RESPONSE OF THE TOBACCO BUDWORM[1] TO PERMETHRIN AND METHYL PARATHION IN ARIZONA, 1977-1989

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ABSTRACT

Field populations of tobacco budworm, *Heliothis virescens* (F.), have been monitored annually since 1977 with topical applications of synthetic pyrethroid insecticides (primarily permethrin) and methyl parathion to detect changes in insecticide susceptibility. These data showed that LD_{50}'s fluctuated somewhat from year to year with permethrin, but the fluctuations were not sufficient to change levels of expected control in the field. Field populations continue to show susceptibility to permethrin even though one Maricopa County population showed an increase in the LD_{50} to 12.4 in 1988. Field populations continue to show resistance to methyl parathion and susceptibility to permethrin. Little difference in susceptibility between permethrin and fenvalerate was found.

INTRODUCTION

The tobacco budworm, *Heliothis virescens* (F.), (TBW) was recorded for the first time as an economic pest of cotton, *Gossypium* spp., in Arizona in 1972 (Watson 1974). Following the discovery of TBW in cotton in AZ, dosage-mortality studies were conducted by Lentz et al. (1974) to determine TBW susceptibility to the then currently used classes of insecticides. Their studies indicated that the TBW was more tolerant than the bollworm, *H. zea* (Boddie), to the insecticides tested and that the heterogeneity of the population showed a high probability that the more resistant individuals would be rapidly selected. Both species have been subjected to the more widely used insecticides since *ca.* 1945 and have developed varying levels of resistance to one or more of the different insecticide classes (Harris et al. 1972). Subsequent studies showed that this did, in fact, occur with methyl parathion (Crowder et al. 1979). The studies of Crowder et al. (1979), provided base-line data for susceptibility to the newer synthetic pyrethroids which were being used on a limited acreage under an Experimental-Use Permit in 1978.

The pyrethroids proved to be extremely effective against the TBW, as well as numerous other cotton pests. Since resistance to pyrethroids had already been found in a number of insect species (Keiding 1976, Chadwick et al. 1977, Priester and Georghiou 1978, Fullbrook and Holden 1980, Liu et al. 1982, Scott et al. 1983), Jensen et al. (1984) conducted a laboratory experiment to determine the capacity of a susceptible field strain of TBW to develop resistance to permethrin and cross-resistance to cypermethrin. Their results showed that after only 11 generations of continuous selection pressure, the LD_{50} in the F_{12} generation had increased 37-fold compared with the LD_{50} of the F_1. Cross-resistance to cypermethrin was also *ca.* 8-fold greater.

Because of the rapidity of change among field populations of insects subjected to various insecticides, we have annually monitored populations of TBW after each growing season to determine changes in susceptibility to the organophosphate and pyrethroid insecticides. Watson et al. (1986) reported results of studies with permethrin, fenvalerate and methyl parathion for the period of 1977-85, 1977-80 and 1972-85, respectively. Results of annual assessment of susceptibility of TBW to permethrin and methyl parathion for the period 1977-1989 are reported herein.

[1] Lepidoptera: Noctuidae
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MATERIALS AND METHODS

TBW cultures were established in the laboratory each year during the period from late September to November, from 1976 to the present time. These cultures provided populations which had undergone the maximum level of insecticide exposure during that particular year.

Larvae were collected from late-season cotton plants from the same general location in AZ each year. They were then taken to the entomology laboratory at the University of Arizona Campus Agricultural Center, and placed in 29.6 ml plastic cups one-half filled with a modified lima bean-agar diet (Patana 1969). Newly-emerged moths were transferred to wide-mouth 3.8 L glass jars, *ca.* 40 moths per jar. A double layer of cheesecloth was used to cover the tops of the jars and to provide a surface for oviposition. Glass and polytheylene tubes, corked at one end and filled with a 5% sucrose solution, were inverted through the cheesecloth to serve as the food source for adults. Egg sheets were treated as described by Patana (1969) and neonate larvae used in topical treatments were placed in plastic shoe boxes containing diet medium to a depth of *ca.* 1 cm. Those reared for the next generation were placed two per cup in the 29.6-ml plastic cups.

Larvae were maintained in an environator at a temperature of *ca.* 30°C. After 4 to 7 days, 3rd instar larvae were transferred to individual 29.6 ml media cups for topical insecticide treatment. LD_{50}'s were determined on early-generation (F_1 to F_3) progeny of the field-collected parents.

Insecticide applications and mortality counts were done by the standard test method for determining resistance in *Heliothis* (Anon. 1970). Larvae weighing an average of 20 mg were topically treated and held as prescribed. Four to five replicates of 20 to 25 larvae each were generally treated at each of four to six dosage concentrations. The control consisted of a similar group treated only with acetone. A sample of *ca.* 20% of each group of larvae was weighed prior to treatment and the weights used in determining the LD_{50}.

Mortality counts were made at 48 and 72 h after treatment. Larvae were considered dead if they failed to respond to repeated prodding with a blunt probe. The 48- and 72-h counts were used to compute the dosage-mortality lines for methyl parathion and permethrin, respectively. Data were analyzed using probit-analysis (Finney 1952). The 95% fiducial limits were used to compare LD_{50} values. Pearson correlation coefficients were computed using SAS for LD_{50} and slope values of both the permethrin and methyl parathion data from Maricopa County.

RESULTS AND DISCUSSION

Table 1 presents toxicological data on TBW from field collections over a 13-year period. These data show some change in the LD_{50} with permethrin from year to year, but only at one time and one location did it rise to a level that would indicate potential problems with control in the field. In general, the LD_{50}'s ranged from < 2.0 $\mu g/g$ to < 6.0. Two exceptions to this were recorded, both in Maricopa County in 1981 and 1988 where LD_{50}'s were 8.35 and 12.4, respectively. These were not significantly different from the previous high of 5.96 in that location. Even at the outset of permethrin use, field populations were more tolerant to the pyrethroids than was the domestic strain cultured in the laboratory by the USDA-ARS in Tucson, AZ (Table 1).

During some years, data were collected for TBW from other locations in AZ, particularly Yuma and Pinal Counties. These data were more limited than were those from Maricopa County but again, variable results were obtained from year to year; in general, the Yuma County populations appeared to be slightly more susceptible to permethrin. However, the LD_{50}'s in the Yuma area indicate a trend towards greater tolerance to permethrin, rising from a low of 1.79 $\mu g/g$ in 1980 to 3.46 in 1981 and then to a high of 5.06 in 1989. It would take more consistent monitoring in this location to establish the significance of these increases. In any event, the 1989 LD_{50} still falls within the range of variation observed in Maricopa County, where more consistent monitoring has been done.

Table 2 shows data on tolerance of TBW to methyl parathion for a 15-year period. In Pinal County in 1972, field control of the TBW was noticeably difficult to achieve and Lentz et al. (1974) reported an LD_{50} of 19.7 $\mu g/g$ for field populations collected in 1972. The next determination was in 1976 when the LD_{50} had reached 141 $\mu g/g$. In 1977, when yearly monitoring was initiated, the LD_{50} of field-collected TBW was 173 compared to 11.5 for that of the domestic susceptible strain. Even though year to year fluctuations have occurred, the LD_{50}

has remained high, except for 1982, when it dropped to 21.3 μg/g, approaching that noted during the initial outbreak year of 1972. Following this, the LD_{50} seemed to increase and stabilize in the 60 to 70 range until 1988 and 1989, when it jumped significantly higher. During this period, a great deal of the cotton acreage in the area was under ULV malathion treatments for boll weevil, *Anthonomus grandis* Boh., control. It is uncertain if the area-wide use of this organophosphate insecticide influenced the sudden increases in the LD_{50}'s. Methyl parathion is still an ineffective insecticide against the TBW in Arizona.

TABLE 1. LD_{50} Values with Confidence Limits and b Values for Permethrin Applied Topically to Tobacco Budworm Larvae, Tucson, Ariz., 1977-89.

Year	Source of Culture	LD_{50} (μg/g)	95% Fiducial Limits	b value (SE)
1977	Maricopa	1.17	0.89 - 1.56	1.56 (0.20)
	Domestic[a]	0.21	0.18 - 0.26	2.75 (0.23)
1978	Maricopa	5.96	4.15 - 17.0	1.57 (0.30)
	Pinal	4.66	3.84 - 7.39	2.59 (0.38)
1979	Pinal	5.89	4.87 - 7.37	2.20 (0.31)
	Yuma	2.69	2.33 - 3.10	1.79 (0.18)
1980	Maricopa	3.48	2.47 - 4.43	1.41 (0.16)
	Yuma	1.79	1.40 - 2.16	1.70 (0.19)
1981	Maricopa	8.35	6.91 - 10.2	1.25 (0.18)
	Yuma	3.46	3.02 - 4.01	1.93 (0.24)
1982	Maricopa	1.79	1.58 - 2.04	2.42 (0.19)
1983	Pinal	2.12	1.87 - 2.41	2.20 (0.20)
1984	Maricopa	3.68	3.19 - 4.25	1.80 (0.17)
1985	Maricopa	1.80	1.62 - 2.01	2.40 (0.16)
1986	Maricopa	5.71	4.99 - 6.54	1.75 (0.14)
1987	Maricopa	3.73	3.05 - 4.57	1.82 (0.10)
1988	Maricopa			
	W. Phoenix	12.40	10.2 - 15.1	1.26 (0.10)
	Laveen	3.06	2.74 - 3.41	2.81 (0.20)
1989	Maricopa			
	W. Phoenix	4.84	4.21 - 5.56	1.61 (0.11)
	Laveen	5.21	3.44 - 7.18	1.33 (0.11)
	Yuma	5.06	4.39 - 5.84	1.97 (0.16)

[a] Culture established from stock obtained from USDA-ARS Biological Control Laboratory, Tucson, AZ.

The slope of dosage mortality lines is sometimes used as an indication of the degree of homogeneity of a population. Homogeneously susceptible (or resistant) populations should exhibit steeper slopes than more heterogeneous populations. These data show a negative correlation between LD_{50} and slope, as expected, but the correlation is weak. For the permethrin data from Maricopa County (Table 1), the Pearson correlation coefficient, $R = -0.60$ ($p = 0.03$), and for the methyl parathion data from Maricopa County (Table 2), $R = -0.46$ ($p = 0.10$).

Limited data showing comparative efficacy of permethrin and fenvalerate for the period 1977-1980 are presented in Table 3. Comparatively little difference was shown in efficacy between the two insecticides. The most striking difference occurred for Yuma-collected TBW in 1980 where LD_{50}'s were 1.79 and 5.41 μg/g, respectively, for permethrin and fenvalerate. Similar differences were shown the same year for TBW collected from Maricopa County.

Even though LD_{50}'s have varied from year to year with the pyrethroids, field control has still been easily obtained, indicating no resistance problems. There is no assurance that control problems will not eventually develop in the field as has occurred in Texas (Plapp and Campanhola 1986) and other locations in the mid-South (Luttrell et al. 1987).

TABLE 2. LD_{50} Values with Confidence Limits and b Values for Methyl Parathion Applied Topically to Tobacco Budworm Larvae, Tucson, Ariz., 1972-89.

Year	Source of Culture	LD_{50} (μg/g)	95% Fiducial Limits	b value (SE)
1972	Pinal[a]	19.7	17.2 - 21.9	2.56 (-)
1976	Maricopa[b]	141	54.9 - 860	1.64 (0.42)
1977	Maricopa	173	127 - 241	1.09 (0.12)
	Domestic[c]	11.5	9.4 - 13.7	2.50 (0.27)
1978	Maricopa	259	210 - 318	1.41 (0.15)
	Pinal	211	180 - 255	1.68 (0.20)
1979	Pinal	142	117 - 172	1.40 (0.19)
	Yuma	100	79.6 - 120	1.53 (0.19)
1980	Maricopa	140	95.0 - 191	1.69 (0.16)
	Yuma	96.3	86.7 - 107	2.47 (0.18)
1981	Maricopa	90.3	64.9 - 118	2.07 (0.24)
	Yuma (Spring)	103	65.6 - 150	1.17 (0.31)
1982	Maricopa	21.3	19.0 - 23.9	2.91 (0.23)
1983	Pinal	76.2	66.4 - 87.5	2.05 (0.20)
1984	Maricopa	62.3	56.2 - 69.1	2.12 (0.13)
1985	Maricopa	67.4	52.9 - 85.7	1.15 (0.11)
1986	Maricopa	62.5	32.1 - 98.6	0.89 (0.08)
1987	Maricopa	75.1	51.3 - 101	1.31 (0.10)
1988	Maricopa			
	W. Phoenix	204	122 - 311	1.12 (0.11)
	Laveen	129	105 - 164	1.94 (0.18)
1989	Maricopa			
	W. Phoenix	153	97.9 - 222	0.97 (0.11)
	Laveen	173	140 - 214	1.19 (0.11)
	Yuma	46.4	30.7 - 64.1	1.63 (0.13)

[a] Data from Lentz et al. (1974).
[b] Data from Crowder et al. (1979).
[c] Culture obtained from USDA-ARS Biological Control Laboratory, Tucson, AZ.

TABLE 3. Comparison of LD_{50} Values with Confidence Limits and b Values for Permethrin and Fenvalerate Applied Topically to Tobacco Budworm Larvae, Tucson, Ariz., 1977-80.

Year	Location (County)	Toxicant	LD_{50} (μg/g)	95% Fiducial Limits	b value (SE)
1977	Domestic[a]	Permethrin	0.21	0.18 - 0.26	2.75 (0.23)
		Fenvalerate	0.34	0.27 - 0.47	1.56 (0.23)
	Maricopa	Permethrin	1.17	0.89 - 1.56	1.56 (0.20)
		Fenvalerate	1.73	1.44 - 2.07	1.60 (0.18)
1978	Maricopa	Permethrin	5.96	4.15 - 17.0	1.57 (0.30)
		Fenvalerate	4.99	4.26 - 6.52	2.71 (0.37)
	Pinal	Permethrin	4.66	3.84 - 7.39	2.59 (0.38)
		Fenvalerate	4.37	3.65 - 10.8	3.07 (0.72)
1979	Pinal	Permethrin	5.89	4.87 - 7.37	2.20 (0.31)
		Fenvalerate	4.44	2.98 - 5.48	1.94 (0.31)
1980	Maricopa	Permethrin	3.48	2.47 - 4.43	1.41 (0.16)
		Fenvalerate	7.55	6.14 - 10.1	1.59 (0.26)
	Yuma	Permethrin	1.79	1.40 - 2.16	1.70 (0.19)
		Fenvalerate	5.41	4.53 - 6.12	2.18 (0.42)

[a] Culture obtained from USDA-ARS Biological Control Laboratory, Tucson, AZ.

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