Susceptibility of Field Populations of Pink Bollworm (Lepidoptera: Gelechiidae) to Azinphosmethyl and Permethrin

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Abstract

Responses of five field-collected populations of the pink bollworm, Pectinophora gossypiella (Saunders), from Arizona and southern California, were compared with those of a standard, susceptible-laboratory strain. Field strains showed less than two-fold difference in response to azinphosmethyl at LD_{50} but had variable levels (1.3- to 18.3-fold) of response to permethrin. Strains from Yuma and Phoenix (Arizona) and Westmoreland (California) had highest levels of resistance to permethrin.

Introduction

Pink bollworm, *Pectinophora gossypiella* (Saunders), is primarily a mid- and late-season pest of cotton. This species is one of the most destructive pests of cotton in most of the cotton-producing countries in the world, including the western cotton belt area of the United States (Roelofs 1978). In Arizona, a pink bollworm infestation was reported as early as 1926; however, serious economic losses remained negligible until 1965 (Watson & Fullerton 1969). Since the 1960's, organophosphorous insecticides have been used effectively as part of the pest management program to control adult pink bollworm. At present, both organophosphate and pyrethroid insecticides are being used to control the pink bollworm in infested areas of the U.S. cotton belt. Recent studies in Arizona and California have revealed that some field populations are resistant to pyrethroids which were introduced in the late 1970's (Bariola & Lingren 1984, Bariola 1985, Haynes et al. 1986).

The objective of our study was to determine whether there are significant differences in responses to azinphosmethyl and permethrin among field populations of pink bollworm collected from Arizona and southern California.

Materials and Methods

Insect Strains. Five strains of pink bollworm collected from natural populations were tested to determine their responses to azinphosmethyl and permethrin. These strains were collected from widely separated sites of commercial cotton production in Arizona (Safford, Marana, Phoenix, and Yuma) and southern California (Westmoreland) and returned to the laboratory. The susceptible pink bollworm strain used for comparison was obtained from the Western Cotton Research Laboratory, USDA-ARS, Phoenix, Arizona where it had been maintained on artificial wheat-germ diet for 17 years and had not been exposed to insecticides during this period.

A large number of infested cotton bolls (approximately 4,000) was collected from each of the field sites. The infested bolls were evenly distributed on steel grids mounted on benches in greenhouses

maintained at about 28°C. Metal trays lined with paper towels placed under the racks provided a substrate for the emerging pink bollworm larvae to pupate. For adult emergence, pupae of the different strains were placed in separate rearing cups (230 ml paper ice cream cups) and held in environmental chambers set at a temperature of 26 ± 1°C and a photoperiod of 14:10 (L:D). The rearing procedure used in this study was adapted from the method used in the pink bollworm rearing facility at the Western Cotton Research Laboratory, USDA-ARS, Phoenix, Arizona (Bartlett & Wolf 1985). The rearing method was adapted for small laboratory cultures.

Chemicals. Technical grade permethrin (Pounce, 98.4%, F.M.C. Corp., Middleport, New York) and technical grade azinphosmethyl (Guthion, 91%, Mobay Chemical Corp., Kansas City, MO) were tested in the population comparison.

Serial dilutions of the chemicals (in acetone) were made on the basis of wt/vol (AI) and concentrations were expressed as $\mu g/\mu l$. The symmetric design for concentration selection recommended by Finney (1971) for precise estimation of LD_{50} was used in all studies. Six to seven different concentrations of the insecticides were tested on 25 insects per concentration. The entire procedure was replicated four times.

Bioassays. Because preliminary tests indicated no significant differences in susceptibility between males and females, bioassays were done using two- to three-d-old unsexed moths of each population. Adults were anaesthetized with carbon dioxide. Each moth was held with a pair of forceps, and 1 μl of the test solution was applied to the dorsum. Topical application was done with a motor-driven microapplicator (Instrumentation Specialists Co., Model M) fitted with a calibrated syringe (tuberculin, 0.25 ml). Control insects were immobilized with CO_2 and treated with acetone only. Treated insects were held in rearing cups, provided with 10% sugar solution, and returned to the environmental chambers. Mortality was recorded 48 h after treatment. Failure of an insect to change position within 30 s following gentle probing with a blunt probe was used as the criterion for death.

Data Analyses. Results of the concentration-mortality experiments were analysed by probit analysis (Finney 1971). Results were expressed as $\mu g/g$ body weight (30 insects were weighed per assay).

Results and Discussion

Susceptibility to Permethrin and Azinphosmethyl in Field Populations. Responses of pink bollworm to azinphosmethyl are summarized in Table 1. LD_{50}'s of all field-collected populations were significantly different from that of the laboratory susceptible strain. Safford, Marana and Westmoreland strains had significantly higher LD_{50}'s compared with those of Yuma and Phoenix strains (Table 1). However, no toxicity ratio at LD_{50} was greater than 1.6.

In contrast, field populations exhibited variable degrees of response to permethrin (Table 2). Resistance to permethrin among the pink bollworm strains ranged from 1.3- to 18.3-fold. LD_{50}'s of the field populations relative to the LD_{50} of the laboratory strain were 1.3-, 3.7-, 13.8-, 14.9- and 18.3-fold for the Safford, Marana, Yuma, Phoenix and Westmoreland strains, respectively. The Westmoreland strain was 14.1-fold more resistant than the most susceptible field strain (Safford strain). No significant differences in toxicities at LD_{50} were observed between the Phoenix and the Yuma populations.

Lack of variation in response to azinphosmethyl suggests that resistance has not developed. Although azinphosmethyl has been extensively used in most areas since 1966, it is still recommended by the Arizona Cooperative Extension Service (Moore et al. 1990) as one of the primary insecticides for control of the pink bollworm. Reagan (1980) reported that the extensive use of azinphosmethyl in pest management programs to control sugarcane borer, *Diatraea saccharalis* (F.), a serious pest of

sugarcane in Louisiana, for 20 years did not induce resistance. In a further investigation, Vines et al. (1984) stated that, although records show that this pest had developed resistance even to the earliest compounds used for its control, resistance did not develop to azinphosmethyl under intense selection pressure.

In contrast, a substantial level of resistance to permethrin has developed among the pink bollworm populations. Resistance appears to be developing more rapidly in populations that historically have been exposed to a high level of intensive insecticidal pressure. Permethrin is a relatively new insecticide that had been used on cotton pests (including pink bollworm) for about 10 years. Recently, however, control failures with pyrethroids have been reported in California (Haynes et al. 1987). Lowry & Tsao (1961) and Noble (1969) reported development of resistance to DDT in pink bollworm populations in Mexico and Texas, respectively. The *kdr* gene has been identified in several species as being responsible for confering cross resistance to pyrethroids (De Vries & Georghiou 1980, Miller et al. 1983). Therefore, pink bollworm populations previously exposed to DDT could be cross resistant to pyrethroids.

Although evidence from these studies is subject to confirmation by more detailed investigations, permethrin resistance found in the Yuma field strain may be related to changes in the target site, rendering it insensitive to pyrethroids. Either the extensive use of DDT in the past or the recent wide scale use of pyrethroids on cotton pests may have accounted for the permethrin resistance detected recently in the field populations of the pink bollworm. Toxicity studies on the pink bollworm population from Yuma indicated cross-resistance to cyfluthrin, a pyrethroid, but not to sulprofos, an organophosphate (T. F. W. & A. A. O., unpublished data). Moreover, studies performed by Bull et al., (1988) on the tobacco budworm, *Heliothis virescens* (F.), revealed that enhanced metabolic detoxication was not a contributing factor during the initial stages of development of resistance but became more important at higher levels of resistance.

Our results indicate that geographically isolated pink bollworm populations showed very low levels of variation in response to azinphosmethyl and variable degrees of resistance to permethrin. The results of laboratory bioassays are difficult to interpret in the absence of information concerning response of the strain before selection was begun (Wood & Bishop, 1981) and the development of resistance could be inferred with more certainty if field control failures were substantiated by laboratory bioassays (Bull 1981). The results of our study could be used as baseline data for future studies on pink bollworm in these localities.

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Table 1.Toxicity of azinphosmethyl to five strains of pink bollworm collected from different locations relative to a standard laboratory susceptible strain[a]

Strain	Slope (±SE)	LD_{50}[b] (95% CL)	LD_{95}	RR[c]
Westmore[d]	7.52 (±0.49)	27.4c (26.4-28.3)	45.3	1.5
Marana	6.19 (±0.52)	26.4c (25.4-27.6)	48.8	1.5
Phoenix	8.09 (±0.52)	24.0b (23.2-24.8)	38.3	1.4
Safford	7.03 (±0.49)	28.0c (27.0-29.0)	48.0	1.6
Yuma	8.58 (±0.54)	22.9b (22.2-23.7)	35.7	1.3
Suscept.	6.23 (±0.53)	17.8a (16.9-18.7)	32.7	1.0

[a] n = 700 in all instances.
[b] μg/g. Values followed by the same letter are not significantly different based on failure of 95% CL to overlap.
[c] RR: Resistance ratio = LD_{50} of strain/LD_{50} of susceptible strain.
[d] Westmoreland, CA.

Table 2. Toxicity of permethrin to five pink bollworm strains collected from different locations relative to a standard laboratory susceptible strain[a]

Strain	Slope (±SE)	LD_{50}[b] (95% CL)	LD_{95}	RR[c]
Westmore[d]	7.53 (±0.50)	22.6e (21.9-23.3)	37.4	18.3
Marana	2.37 (±0.22)	4.5c (4.0-5.1)	22.4	3.7
Phoenix	5.94 (±0.45)	18.5d (17.8-19.2)	35.0	14.9
Safford	3.83 (±0.26)	1.6b (1.5-1.7)	4.3	1.3
Yuma	4.86 (±0.41)	17.1d (16.3-17.9)	37.3	13.8
Suscept.	4.09 (±0.30)	1.2a (1.2-1.3)	3.1	1.0

[a] n = 700 in all instances.
[b] μg/g. Values followed by the same letter are not significantly different based on failure of 95% CL to overlap.
[c] RR: Resistance ratio = LD_{50} of strain/LD_{50} of susceptible strain.
[d] Westmoreland, CA.