RESISTANCE OF COTTON WHITEFLY, *BEMISIA TABACI* TO CYPERMETHRIN, ALPHACYPERMETHRIN AND ZETACYPERMETHRIN IN PAKISTAN

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Abstract

Resistance to cypermethrins was recorded in *Bemisia tabaci* populations of Pakistan using a leaf-dip method. A very high resistance to cypermethrin was found in most of the populations during 1993 to 1995. Then, due to reduced use of cypermethrin targeted against whitefly, and owing to the introduction of new chemistries with novel modes of action and having no cross resistance to conventional insecticide groups, cypermethrin resistance generally dropped to very low levels during 1996 to 1999. Resistance to zetacypermethrin was mostly low and to alphacypermethrin was still very low. Some of the whitefly populations, which had a low resistance to alpha- and zeta-cypermethrin, showed a moderate resistance to cypermethrin. This implies that different mechanisms of resistance differ in conferring resistance to different isomers of cypermethrin in whitefly. The use of novel chemistries in rotation along with other IPM tactics is recommended to manage whitefly and its resistance development in future.

Introduction

The cotton whitefly, *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae), is endemic in the Indo-Pakistan subcontinent and has been a key pest of cotton and other crops in this region. It however became a very serious pest during nineties, because its populations increased phenomenally due to the development of resistance to conventional insecticides including pyrethroids (Ahmad, 1996; Cahill et al., 1994, 1995) and it acted as a vector of a devastating leaf curl virus of cotton.

Pyrethroids were introduced in Pakistan in the early eighties, basically to control 'difficult to control' caterpillars on cotton and other crops. They were the cheapest and most effective not only against caterpillars but also against majority of sucking insect pests. To get an assurance of a clean crop, farmers tended to use pyrethroids indiscriminately with a minimum expenditure. Cypermethrins were the earliest, and still are the most commonly used pyrethroids. Although they are not targeted against whitefly, yet they are used quite frequently on cotton for other pests and whiteflies are exposed inadvertently. During nineties, following the use of cypermethrins and other pyrethroids, instead of being controlled or suppressed, whitefly actually flared up.

The objective of the present study, conducted during 1992 to 1999, was to monitor the development of whitefly resistance to cypermethrins in Pakistan.

Materials and Methods

Whitefly Collections

Adult whiteflies were collected from different crops in the southern Punjab within a radius of 50km from Multan. Whiteflies were sampled randomly across a 2-ha block of a particular crop. Adults were collected with a battery-operated aspirator in the early hours of morning. Samples were pooled in wide mouth jars (11x11x19cm) and transferred to the laboratory in a cool-box to prevent damage. The whiteflies were used for bioassays within a couple of hours after receiving in the laboratory. Before treatment the jars were inverted (mouth down on a table) so that healthy individuals would climb to the top due to positive phototaxis. Disabled and dead individuals at the bottom were discarded.

Insecticides

Formulated insecticides used in bioassays were cypermethrin (Arrivo, 100g/l EC [emulsifiable concentrate]), alphacypermethrin (Bestox, 50g/l EC) and zetacypermethrin (Fury, 181g/l EC). They were obtained from FMC International, Philadelphia, PA, U.S.A.

Toxicity Tests

The testing technique corresponded to that described by Dittrich et al. (1985). It is based on exposure of whitefly adults of both sexes to treated leaf disks (4cm diameter) that are laid flat on about 1mm thick layer of agar in plastic petri dishes. Disks of cotton leaves were dipped into an ascending sequence of test concentrations of the respective toxicants for 10s. Whiteflies were briefly immobilized with carbon dioxide, and transferred about 25-30 adults per dish. Deep petri dishes of the same size were used as lids with mesh-covered holes on either side for ventilation. Treatment with each insecticide concentration was replicated four times along with a similar untreated check. Serial dilutions of the test compounds at 0.4-fold intervals were used. After the treatment the laboratory temperature was maintained at 25±2ºC with a photoperiod of 14:10 (L: D) h.

Data Analysis

Mortality was checked after 24h. Results were expressed as percentage mortalities, correcting for untreated (check) mortalities using Abbott's (1925) formula. Data were analyzed on the computer by probit analysis according to Finney (1971). To determine resistance factors (RFs), lethal concentration (LC) values of different insecticides for each

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population were divided by the corresponding LC values for the T.S.Pur population.

Results and Discussion

Baselines

The LC values for the T.S.Pur population were used as baselines, for they were the lowest. The baseline LC_{50} of cypermethrin for the T.S.Pur population was 5.2ppm (Table 1) whereas the baseline LC_{50} of cypermethrin recorded by Dittrich et al. (1985) on a sensitive laboratory strain of *B. tabaci* was 2.7ppm. The baseline LC_{50} of alphacypermethrin was similar to cypermethrin whereas the LC_{50} of zetacypermethrin was about a half of that of cypermethrin for the T.S.Pur population. Slopes of regression lines for T.S.Pur population and other strains were low, which is typical of field populations.

Cypermethrin

Cypermethrin consists of 4 *cis* and 4 *trans* isomers. Resistance factors for cypermethrin in 1992 were low (5 and 12 at LC_{50}). In 1993 to 1995, except for Jehanian-1 and Multan-2 populations, the cypermethrin-resistance rose to very high levels (30-70 fold at LC_{50} and 65-814 fold at LC_{90}). In subsequent years (1996 to 1999), the resistance dropped to moderate to very low levels (6-37 fold at LC_{50} and 6-54 fold at LC_{90}). During 1998 and 1999, cypermethrin-resistance did not exceed a RF of 10 both at LC_{50}s and LC_{90}s in the five populations tested. The significant drop of cypermethrin resistance over the last 4 years may be attributable to not directly targeting whitefly to cypermethrins as advocated by the agriculture department, and to the change in control practices, particularly using new chemistries. These new chemistries are equally effective against whitefly populations resistant to conventional chemistries.

Cypermethrin has been the most commonly used pyrethroid in Pakistan and therefore there is no wonder that it has produced high levels of resistance in the cotton whitefly. Cypermethrin also exhibited high resistance in *Helicoverpa armigera* populations of Pakistan (Ahmad et al. 1995, 1997, 1998).

Alphacypermethrin

Alphacypermethrin consists of 4 *cis* isomers of cypermethrin. All the five whitefly populations tested during 1995 to 1999 showed very low resistance ($\leq$10-fold) to alphacypermethrin both at LC_{50}s and LC_{90}s. Shershah-3 and Bosan-2 populations had a very low resistance to alphacypermethrin but a moderate resistance to cypermethrin; whereas Jehanian-2, Khanewal-2 and Shujabad-3 populations had a similar resistance to alphacypermetrhin as well as cypermethrin.

Zetacypermethrin

Zetacypermethrin contains the same 8 isomers of cypermethrin but the 4 insecticidally active ones (2 *cis* and 2 *trans*) are present at a concentration of about 22% each. The resistance to this pyrethroid was moderate (16-35 fold both at LC_{50} and LC_{90}) in Shujabad-1 and Multan-2 populations tested in 1993 and 1994. There was no resistance in two samples tested in 1995 and 1996. Further, resistance remained at low level (11-20 fold) during 1997 and 1998. During 1999, resistance dropped to very low level ($\leq$10) in the two whitefly populations tested.

The populations viz. Shujabad-1 and Lar-1 had low resistance (14-16 fold at LC_{50}) to zetacypermethrin but a moderate resistance to cypermethrin (30-37 fold at LC_{50}). Shershah-3 and Bosan-2 populations exhibited a very low resistance to zetacypermethrin and alphacypermethrin but a moderate (33- and 20-fold at LC_{50} and 65- and 34-fold at LC_{90}) resistance to cypermethrin. Contrarily, Multan-2, Jehanian-2, Khanewal-2 and Lar-2 populations had much higher resistance to zetacypermethrin than to cypermethrin. Resistance to zetacypermethrin in Khokhran-2 and Shujabad-3 populations was very low and similar to cypermethrin and alphacypermethrin.

Table 1 indicates that the development of resistance to zetacypermethrin and alphacypermethrin in *B. tabaci* did not follow the same trend as that of cypermethrin. Resistance to cypermethrin was generally higher in the same strains of whitefly, implying that different mechanisms of resistance conferred variable levels of resistance to different isomers. Similarly, highly resistant populations to cypermethrin had low resistance to zetacypermethrin in *H. armigera* (Ahmad et al., 1997). Conversely, highly resistant populations to zetacypermethrin had a low resistance to cypermethrin in cotton jassid, *Amrasca devastans* (Ahmad et al., 1999a). This apparent phenomenon of negative cross-resistance to different isomers of cypermethrin in different insects is very encouraging for the management of insecticide resistance.

Mechanisms of Resistance

Synergism studies on Pakistani whiteflies indicate that both oxidative and hydrolytic detoxifications are involved in imparting partial resistance to pyrethroids (Ahmad et al., 1999b). Earlier studies also show that metabolic detoxification of pyrethroids in resistant populations of whitefly is both due to monooxygenases (Prabhaker et al., 1988; Dittrich et al., 1990) and esterases (Disttrich et al., 1985, 1990; Ishaaya et al., 1987; Horowitz et al., 1988; Prabhaker et al., 1988). However, very high levels of resistance to cypermethrin in some Pakistani populations may involve target-site insensitivity and reduced cuticular penetration, which needs to be studied.

Resistance Management

Resistance to cypermethrins in the Pakistani populations of whitefly represents a typical case of development of resistance in a non-target organism, which is the result of indiscriminate use of pesticides and their mixtures. To avoid such a situation, selective insecticides applied on a need basis, coupled with good IPM practices that emphasize on non-chemical control measures, can play a vital role. Conservation of beneficials is extremely important for an insect like whitefly whose nymphal stages are immobile. Luckily, new chemistries, having novel modes of action, have been discovered and are available in the market at affordable prices. The new chemical groups such as thiourea, neonicotinoids, and IGRs are very effective against whitefly and yet safer to most of the natural enemies. If used judiciously in rotation, these novel compounds can go a long way in combating whitefly and development of insecticide resistance in this pest.

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Table 1. Toxicity of three pyrethroids to field populations of adult *Bemisia tabaci* using leaf-dip method

Insecticide	Location	Host plant	Date collected	No. tested	Slope ± S.E	LC_{50}, ppm (95% FL)	RF at LC_{50}	LC_{90}, ppm (95% FL)	RF at LC_{90}
Cypermethrin	T.S.Pur	Cotton	Aug. 92	1309	1.66 ± 0.08	5.16 (4.58-5.81)	1.0	30.4 (25.2-36.6)	1.0
	Multan-1	Cotton	Oct. 92	1602	0.85 ± 0.04	63.5 (52.9-76.1)	12	2078 (1386-3115)	68
	Bosan-1	Squash	Dec. 92	638	1.94 ± 0.12	27.1 (23.3-31.5)	5.3	124 (97.4-159)	4.1
	Shershah-1	Brinjal	May 93	2142	1.29 ± 0.06	1129 (898-1418)	219	11203 (7848-15991)	369
	Jehanian-1	Cotton	Aug. 93	1372	1.12 ± 0.05	47.7 (39.8-57.1)	9.2	668 (512-870)	22
	Shujabad-1	Cotton	Sep. 93	1712	0.86 ± 0.03	155 (128-188)	30	12489 (8284-18828)	411
	Khanewal-1	Brinjal	Mar. 94	858	1.31 ± 0.07	1910 (1589-2297)	370	18023 (13375-24286)	593
	Shershah-2	Brinjal	June 94	1382	0.92 ± 0.06	1018 (669-1548)	197	24738 (12077-50674)	814
	Multan-2	Cotton	Oct. 94	1513	1.19 ± 0.05	19.6 (16.8-22.8)	3.8	232 (178-302)	7.6
	Multan-3	Brinjal	July 95	882	1.17 ± 0.07	403 (331-491)	78	5031 (3630-6972)	165
	Shershah-3	Cotton	Sep. 95	957	1.20 ± 0.07	168 (139-203)	33	1982 (1443-2721)	65
	Khokhran-1	Brinjal	Nov. 95	858	1.28 ± 0.07	1823 (1512-2199)	353	18131 (13379-24570)	596
	Shujabad-2	Squash	Jan. 96	791	1.32 ± 0.08	36.7 (30.3-44.4)	7.1	340 (249-464)	11
	Bosan-2	Cotton	Aug. 96	1132	1.28 ± 0.06	104 (89.0-123)	20	1046 (798-1370)	34
	Lar-1	Brinjal	June 97	885	1.38 ± 0.12	191 (132-278)	37	1630 (856-3106)	54
	Jehanian-2	Cotton	Sep. 97	969	1.63 ± 0.09	32.3 (28.1-37.2)	6.3	197 (156-249)	6.5
	Khanewal-2	Cotton	July 98	908	1.64 ± 0.17	52.0 (31.9-84.8)	10	315 (138-717)	10
	Lar-2	Cotton	Sep. 98	948	1.50 ± 0.08	22.3 (19.3-25.8)	4.3	159 (123-205)	5.2
	Bosan-3	Brinjal	Mar. 99	1289	1.36 ± 0.12	34.8 (22.1-54.8)	6.7	303 (137-667)	10
	Khokhran-2	Cotton	Sep. 99	709	1.29 ± 0.08	23.3 (19.2-28.3)	4.5	229 (162-324)	7.5
	Shujabad-3	Brinjal	Oct. 99	527	1.55 ± 0.11	14.4 (11.9-17.4)	2.8	96.4 (69.1-134)	3.2
Alphacypermethrin	T.S.Pur	Cotton	Aug. 92	690	1.84 ± 0.19	4.85 (3.27-7.20)	1.0	24.1 (13.0-44.6)	1.0
	Shershah-3	Cotton	Sep. 95	679	1.45 ± 0.10	14.4 (12.1-17.2)	3.0	110 (80.7-150)	4.6
	Bosan-2	Cotton	Aug. 96	1144	1.33 ± 0.11	11.6 (7.52-17.9)	2.4	107 (52.5-217)	4.4
	Jehanian-2	Cotton	Sep. 97	893	1.66 ± 0.09	28.4 (24.7-32.7)	5.9	168 (134-212)	7.0
	Khanewal-2	Cotton	July 98	1153	1.45 ± 0.07	31.3 (27.2-35.9)	6.5	241 (188-309)	10
	Shujabad-3	Brinjal	Oct. 99	411	1.66 ± 0.13	13.4 (10.9-16.5)	2.8	78.9 (55.4-113)	3.3
Zetacypermethrin	T.S.Pur	Cotton	Aug. 92	728	1.48 ± 0.09	3.01 (2.52-3.59)	1.0	22.1 (16.5-29.5)	1.0
	Shujabad-1	Cotton	Sep. 93	1296	1.20 ± 0.06	49.4 (42.0-58.1)	16	578 (440-759)	26
	Multan-2	Cotton	Oct. 94	893	1.34 ± 0.07	85.7 (71.9-102)	28	780 (577-1055)	35
	Shershah-3	Cotton	Sep. 95	987	1.30 ± 0.10	3.83 (2.58-5.69)	1.3	37.2 (20.0-69.2)	1.7
	Bosan-2	Cotton	Aug. 96	1020	1.26 ± 0.07	3.59 (3.02-4.26)	1.2	37.1 (27.9-49.4)	1.7
	Lar-1	Brinjal	June 97	1253	1.57 ± 0.14	41.0 (26.8-62.8)	14	270 (123-590)	12
	Jehanian-2	Cotton	Sep. 97	1415	1.61 ± 0.13	40.4 (27.2-60.0)	13	253 (130-493)	11
	Khanewal-2	Cotton	July 98	1023	1.54 ± 0.08	61.0 (52.8-70.4)	20	415 (327-528)	19
	Lar-2	Cotton	Sep. 98	850	1.71 ± 0.10	58.2 (50.5-67.1)	19	329 (261-413)	15
	Khokhran-2	Cotton	Sep. 99	757	1.68 ± 0.10	18.6 (15.8-21.8)	6.2	108 (83.9-139)	4.9
	Shujabad-3	Brinjal	Oct. 99	397	2.17 ± 0.18	7.61 (6.44-9.01)	2.5	29.6 (22.6-38.7)	1.3