# Analysis of Pyrethroid Resistance in *Helicoverpa armigera* in Pakistan

*M. Ahmad, M.I. Arif and Z. Ahmad*
Central Cotton Research Institute, Multan, Pakistan

## ABSTRACT

*Resistance to seven pyrethroids was regularly monitored in field populations of Helicoverpa armigera in Pakistan during 1991 to 1997 using an IRAC leaf-dip method. From 1991 to 1993, resistance was moderate to cypermethrin and cyfluthrin, low to alphacypermethrin, zetacypermethrin and deltamethrin, and very low to lambdacyhalothrin and bifenthrin. In 1994, there was a heavy outbreak of H. armigera on cotton which prompted farmers to apply pesticides frequently, especially pyrethroids. Consequently, resistance to cypermethrin, cyfluthrin, alphacypermethrin and deltamethrin rose to high levels in subsequent years. Resistance to zetacypermethrin and lambdacyhalothrin remained low during 1994 and 1995, but also reached high levels during 1996 and 1997 following their increased usage. Bifenthrin resistance was low up to 1996, rising to moderate levels in 1997. The variable patterns of development of pyrethroid resistance in H. armigera may be due to the selection of different mechanisms of resistance to different degrees with particular pyrethroids. This diversity of mechanism selection provides a good opportunity for insect resistance management within the pyrethroid class of chemicals.*

## Introduction

Owing to the favourable environmental and farming conditions coupled with the aftermath of extensive and indiscriminate use of pesticides, the cotton bollworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae), has assumed the status of a major pest of cotton and other crops in Pakistan during the nineties. The pyrethroids, which were considered the most potent insecticides for its control, progressively lost their efficacy against it. Our studies confirmed significant resistance to the commonly-used insecticides, particularly pyrethroids (Ahmad *et al.*, 1995, 1997, 1998). This development of resistance led to serious control problems which were largely responsible for the severe outbreaks of *H. armigera* that drastically reduced cotton yields in Pakistan from about 13 million bales in 1991 to only 9 million in 1997. The present paper describes the chronological development of pyrethroid resistance in *H. armigera* in Pakistan from 1991 to 1997.

## Materials and methods

### *Insects*

Fifth or sixth instars of *H. armigera* were collected from various locations of Pakistan. Each collection was made from within a 5-acre block of a particular host crop. The larvae were fed in the laboratory on a semi-synthetic diet (modified from Ahmad and McCaffery, 1991), which consisted of chickpea flour (300g), ascorbic acid (4.7g), methyl-4-hydroxybenzoate (3g), sorbic acid (1.5g), streptomycin (1.5g), corn oil (12ml), yeast (48g), agar (17.3g) and distilled water (1300ml) with a vitamin mixture. Adults were fed on a sucrose solution with the addition of vitamins and methyl-4-hydroxybenzoate.

### *Insecticides*

Commercial formulations of cypermethrin (Arrivo, 100 g/l EC, FMC), alphacypermethrin (Bestox, 50 g/l EC, FMC), zetacypermethrin (Fury, 181 g/l EC, FMC), deltamethrin (Decis, 25 g/l EC, AgrEvo), cyfluthrin (Baythroid, 50 g/l EC, Bayer), bifenthrin (Talstar, 100 g/l EC, FMC) and lambdacyhalothrin (Karate, 25 g/l EC, Zeneca) were obtained from the respective manufacturers.

### *Bioassays*

Newly moulted second instars from the $F_1$ laboratory generations were exposed to different insecticides using the leaf-dip method as recommended by the Insecticide Resistance Action Committee (IRAC) (Anonymous, 1990). Serial dilutions of the test compounds were prepared as ppm of the active ingredient using distilled water. Cotton leaf discs (5 cm diameter) were cut and dipped into the test solutions for 10 seconds with gentle agitation, then allowed to dry on paper towel. Five larvae were released on to each leaf disc placed in 5-cm-diameter petri dishes. Eight batches of five larvae were used for each concentration and 7 to 11 serial concentrations were used for each test insecticide (i.e., 280-440 larve per insecticide). The same number of leaf discs was used for each concentration and was dipped into distilled water to serve as untreated checks. Moistened filter papers were placed beneath the leaf discs to avoid desiccation of leaves in the petri dishes. After releasing the larvae, test containers were covered with a piece of

*Proceedings of the World Cotton Research Conference-2. Athens, Greece, September 6-12, 1998. pp.697-700.*

black cloth to minimize cannibalism. Before and after the treatment, larvae were kept in the laboratory at a constant temperature of 25+2$^{o}$C with a photoperiod of 14 h.

***Data analysis***

Larval mortalities were assessed after 48 h. Larvae were considered dead if they failed to respond to stimulation by touch. Results were expressed as percentage mortalities, corrected for untreated (check) mortalities using Abbott's (1925) formula. Data were analyzed on the computer by probit analysis according to Finney (1971). Resistance factors (RFs), were determined at $LC_{50}$s relative to the corresponding lowest $LC_{50}$s from available data on Pakistan strains. These were from the Vehari district of the Punjab for cypermethrin, alphacypermethrin, deltamethrin and bifenthrin and from Islamabad for zetacypermethrin, cyfluthrin and lambdacyhalothrin.

## Results and discussion

The averages of RFs for the populations tested in a single year (usually 2 to 3 populations) for each chemical are presented in Figure 1. As the collection was from a variety of crops and different areas over the years, the figures presented here should reflect the general trend in resistance levels.

***Cypermethrin***

Resistance to cypermethrin in *H. armigera* was moderate from 1991 to 1993 (34- to 46-fold) (Figure 1a). It then increased to very high levels during 1994 to 1996 (84- to 157-fold). This was the direct result of intensive applications of pyrethroids especially cypermethrin to combat a heavy outbreak of *H. armigera* on cotton in 1994. There was again a serious outbreak of *H. armigera* on cotton and other crops in 1997. But this time, learning from the control failures of last three years, farmers did not use cypermethrin to control *H. armigera*. Consequently, though still high, cypermethrin resistance dropped to half (68-fold) as compared with 1995 (157-fold) and 1996 (153-fold) levels.

***Alphacypermethrin***

Resistance was comparatively lower to alphacypermethrin than to cypermethrin. It was low (10- to 20-fold) during 1991 to 1993 (Figure 1b). It jumped to high levels, 46-fold in 1994, 108-fold in 1995 and 137-fold in 1996 following the 1994 outbreak of *H. armigera* on cotton. Like cypermethrin, the RF of alphacypermethrin in 1997 also dropped by half (i.e. 57) as compared with RFs of 1995 and 1996.

***Zetacypermethrin***

Resistance to zetacypermethrin remained low up to 1995 (2- to 23-fold) (Figure 1c). Owing to its being still effective, zetacypermethrin use increased progressively which ultimately pushed its RFs to high levels i.e. 73-fold and 123-fold in 1996 and 1997 respectively. In 1997, the average RF of zetacypermethrin was twice that of cypermethrin and alphacypermethrin.

***Cyfluthrin***

Except for 1991, cyfluthrin produced high to very high RFs (42- to 163-fold) during 1992 to 1997 (Figure 1d). Again the *Helicoverpa* outbreak of 1994 enhanced cyfluthrin resistance to very high levels in subsequent years. Although cyfluthrin has not been used much in Pakistan, yet its RFs (except for 1991 and 1996) were even higher than cypermethrin. It may be a typical case of cross resistance resulting from the use of other pyrethroids like cypermethrin.

***Deltamethrin***

Resistance to deltamethrin remained low during 1991 to 1994 (9- to 23-fold) (Figure 1e). Again after the *Helicoverpa* outbreak of 1994, it increased to high levels during 1995 to 1997 (55- to 69-fold). Deltamethrin use has been low. The increase in its resistance was probably due to the progressive selection of resistant insect genotypes either through its own use or that of other pyrethroids selecting for the same mechanisms.

***Lambdacyhalothrin***

Unlike the above-mentioned pyrethroids, resistance to lambdacyhalothrin was very low during 1991 to 1993 (4- to 7-fold) and low during 1994 and 1995 (20 and 23 fold respectively) (Figure 1f). It then suddenly rose to high levels during 1996 and 1997 (55- to 68-fold). Since this pyrethroid remained effective in the field till 1995, its use had been increasing, which consequently pushed its resistance to high levels.

***Bifenthrin***

Like lambdacyhalothrin, bifenthrin resistance was very low during 1991 to 1993 (2- to 9-fold) (Figure 1g). It still remained low during 1994 to 1996 (13- to 16-fold) whereas it had been increasing to high levels for the other pyrethroids in the same period. In 1997, bifenthrin resistance increased to 27-fold which was still much lower than the other pyrethroids. If the use of bifenthrin can be limited to only one spray per season at this stage, bifenthrin resistance may decrease and this useful pyrethroid can be preserved for future use against *H. armigera* and other pests.

## Resistance management

The situation regarding pyrethroid resistance in *H. armigera* in Pakistan is very alarming. There has been a progressive erosion of susceptibility to all the pyrethroids. Similarly, resistance has also been increasing to endosulfan, and RFs to chlorpyrifos and profenofos crossed 20 in 1996 and 1997 from their previous low levels (Ahmad *et al.*, 1998). This chronological increase in insecticide resistance in *H.*

*armigera* suggests that if a resistance mechanism is present, even in low frequencies, it can quickly be selected to high frequencies when subjected to continuous high selection pressure. The upward trend of resistance development to useful insecticides like pyrethroids can still be slowed if a good resistance management strategy, based on the rotation of effective insecticides, is implemented.

The new chemistries, such as spinosad and indoxacarb can come to our rescue for the control of resistant *H. armigera* and other pests. With their new modes of action, these novel chemistries have not shown cross resistance to the conventional pesticides (Sparks *et al.*, 1995; Harder *et al.*, 1997). Learning from the past experience, the new chemistries also require to be regulated and rotated to avoid the potential development of resistance to these compounds. There is also a greater need than ever before to exploit non-chemical control methods for *Helicoverpa* and other pests if our valuable crops are to be grown profitably.

## References

Abbott, S.W. (1925). A method of computing the effectiveness of an insecticide. J. Econ. Entomol. 18:265-267.

Ahmad, M., M.I. Arif and Z. Ahmad. (1995): Monitoring insecticide resistance of *Helicoverpa armigera* (Lepidoptera: Noctuidae) in Pakistan. J. Econ. Entomol. 88:771-776.

Ahmad, M., M.I. Arif and M.R. Attique. (1997): Pyrethroid resistance of *Helicoverpa armigera* (Lepidoptera: Noctuidae) in Pakistan. Bull. Ent. Res. 87:343-347.

Ahmad, M., M.I. Arif, Z. Ahmad and M.R. Attique. (1998): *Helicoverpa armigera* resistance to insecticides in Pakistan. In: Proc. Beltwide Cotton Conf. J. Dugger and D.A. Richter (Ed). Natl. Cotton Council, Memphis, TN. Pp. 1138-1140.

Ahmad, M. and A.R. McCaffery. (1991): Elucidation of detoxication mechanisms involved in resistance to insecticides in the third instar larvae of a field selected strain of *Helicoverpa armigera* with the use of synergists. Pestic. Biochem. Physiol. 41:41-52.

Anonymous. (1990). Proposed insecticide/acaricide susceptibility tests, IRAC method No. 7. Bull. Eur. Plant Protect. Org. 20:399-400.

Finney, D.J. (1971). Probit Analysis. 3rd Ed. Cambridge University Press, Cambridge.

Harder, H.H., S.L. Riley, S.F. McCann and D.W. Sherrod. (1997): DPX-MP062: A novel broad-spectrum, environmentally soft, insect control compound. In: Proc. Beltwide Cotton Conf. J. Dugger and D.A. Richter (Ed). Natl. Cotton Council, Memphis, TN. Pp. 48-50.

Sparks, T.C., G.D. Thompson, L.L. Larson, H.A. Kirst, O.K. Jantz, T.V. Worden, M.B. Hertlein and J.D. Busacca. (1995): Biological characteristics of the spinosyns: A new class of naturally derived insect control agents. In: Proc. Beltwide Cotton Conf. D.A. Richter and J. Armour (Ed). Natl. Cotton Council, Memphis, TN. Pp. 903-907.

**Figure 1. Resistance factors of *Helicoverpa armigera* to a) cypermethrin, b) alphacypermethrin, c) zetacypermethrin, d) cyfluthrin, e) deltamethrin f) lambdacyhalothrin and g) bifenthrin.**