIDES IN CENTRAL AND NORTH AMERICA

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Abstract

From 1990 to 1993, bollworms, *Heliocoverpa zea* (Boddie), collected from corn in the Lower Rio Grande Valley (LRGV) of Texas, USA and Tamaulipas, Mexico had LD_{50}'s which ranged from 0.04 to 1.67 μg for methomyl (Lannate) and methyl parathion/larva. Populations were susceptible to these insecticides. In 1993, a strain collected from cotton in Guatemala, Central America, had an LD_{50} of 6.34 μg methyl parathion/larva which was equal to LD_{50}'s shown from 1970 to 1972 from the same country. In 1980 a strain from El Salvador was not shown to be resistant to methomyl. In 1993 LD_{50} of cypermethrin (Ammo) for this same strain from Guatemala was greater than any shown in North America. This is the first report suggesting that there is resistance to any pyrethroid in the Americas. LD_{50}'s for deltamethrin (Decis) by a laboratory reference strain and three field collected strains in 1989 to 1991 from Nicaragua, Central America were equal.

Introduction

The bollworm, corn earworm or tomato fruitworm, *Heliocoverpa zea* (Boddie), is part of the bollworm complex (Hartwick 1970), and is consistently a pest of corn in the Americas. It is also a pest of cotton in the Americas. Methomyl is probably the standard insecticide used against this pest on corn in North America since the early 1970's. Methyl parathion was the standard insecticide of this pest in Central America on cotton to the late 1970's. Resistance to methyl parathion was first shown by a population of this insect from Nicaragua, Central America (Wolfenbarger et al 1971). We suggest that the majority of bollworm populations from the Central American countries are present on cotton each generation. These populations are subject to selection by methyl parathion which is the most widely used insecticide for control of the boll weevil, *Anthonomus grandis* Boheman (Coleoptera: Curculionidae). Populations from North America were all susceptible to methyl parathion (Wolfenbarger et al. 1973). In 1980 a population from El Salvador was also resistant to methyl parathion while those from the Lower Rio Grande Valley (LRGV) of the United States and northern Mexico were susceptible (Wolfenbarger et al. 1981). Resistance to methomyl by this pest in El Salvador (Wolfenbarger et al 1981) and the United States was not indicted (Wolfenbarger et al 1987).

The pyrethroids have been used against this pest on both these crops since the late 1970's in the America's. and they are considered to be the standard insecticides. There is no information on toxicity by any pyrethroid insecticide from any Central American country.

Determined here are LD_{50}'s of deltamethrin from 1989 to 1991 from Nicaragua, cypermethrin in 1993 from Guatemala and in 1990 from the LRGV of Texas and Tamaulipas, Mexico. This was done to compare toxicity of pyrethroids to bollworms from Central and North America. In 1993 LD_{50}'s of methyl parathion to a strain of bollworm from corn in southern Tamaulipas, Mexico and cotton from Guatemala were also determined. This was done to compare toxicity by methyl parathion to the bollworm in the 1990's with toxicities determined in various Central American countries in the early 1970's and 1980. Toxicity by macrolactone insecticides, i.e. abamectin (Zephyr) and emamectin hydrochloride, were also determined because this is a new class of insecticides available for testing in the late 1980's.

Materials and Methods

Technical abamectin (94%), bifenthrin (93.2%), cypermethrin (92%), cyfluthrin (94%), deltamethrin (100%), emamectin hydrochloride (93%), esfenvalerate (89%), Lambda cyhalothrin (95%), methomyl (99%), methyl parathion (98%), profenofos (94%), sulprofos, (94%) and tralomethrin (94%) were obtained from Merck Inc. Parsipinay, NJ; FMC, Princeton, NJ; FMC; Bayer Inc., Kansas City, KS; Agro-Evo, Wilmington, DE; Merck Inc.; Dupont, Wilmington, DE; Zeneca, Inc., Richmond, CA; Merck; Dupont; Cheminova Inc., Wayne, NJ; Novartis, Inc., Greensboro, NC; Bayer and Agro-Evo, respectively, and tested.

Thirty to 75 eggs and larvae were collected on one day from corn or cotton during the growing seasons in Nicaragua, Guatemala, Mexico and the LRGV, Texas, USA and treated for one to three generations while reared on artificial diet (Shaver and Raulston 1971). All available larvae were treated each generation. Adams and Young (1969) indicated that 20 pairs of brother-sister bollworms in a 3.78 liter container were an optimum number for oviposition. This is generally the number we paired for two or more containers at the laboratories in Nicaragua and Weslaco, Texas/generation. Strain collected in Guatemala from cotton was sent to Weslaco for testing. Strain collected from corn at Eustachian Cuauhtemoc, Tamaulipas, Mexico was reared and tested at Weslaco, Texas.

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The same laboratory reference strain was used in Weslaco, Texas, in 1980 and 1990. A strain was collected from cotton near Poseltega, Nicaragua in 1988 and used as a reference strain. Moths were handled as described for field collected strains.

Topical applications were made to 22±7 mg bollworm larvae with all insecticides at all locations as described by Wolfenbarger et al (1973 and 1981). One microliter with dose of insecticide in acetone (Valley Solvents, Santa Rosa, Texas) was applied to the dorsum of the thorax of each larva. Number alive and dead were determined. Larvae were considered dead when they did not respond to gentle probing.

Doses of methomyl, methyl parathion, profenofos (Curacron) and sulprofos (Bolstar) were 12.5 to 0.0975 μg/larva. Dilutions of doses were 50%. Pyrethroids, i.e. bifenthrin (Capture), cypermethrin, cyfluthrin (Baythroid), deltamethrin, esfenvalerate (Asana), Lambda cyhalothrin (Karate), permethrin (Pounce) and tralomethrin (Scout), were treated at 0.5 to 0.000012 μg/larva. Dilutions of doses were 50%. Emamectin hydrochloride was treated at doses from 0.05 to 0.0003875 μg/larva while abamectin was tested at 1.25, $0.625x10^5$, $0.625x10^{-6}$, $0.625x10^{-7}$ and $0.625x10^{-8}$ μg/larva.

Mortalities of larvae were determined after 48 h in the test from Guatemala and Estacion Cuauhtemoc, Mexico in 1993 and in the test from the LRGV, 1990 and 1991. Mortalities were determined after 48 h of progeny reared from eggs of colony from Nicaragua in 1989, 1990 and 1993. LD_{50}, slope ± standard error and 95% Confidence Interval (CI) were determined by probit analysis (SAS 1988). Number of insects treated was also determined. Significant differences between LD_{50}'s were shown when 95% CI did not overlap. When ratio of slope/SE was t=<1.96, P=∞ slope was not significantly different from zero.

Results and Discussion

Resistance by bollworms collected from corn to any of the insecticides tested in the LRGV of Tamaulipas, Mexico and Texas, USA, was not indicated in 1990, 1991, and 1993 (Table 1). There was a 2,385,714-fold difference in LD_{50} from the least toxic (methomyl) to the most toxic (abamectin), yet this population was susceptible to both insecticides because LD_{50}'s were so low.

In 1990 and 1993, there was no significant difference in LD_{50}'s for methyl parathion between the field collected strains (Table 1) and the laboratory reference strain (Table 2). Prior to these results LD_{50s} by methyl parathion to field-collected bollworms from the LRGV of Tamaulipas, Mexico and Texas USA for 1967, 1969, 1970, 1971, 1990 and 1991 were 0.25, 0.25, 0.11, 0.85 to 3.0, 0.1 and <1.56 μg methyl parathion/larva as shown by Nemec and Adkisson (1967), Wolfenbarger et al. (1970), Wolfenbarger et al. (1971), Wolfenbarger et al (1973), here (Table 1) and Vargas and Wolfenbarger (1992), respectively. Only the LD_{50} of 3.0 μg methyl parathion/larva collected in 1971 from Mexico (Wolfenbarger et al 1973) showed a level of resistance. None of the other populations showed any level of resistance to methyl parathion.

In 1970 an LD_{50} of 9.0 μg methyl parathion/larva was shown for a strain from Nicaragua (Wolfenbarger et al 1973). In 1971 an LD_{50} of 54 μg/larva was determined in the same country (Wolfenbarger et al 1981). Also, in 1970 an LD_{50} of 15.5 μg methyl parathion/larva was determined for a larval collection from El Salvador (Wolfenbarger et al 1973). For comparison LD_{50} values of 0.15 to 0.35 μg/larva were determined from strains collected from Columbia and Peru, respectively, Wolfenbarger et al (1973). Resistance was not shown in either South American country. In 1980 an LD_{50} of 756.9 μg methyl parathion/larva was shown for a strain from El Salvador (Wolfenbarger et al 1981). An LD_{50} of same reference strain in 1980 for this insecticide was 0.42 μg/larva (Wolfenbarger et al 1981) which was equal to that shown in Table 2.

In 1970 we determined LD_{50}'s from 4.65 to 15.5 μg methyl parathion/larva from Guatemala (Wolfenbarger et 1973); in 1993 an LD_{50} of 6.38 μg/larva was determined (Table 1) which was within the range shown in 1970. Populations of bollworm collected from cotton in all countries in Central America from 1970 to 1993 show resistance to methyl parathion.

In 1990 and 1993, $LD_{50's}$ of methomyl collected from corn in LRGV indicated susceptibility for these populations (Table 1). There was a significant difference in LD_{50}'s between the field collected strains(Table 1) and the laboratory reference strain (Table 2). The LD_{50} of the field collected strain from 1993 was significantly lower while that from 1990 was significantly greater than the reference strain (Table 1). Prior to these results bollworm populations collected from various hosts across the United States (Wolfenbarger et al 1987) were determined to be susceptible to methomyl. In 1980 a population collected from cotton in El Salvador showed an LD_{50} of 2.38 μg methomyl/larva while the same reference strain showed an LD_{50} of 0.078 μg/larva, a 30 fold difference. Results indicate the field collected population from El Salvador in 1980 and the field collected strain in the LRGV in 1990 were equal to methomyl because the 95% confidence interval of the LD_{50}'s overlapped. The LD_{50} for the 1993 strain was significantly lower than both the field collected strains from El Salvador and LRGV in 1990. The 95% confidence interval determined for methomyl by the bollworm from El Salvador in 1980 was 1.17-4.04 (not shown in Wolfenbarger et al 1981) which overlapped the interval shown in 1990.

In 1990 and 1991 bollworms collected from corn in LRGV were susceptible to profenofos. There was no significant difference between LD_{50}'s of profenofos to field collected (Table 1) and reference strains (Table 2). In 1980 a field collected strain from cotton in El Salvador showed an LD_{50} of 2.37 μg sulprofos/larva. The 95% confidence interval shown in Table 1 for sulprofos was significantly less than shown for 95% confidence interval of 1.42-3.56 (not shown in Wolfenbarger et al 1981). In 1980 the same laboratory reference strain showed an LD_{50} of 0.41 (Wolfenbarger et al 1981) to 0.35 μg sulprofos/larva shown in 1990 (Table 2). The 95% confidence intervals of LD_{50} for the reference strain in 1990 overlapped the LD_{50} in 1980.

LD_{50} of cypermethrin from cotton in Guatemala in 1993 were significantly different and 29 (Table 1) and 115 (Table 2) fold greater than the field-collected strain in Weslaco and reference strain the same year, respectively. Results suggest resistance by bollworm to cypermethrin in Guatemala.

The LD_{50} for permethrin to bollworm indicated susceptibility in LRGV of Tamaulipas in Mexico in 1991 (Vargas and Wolfenbarger 1992). In 1990 and 1993 bollworms collected from corn were also susceptible to permethrin in LRGV (Table 1). Deltamethrin showed an LD_{50} of 0.0004 μg/larva to our laboratory reference strain (Table 2). LD_{50}'s for pyrethroids, i.e. permethrin and fenvalerate, to a bollworm strain from El Salvador in 1980 showed susceptibility and equal values based on the susceptible reference strain and field strains from the LRGV (Wolfenbarger et al 1981). These populations were not resistant to pyrethroids.

The LD_{50} for deltamethrin against the laboratory reference strain from Poseltega in Nicaragua for this insect ranged from 0.010 to 0.013 μg/larva in 1989 to 1991, respectively. These LD_{50}'s by reference strains from Poseltega, Nicaragua were not significantly different from that of the laboratory reference strain (0.0004 μg/larva). Resistance to this pyrethroid was not indicated.

LD_{50}'s of <0.015 μg/larva were shown for bifenthrin, cyfluthrin, cypermethrin, lambda cyhalothrin, permethrin, tralomethrin, deltamethrin and esfenvalerate for the same two strains; LD_{50}'s were equal as confidence intervals overlapped (Tables 1 and 2). The field collected population was considered to be susceptible to these eight pyrethroids in the LRGV.

The $LD_{50's}$ of deltamethrin were similar against field collected strains from two locations in Nicaragua from 1989 to 1991 (Table 3). Our field collected strain from the LRGV had an LD_{50} of 0.00015 μg deltamethrin/larva (Table 1). Strains from Leon and Chinadega, Nicaragua (Table 3) had LD_{50}'s which were 10 fold greater, but they had overlapping 95% CI. Both the reference strain and the field collected strain were equally susceptible to this pyrethroid.

Abamectin, a macrolactone, was the most toxic insecticide tested against the field collected strain of this insect from the LRGV (Table 1). It was previously shown to be toxic to this insect (Wolfenbarger et al 1985). Emamectin hydrochloride, a salt of the dimethylamino analogue of abamectin, was equally toxic to the field collected (Table 1) and the laboratory reference strain (Table 2) of the bollworm.

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Table 1. Toxicity of insecticides after 48 h to bollworm from Tiquisate, Guatemala. Lower Rio Grande Valley, TX. USA and Estacion Cuahtemoc, Tamaulipas, Mexcio. 1990-1993.

Insecticide	Number Tested	Slope ± SE
	Guatemala 1993	
Cypermethrin	219	1.23±0.2
Methyl Parathion	213	0.74 ± 0.2
	Lower Rio Grande Valley 1990	
Methomyl	242	1.46 ± 0.3
Methyl Parathion	324	2.69 ± 0.8
Profenofos	296	0.73 ± 0.2
Sulprofos	297	1.13 ± 0.2
Cyfluthrin	208	0.67 ± 0.3
Bifenthrin	198	1.35 ± 0.6
Cypermethrin	151	1.21 ± 0.3
Lambda Cyhalothrin	264	1.31 ± 0.06
Permethrin	305	1.19 ± 0.07
Tralomethrin	268	2.68 ± 0.6
Emamectin hydrochloride	283	1.32 ± 0.6
Deltamethrin	356	1.54 ± 0.4
Esfenvalerate	368	2.31 ± 0.2
Abamectin	429	1.87 ± 0.3
	1991	
Permethrin	213	1.66 ± 0.
Profenofos	103	3.57 ± 0.3
	1993	
Methomyl	166	0.96 ± 0.3
Methyl Parathion	189	1.37 ± 0.4
Permethrin	199	1.06 ± 0.3
	Estacion Cuahtemoc 1993	
Methyl Parathion	246	0.93 ± 0.3

Table 1. [cont.]. Toxicity of insecticides after 48 h to bollworm from Tiquisate, Guatemala, Lower Rio Grande Valley, TX, USA, and Eastern Cuahtemoc, Tamaulipas, Mexico. 1990-1993

Insecticide	LD_{50}	(95% Confidence Interval)
	Guatemala 1993	
Cypermethrin	0.15	(0.070 - 0.47)
Methyl Parathion	6.38	(2.62 - 38.85)
	Lower Rio Grande Valley 1990	
Methomyl	1.67	(1.24 - 2.20)
Methyl Parathion	0.1	(0.057 - 0.23)
Profenofos	0.24	(0.0012- 0.72)
Sulprofos	0.089	(0.024 - 0.31)
Cyfluthrin	0.0083	(0.0050-0.012)
Bifenthrin	0.0074	(0.00012 - ∞)
Cypermethrin	0.0051	(0.0017 0.014)
Lambda Cyhalothrin	0.0036	($1.4x10^{-6}$0.022)
Permethrin	0.0022	(0.00013 0.01)
Tralomethrin	0.0018	(0.00140.0022)
Emamectin hydrochloride	0.0012	(0 - 0.12)
Deltamethrin	$1.5x10^{-4}$	(∞]
Esfenvalerate	$7.6x10^{-5}$	(∞-0.076)
Abamectin	$7.4x10^{-7}$	(∞]
	1991	
Permethrin	0.014	(0.0017 - ∞)
Profenofos	0.47	(0.3 - 0.5)
	1993	
Methomyl	0.040	(0.00030 - 0.12)
Methyl Parathion	0.040	(0.0076 - 0.091)
Permethrin	0.00023	($.17x10^{-5}$-0.00060)
	Estacion Cuahtemoc 1993	
Methyl Parathion	0.089	($4.43x10^{-9}$ -0.21)

Table 2. Toxicity of insecticides after 48 h to laboratory susceptible strain to bollworm. Weslaco, USA and Poseltega, Nicaragua. 1989-1990, and 1993.

Insecticide	Number Tested	Slope ± SE
	Weslaco 1990	
Methomyl	[a/]	
Sulprofos	133	0.85 ± 0.09
Profenofos	179	1.28 ± 0.5
Methyl Parathion	[b/]	
Emamectin Hydrochloride	429	0.42 ± 0.1
Permethrin	[b/]	
Esfenvalerate	373	0.73 ± 0.2
Cypermethrin	318	0.7 ± 0.2
Lambda Cyhalothrin	263	1.47 ± 0.5
Bifenthrin	235	1.01 ± 0.0001
Cyfluthrin	369	0.75 ± 0.07
Deltamethrin	368	2.03 ± 0.2
Tralomethrin	266	0.67 ± 0.0003
Abamectin	235	0.36 ± 5.3
	Poseltega 1989	
Deltamethrin	910	1.70 ± 0.2
	1990	
Deltamethrin	630	1.37 ± 0.5
	1991	
Deltamethrin	350	1.62 ± 0.2

[a/] Taken from Wolfenbarger et al. (1987)
[b/] Taken from Wolfenbarger et al. (1971 and 1981)

Table 2. [cont.] Toxicity of insecticides after 48 h to laboratory susceptible strain to bollworm. Weslaco, USA and Poseltea, Nicaragua. 1989-1990, and 1993.

Insecticide	LD_{50} (µg/larva)	(95% Confidence Interval)
	Weslaco 1990	
Methomyl	0.35	(0.27 - 0.44)
Sulprofos	0.35	(0.16 - 1.65)
Profenofos	0.28	(0.19 - 0.41)
Methyl Parathion	0.12	(0.028 - 0.27)
Emamectin Hydrochloride	0.012	(0.0048-0.14)
Permethrin	0.0058	(0.0026 - 0.01)
Esfenvalerate	0.003	(0.0017- 0.0048)
Cypermethrin	0.0013	(0.0007 - 0.002)
Lambda Cyhalothrin	0.00072	(0.000067-0.0022)
Bifenthrin	0.0007	(0.00044-0.0011)
Cyfluthrin	0.00058	(0.00034-0.0008)
Deltamethrin	0.0004	(0 - 3384.9)
Tralomethrin	0.00028	($8.6X10^{-6}$-0.00066)
	Poseltega 1989	
Deltamethrin	0.01	(0.003-0.013)
	1990	
Deltamethrin	0.011	(0.0082-0.13)
	1991	
Deltamethrin	0.013	(0,01 - 0.016)

[a/] Taken from Wolfenbarger et al. (1987)
[b/] Taken from Wolfenbarger et al. (1971 and 1981)

Table 3. Toxicity of µg deltamethrin/larva to bollwoem after 48 h. Nicaragua, 1989-1991.

Location	Insects Tested	Slope ± SE
	1989	
Leon	910	1..81 ±0.2
Chinadega	910	1.18 ± 0.2
	1990	
Leon	630	1.57 ± 0.4
Chinadega	630	1.51 ± 0.6
	1991	
Leon	350	1.37 ± 0.2
Chindanega	910	1.30 ± 0.3

Table 3. Toxicity of µg deltamethrin/larva to bollwoem after 48 h. Nicaragua, 1989-1991.

Location	LC_{50} (µg/larvae)	(95% Confidence interval)
	1989	
Leon	0.0072	(0.0051-0.009)
Chinadega	0.0074	(0.0051-0.0098)
	1990	
Leon	0.012	(0.0081-0.0184)
Chinadega	0.011	(0.0081-0.013)
	1991	
Leon	0.0095	(0.0068-0.013)
Chindanega	0.013	(0.01-0.016)