TRENDS IN RELATIVE SUSCEPTIBILITIES OF WHITEFLIES TO INSECTICIDES THROUGH THE COTTON SEASON IN THE IMPERIAL VALLEY, CA

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Abstract

Three consecutive years (1993-95) of monitoring responses of *Bemisia tabaci* (Gennadius) adult populations from cotton fields in the Imperial Valley, CA to various insecticides failed to detect progression to higher levels of resistance. Instead, regressions of LC_{50s} generated by bioassays of field populations against time for each year indicated a lower mean response for 1995 compared to 1993 for bifenthrin and endosulfan. Negative slopes significantly different from zero ($P<0.05$) for both insecticides in 1994 and for endosulfan in 1995 indicated higher susceptibilities at the end of each season despite instances of intensive insectide use. This same pattern was observed for other insecticides representing different classes, thus suggesting the involvement of ecological stress factors such as declining crop quality, overcrowding and/or rampant dispersion leading to physiologically-weakened adult whiteflies.

Declining levels of LC_{50s} between 1993-95 are thought to be due to various agricultural and agronomic factors, including large acreages of alfalfa that act as insecticide refuges for whiteflies and maintain a high frequency of susceptible genotypes; largescale dispersion and subsequent matings of susceptible and resistant genotypes that result in lower frequencies of putative resistant genes; the prevalent use of insecticide mixtures that potentially eliminate individuals resistant to single insecticides; and the recent addition of several effective insecticides representing different classes to the insecticide arsenal available to growers and pest control advisors.

Introduction

Outbreaks of *Bemisia tabaci* populations in cotton have often been linked to insecticide resistant populations. Resistance to insecticides belonging to different insecticide classes has been documented in *B. tabaci* populations from around the world, including Sudan (Dittrich and Ernst, 1985), USA (Prabhaker et al., 1985), Turkey and Central America (Dittrich et al., 1990), and Israel, Pakistan and Cypress (Cahill et al., 1995). The occurrence of resistance has forced excessive insecticide use to account for diminishing efficacies, which at the same time is suspected to have exacerbated outbreaks by diminishing natural enemy populations (Joyce, 1955; Eveleens, 1983). Recent outbreaks of *B. tabaci* in regions of North America that had not previously experienced high infestations were suspected to be due in part to insecticide resistance. Similarly, renewed or increased levels of resistance was suspected as an important factor in large outbreaks resuming in 1991 in California's Imperial Valley following a series of damaging outbreaks in the early 1980s in cotton.

The destructive outbreak of 1991 in the Imperial Valley brought recognition of the critical need for assessing the status of resistance to various insecticides being used to combat whiteflies. A program was initiated as early as March, 1992 using the coated glass vial bioassay technique (Staetz et al., 1992), but this gave way to the yellow sticky card bioassay (Prabhaker, 1988) beginning in June, 1993. Since then, resistance monitoring of whitefly populations has been conducted on a year-round basis by following whiteflies through a sequence of crops beginning with spring cantaloupes, then summer cotton followed by fall-winter cole crops. With an abundance of whiteflies present through nearly the entire annual cycle, it has been possible to accumulate a large body of data measuring whitefly population responses to various insecticides. The data collected from cotton fields for 1993-95 will be presented to assess macro trends between years as well as micro trends from within-season monitoring data.

Materials and Methods

Bioassays were conducted using the yellow sticky card technique described by Prabhaker et al. (1988, 1992). Insecticide treatments included four single compounds (bifenthrin, endosulfan, fenpropathrin and chlorpyrifos) and two mixtures (bifenthrin+endosulfan and fenpropathrin+acephate). For each treatment, six concentrations were prepared and applied with a Potter tower to a set of 3x5" yellow cards lightly coated with Tanglefoot®, one concentration per card. Each set of cards for the respective insecticide treatments were transported to a cotton field in an ice chest to avoid desiccation and high temperatures. Whitefly-attractive yellow cards were removed one or two at a time and held in the cotton canopy while disturbing the foliage to encourage flight and landing onto the cards. Following collection of 50-80 adults per card, the sets were transported back to the laboratory and placed in storage chests for overnight incubation. High humididty and room temperature was maintained in individual chests, each one containing one insecticide treatment set. Mortality on each yellow card was scored ca. 24 hours following collection, and probit analysis was conducted to calculate LC_{50s} and 95% confidence limits.

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Whitefly adults were collected from various cotton fields scattered throughout the Imperial Valley between June and September-October. Regression analysis for each treatment with LC_{50s} as the response variable and time as the independent variable was conducted to reveal temporal trends. Within season tests of significance for regression coefficients were made for each treatment by assuming the null hypothesis (H_0=0). For the three years of monitoring data for bifenthrin and endosulfan, LC_{50s} were segregated into frequency distribution classes, and from these cumulative frequency curves were overlayed for between-year comparisons.

Results

Similar trends over three consecutive years were observed for the bifenthrin and endosulfan bioassay data (Figure 1). The highest mean response over an entire cotton season was in 1993 for both compounds. Progressively lower mean LC_{50s} were observed in 1994 and 1995. The within-season trends produced negative slopes in five of the six data sets for both compounds. Regression coefficients significantly different from zero were observed for bifenthrin in 1994 and for endosulfan in 1994-95 (Table 1).

No consistent trend between years was evident for chlorpyrifos or for fenpropathrin (Figure 2). Less variability in LC_{50s} in 1995 produced a higher R^2 value for chlorpyrifos compared to 1994 and a significantly negative slope (Table 1). A departure for fenpropathrin from other insecticide treatments in this study was evident by the positive slope for the 1994 bioassay data. Emergency registration for fenpropathrin was approved in late June, 1994, and use of this compound in combination with acephate was intensive in most cotton fields. Lower whitefly pressure in 1995 drastically reduced the number of applications of fenpropathrin as well as other insecticides.

Nearly identical data sets were obtained in 1994-95 for the bifenthrin+ endosulfan mixture treatment (Figure 3). The higher toxicity of the fenpropathrin+acephate mixture compared to the bifenthrin+endosulfan mixture was evident by a lower mean response. A significantly negative slope for the fenpropathrin+acephate mixture suggests that whitefly populations became more susceptible to this treatment as the cotton season wore on (Figure 3).

Cumulative frequency curves for bifenthrin and endosulfan provided another perspective on the increasing susceptibilities of *B. tabaci* populations in the Imperial Valley to both insecticides between 1993-95 (Figure 4).

Discussion

Three years of monitoring responses of *B. tabaci* populations from cotton fields to various insecticides have produced unexpected results when considered against past studies of resistance in this species and other arthropod species in general. Progression to higher levels of insecticide resistance has not occurred despite intensive insecticide use, and indeed just the opposite appears to be the case. Similarities in year to year responses to insecticides from different classes suggests the absence of any specific metabolic mechanisms that might confer resistance, but instead point to general ecological factors that influence physiological responses of adult whiteflies to xenobiotic compounds. The generality of within-season responses (11 of 13 slopes were negative; 6 of 13 significantly different from zero; Table 1) to different insecticides may indicate deterioration of environmental conditions through the cotton season. Cotton host quality probably declines substantially between mid to late season concomitant to the time that regional populations are building to high levels, frequently under conditions of overcrowding. Consequently, adult whiteflies may be physiologically stressed at the time they are collected in cotton fields for bioassays.

The agriculture in the Imperial Valley as defined by the types and sequences of crops grown and their relative acreages, as well as the insecticide use patterns are important to understanding *B. tabaci* infestations in general and specifically insecticide resistance levels. Approximately 200,000 acres, or 40% of all irrigated land is planted in alfalfa compared to 6-8,000 acres of cotton during the past few years. The importance of this crop differential is that alfalfa is rarely treated with insecticides during the summer when large numbers of whitefly adults accumulate and colonize the alfalfa, sometimes to damaging levels. By and large, alfalfa appears to be a somewhat marginal host for *B. tabaci*, but the magnitude of land coverage with alfalfa suggests substantial numbers of whiteflies are generated in what amounts to an insecticide free zone. When coupled with the large scale dispersal that occurs through the summer in the Imperial Valley, the presence of high numbers of insecticide-susceptible genotypes is important to understanding why resistance levels do not increase through the cotton season despite intensive insecticide use. High immigration rates into cotton fields from untreated crop, ornamental and wild host sources outside of insecticide use areas lead to interbreeding of different genotypes and the probable dilution of putative resistance gene frequencies.

The availability of four additional insecticides new to the Imperial Valley since 1992 (bifenthrin, fenpropathrin, amitraz, and imidacloprid) has benefitted whitefly management efforts and helped to diversify the chemistries of insecticides used against whiteflies. Moreover, the prevalent use of these insecticides and others as mixtures may have helped mitigate the climb to higher resistance levels. Insecticide mixtures are often cited as a potentially viable approach to managing insecticide resistance (Roush, 1989; Mallet, 1989). Computer simulations of populations in which susceptible genotypes are maintained and inheritance of resistance genes is recessive have shown the multiple toxin approach (i.e. mixtures) to be effective in delaying progression to higher resistance levels (Gould, 1991). Although the method of inheritance of putative resistance genes in *B. tabaci* populations is unknown, the resistance monitoring record of the past three years suggests that *B. tabaci* populations have not been driven to higher levels through the use of mixtures. With increasing problems due to *B. tabaci* outbreaks being encountered throughout the world, there may be important lessons from the Imperial Valley on how insecticide resistance can be managed.

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Table 1. Regression statistics for within season analyses of adult *B. tabaci* responses to various insecticides.

Insecticide Treatment	Year	Number of Fields	Slope	P-value	R^2
	1993	38	-0.0004	0.78	0.002
Bifenthrin	1994	61	-0.003	0.000	0.40
	1995	24	-0.002	0.08	0.13
	1993	41	0.0001	0.65	0.005
Endosulfan	1994	61	-0.0006	0.000	0.37
	1995	22	-0.0006	0.01	0.27
Chlorpyrifos	1994	53	-0.0004	0.052	0.07
	1995	26	-0.0008	0.000	0.42
Fenpropathrin	1994	36	0.0001	0.06	0.10
	1995	26	-0.005	0.07	0.13
Bifenthrin +	1994	49	-0.0002	0.003	0.17
Endosulfan	1995	22	-0.0002	0.07	0.15
Fenpropathrin + Acephate	1995	24	-0.0002	0.000	0.60

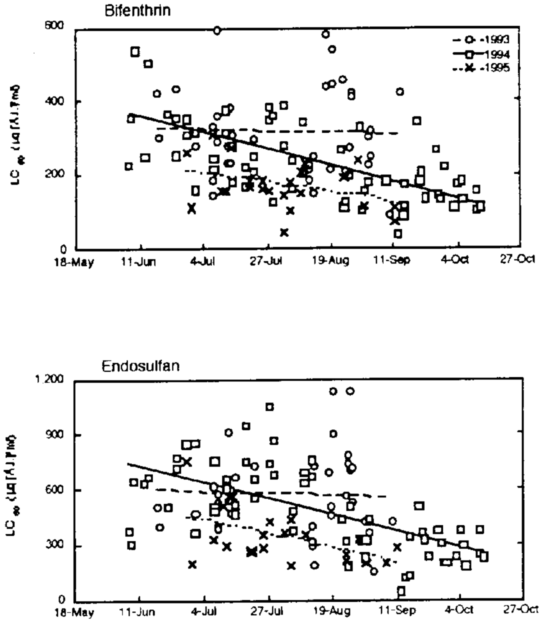

Figure 1. Fitted-line regressions for each of three years bioassay data for bifenthrin and endosulfan.

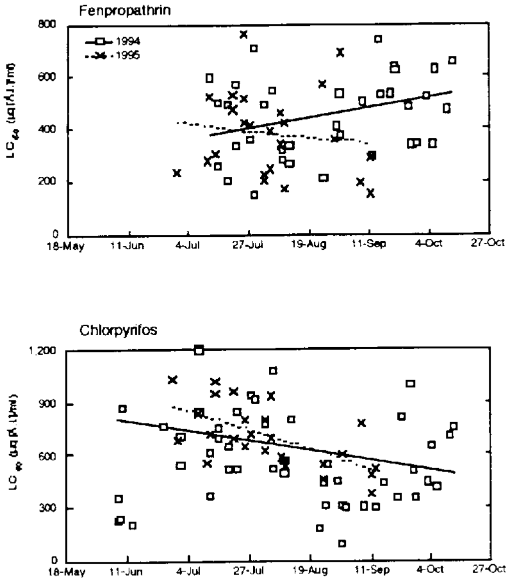

Figure 2. Fitted-line regressions for each of two years bioassay data for fenpropathrin and chlorpyrifos.

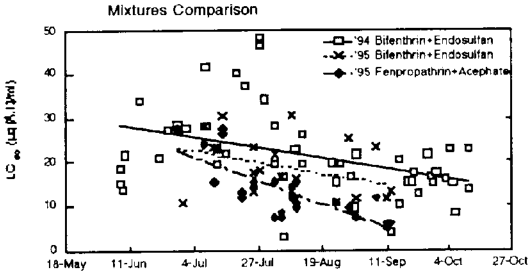

Figure 3. Fitted-line regressions for each of two years bioassay data for bifenthrin+endosulfan and for 1995 fenpropathrin+acephate.