PYRETHROID RESISTANCE IN THE TOBACCO BUDWORM[1]: FIVE YEARS LATER

Frederick W. Plapp, Jr.

Entomology Department, Texas A&M University,
College Station, Texas 77843

ABSTRACT

The occurrence and nature of pyrethroid resistance in the tobacco budworm, *Heliothis virescens* (F.), are described. The development of resistance monitoring assays and resistance management strategies are presented as is the basis for their successful implementation.

INTRODUCTION AND BACKGROUND

It has been five years since control difficulties with pyrethroids were first observed in the tobacco budworm (TBW), *Heliothis virescens* (F.), in Texas. In the intervening years pyrethroid resistance in the TBW has been documented throughout the southwest and midsouth of the U. S. In response to the problem, research and extension entomologists and pyrethroid manufacturers have successfully worked with cotton producers and private consultants to devise ways to manage resistance. This success may be contrasted with our less successful record in dealing with pest resistance problems in cotton in the past. In this brief review, I shall try to summarize some of the reasons for this success and some of the things we have learned that may prove useful in dealing with resistance management problems in the future.

First, it is important to note that modification of agronomic practices involved in cotton production is at least as important as are modifications in insecticide use practices. It is the extension of cotton production until late in the season and attempts to maximize yield that require the heaviest use of insecticides and leads to resistance problems. Accordingly, crop production practices that reduce the need for late season insecticides, eg., earliness in the crop and reduced inputs of water and fertilizer, are critically important to the success of resistance management programs.

Another major impetus for the development of a successful resistance management program has been the lack of viable alternatives. At this time there are no types of insecticides that can replace pyrethroids. Further, the development of transgenic insect resistant cottons has not yet reached fruition and can not serve as an alternative pest management strategy.

In the past, resistance in the TBW and other pests has occurred with DDT, cyclodienes and the cholinesterase inhibiting organophosphates and carbamates. Pyrethroids are not new in this sense. They have the same mode of action as DDT and presumably, they share the same mechanism of target site resistance. Indeed, they work only because field populations of TBW had lost their resistance to DDT in the years between the 1970 ban of DDT and the 1978 introduction of pyrethroids. Initial reports of pyrethroid resistance (see Sparks, 1981 for a review) may very well have represented a carry-over of resistance from DDT exposure a decade earlier.

[1]Lepidoptera: Noctuidae

The critically important factor we need to understand is that DDT resistance was lost in the years the insecticide was not used. This implies that resistance to DDT must have had a deleterious effect on the TBW population and that in the absence of selection with DDT, resistance to it was substantially eliminated from the population. In other words, there are costs to the TBW associated with resistance to DDT and pyrethroids. Identifying the costs and understanding how best to utilize them have been the basis for the successful resistance management programs that have been instituted.

The usefulness of the deleterious effects of resistance can be seen by comparing the development of resistance in the U. S. and in Australia. In Australia, pyrethroid introduction followed immediately upon the cessation of DDT use and resistance arose at once (Gunning et al. 1984). This situation is very different from that in the U. S. where an eight year hiatus in the use of insecticides with this mode of action allowed resistance to disappear from the field.

EXPERIMENTAL

Occurrence of Resistance. The first reports of pyrethroid resistance in TBW populations came from west Texas in September, 1985 (Plapp and Campanhola 1986). Larvae from the Garden City and Uvalde areas were collected and sent to the toxicology laboratory, Texas A&M, for confirmation of the problem. In the laboratory, we had considerable difficulty in establishing the strains. We did not obtain sufficient numbers of F_1 larvae to allow for testing of third instars, the life stage usually employed for insecticide toxicity measurements with the TBW. Finally, in December, 1985 we obtained a number of neonate larvae from the field populations. Preliminary studies with a laboratory strain indicated it was possible to measure response to pyrethroids in neonates exposed to insecticide residues in glass vials. Therefore, we used this method to test neonates from the field. In these early tests we established (a) the presence of resistance to pyrethroids in both the Garden City and Uvalde populations and (b) the occurrence of synergism by chlordimeform to such an extent as to essentially restore normal levels of sensitivity in the field population.

Several things were learned from these preliminary tests. First of all, it took us far too long to establish the presence of resistance in the test populations. Producers and entomologists need information on the occurrence of resistance in a timely manner, eg. within a day or two. The three months it took us to obtain results did not meet this need. Secondly, the presence of resistance in first instar larvae immediately suggested to us that resistance was likely to be of the kdr (for knockdown resistance) or target insensitivity type. Target site resistance to insecticides is expressed in all life stages while metabolic resistance is well expressed only in life stages feeding actively on plant tissues containing high levels of toxins. This is in contrast to earlier results with organophosphates where metabolic resistance was clearly present (Whitten and Bull 1970). Finally, the probable occurrence of target site resistance in neonates suggested that we should be able to measure resistance in adults as well as larvae. It was this realization that led us in early 1986 to attempt the development of an adult assay for the determination of pyrethroid resistance in field populations of the TBW.

Development of Adult Resistance Monitoring Assay. The first step in developing an adult resistance test was to develop a dose-response line for males of a susceptible tobacco budworm strain exposed to a pyrethroid insecticide. Rather than use a topical treatment we elected to develop a glass vial exposure method in which adults were exposed to residues of a test insecticide in 20 ml glass vials. For the insecticide we chose the widely used pyrethroid cypermethrin. Results of the assays (Plapp et al. 1987) showed that susceptible insects had an LC50 of 1-2.5 ug cypermethrin per vial and that cypermethrin residues lasted at least 3 months in vials. This allowed us to prepare vials in the laboratory and send them to entomologists in the field who were faced with problems of determining the presence of pyrethroid resistance in their areas.

Based on the laboratory tests, we initiated tests with TBW males collected in pheromone traps in the Brazos Valley by USDA researchers who were conducting population studies of the TBW. We started tests with doses near the LC50 in ug/vial for the laboratory strain and quickly established the presence of resistance in field-collected insects. As the season progressed and the usefulness of the assay technique was established, we provided treated vials to extension service entomologists throughout the state. Late in the season, treated vials were supplied to entomologists in Louisiana and Arkansas where tests also established the presence of resistance. Similar tests with similar resulted were conducted by entomologists in Mississippi (Luttrell et al. 1987).

Characteristics of the Adult Assay. In initial tests we used an array of doses of insecticide based on the d-m response of susceptible insects. Data from these tests quickly indicated that field populations were mixed, composed partly of both susceptible and resistant insects. Based on this, we decided that the main goal of the measurements was to determine the percent of resistant individuals in the field rather than the change in LC50 for the population as a whole. Tests in 1986 utilized four doses of cypermethrin with the lowest being about the LC99 for susceptible males. This was reduced to three doses in 1987 and to two in 1988. The doses chosen both killed all susceptible individuals. One dose, 5 ug/vial, allowed partial survival of heterozygous resistant insects. The second dose, 10 ug per vial, allowed only homozygous resistant insects to survive.

Characteristics of Resistant Populations in the Field. The initial measurements of field resistance made in the Brazos Valley in April, 1986 indicated a high level of resistance in the field (Plapp 1987). To our surprise, the proportion of resistant individuals declined dramatically in May and June and increased in July and early August only to be followed by a second decline as the season ended. The final resistance proportion in September, 1986 was very similar to that seen in April. In other words, the situation was no worse at the end of the season then at the beginning. Tests done in 1987 and 1988 in numerous sites in Texas, Louisiana and Arkansas confirmed this seasonal variation in the occurrence of resistance as the usual pattern. The loss of resistance early in the season served as the basis for establishing a resistance management strategy based on avoidance of early season use of pyrethroids (Anon. 1986, Frisbie & Plapp 1987).

Extent and Nature of Resistance in Neonates, Third Instars and Adults. The identification of pyrethroid resistance in adult TBW was of interest, but it was not clear if data obtained with adults was transferable to the pestiferous larval stage. In a series of tests with pyrethroids, Campanhola and Plapp (1989b) established that resistance levels to cypermethrin were similar in adult males and neonates. Only in third instars were resistance levels higher. Since neonates are the life stage at which control is usually aimed, the similarity in resistance between adults and neonates, fortified the hypothesis that adult assays were a useful predictor of resistance in the field.

Costs of Resistance to the TBW. The resistance management program would not work if there were no costs to the insect associated with resistance to the insecticides. The loss of DDT resistance in the 1970s and 1980s and the loss of pyrethroid resistance in the field observed in 1987 and 1988 at times when pyrethroids were not used strongly suggested that such costs must exist. In studies conducted at College Station, the occurrence of such costs was confirmed and their nature identified. As reported by Campanhola and Plapp (1989a), decreases in fecundity are a factor in the decreased reproductive success of the highly resistant ICI strain of TBW. McCutchen et al. (1989a) identified additional costs associated with resistance. In the summer of 1988, they showed that susceptible TBW females attracted males more readily than resistant females. In experiments with males, data were obtained indicating that resistant males were less attracted to pheromone traps than susceptible males. These decreases in mating success had not previously been shown for either DDT or pyrethroid resistance, but are probably very important in the replacement, early in the season when TBW numbers are low of resistant insects by susceptibles.

Future Management Efforts: Development of Neonate Larval Assay. The use of adult assays as described above has proven valuable in determining the extent of pyrethroid resistance in the TBW. However, data are needed with neonates, the actual pest stage. In a study by McCutchen et al. (1989b) it was demonstrated that use of a discriminating dose was an effective way of determining resistance in larval populations of *Heliothis* collected from the field. The system was field-tested in 1989 (McCutchen et al. 1990), but has not yet been widely adopted. The potential importance of larval monitoring to resistance management can not be overestimated. With this technique producers could stop pyrethroid use as soon as resistance occurs, thus greatly reducing selection for resistance and decreasing the frequency of resistance in field populations.

Pyrethroid Resistance in the Bollworm. A potentially serious problem for cotton producers concerns the bollworm, *Helicoverpa zea* (Boddie). If this species were to become resistant to pyrethroids, control of pest damage on cotton would be more difficult if not impossible. Monitoring data with the bollworm have been obtained in several states, but at the present time, there is no strong evidence for resistance in this species, or at least no control failures under field conditions.

SUMMARY

In this brief report I have summarized evidence for the development of successful management programs for pyrethroid resistance in the TBW on cotton. So far, the programs seem to be working. Whether or not they will stand the test of time remains to be seen Whether they do or not, much has been learned about resistance management. The need for good monitoring techniques and the use of strategies that restrict insecticide use to part of a season seem the most pertinent lessons learned so far.

ACKNOWLEDGMENT

I wish to thank C. Campanhola, R. D. Bagwell, and B. F. McCutchen, graduate students at Texas A&M, who provided many of the ideas and did most of the work described in this report. The assistance and cooperation of my peers in other states of the area is much appreciated.

LITERATURE CITED

Anonymous. 1986. Cotton entomologists seek to delay pyrethroid resistance in insects. MAFES Res. Highlights 49 (12): 8.

Campanhola, C. and F. W. Plapp, Jr. 1989a. Managing pyrethroid resistance in the tobacco budworm: bioassays, resistance mechanisms and biological constraints, pp. 352-359. *In*: Proc. Beltwide Cotton Prod. Res. Conf., Nat. Cotton Council, Memphis, Tenn.

Campanhola, C. and F. W. Plapp, Jr. 1989b. Toxicity and synergism of insecticides against susceptible and pyrethroid resistant neonate larvae and adults of the tobacco budworm (Lepidoptera:Noctuidae). J. Econ. Entomol. 82: 1527-1533.

Frisbie, R. E. and F. W. Plapp, Jr. 1987. Managing insecticide resistant tobacco budworm in Texas cotton. TAES: 500-5-87, 2pp.

Gunning, R. V., L. R. Easton, L. R. Greenup, and V. E. Edge. 1984. Pyrethroid resistance in Heliothis armigera (Lepidoptera: Noctuidae) in Australia. J. Econ. Entomol. 77: 1283-1287.

Luttrell, R. G., R. T. Roush, A. Ali, J. S. Mink, M. R. Reid, and G. L. Snodgrass. 1987. Pyrethroid resistance in field populations of Heliothis virescens (Lepidoptera: Noctuidae) in Mississippi in 1986. J. Econ. Entomol. 76: 983-986.

McCutchen, B. F., F. W. Plapp, Jr. and H. J. Williams. 1989a. Reproductive deficiencies associated with pyrethroid resistance in the tobacco budworm, pp. 364-365. *In*: Proc. Beltwide Cotton Prod. and Res. Conf., Nat. Cotton Council, Memphis, Tenn.

McCutchen, B. F., F. W. Plapp, Jr., S. J. Nemec and C. Campanhola. 1989b. Development of diagnostic larval pyrethroid resistance monitoring techniques for Heliothis spp. (Lepidoptera: Noctuidae) in cotton. J. Econ. Entomol. 82: 1502-1507.

McCutchen, B. F., C. G. Sansone, F. W. Plapp, Jr. and D. A. Kostroun. 1990. A field technique for determining pyrethroid resistance and levels of parasitism of Heliothis spp. eggs and neonate larvae in cotton, pp. 360-364. *In*: Proc. Beltwide Cotton Prod. and Res. Conf., Nat. Cotton Council, Memphis, Tenn.

Plapp, F. W., Jr. 1987. Managing resistance to synthetic pyrethroids in the tobacco budworm, pp. 224-226. *In*: Proc. Beltwide Cotton Prod. and Res. Conf., Nat. Cotton Council, Memphis, Tenn.

Plapp, F. W. Jr. and C. Campanhola. 1986. Synergism of pyrethroids by chlordimeform against susceptible and resistant Heliothis, pp. 167-169. *In*:Proc. Beltwide Cotton Prod. and Res. Conf., Nat. Cotton Council, Memphis, Tenn.

Plapp, F. W., Jr., G. M. McWhorter and W. H. Vance. 1987. Monitoring for resistance to synthetic pyrethroid insecticides in the tobacco budworm, pp. 324-326. *In*: Proc. Beltwide Cotton Prod. and Res. Conf., Nat. Cotton Council, Memphis, Tenn.

Sparks, T. C. 1981. Development of insecticide resistance in Heliothis zea and Heliothis virescens in North America. Bull. Entomol. Soc. Amer. 27: 186-192.

Whitten, C. J. and D. L. Bull. 1970. Resistance to organophosphorous insecticides in tobacco budworm. J. Econ. Entomol. 63: 1492-1495.