TRENDS IN PEST DENSITIES, PESTICIDE USE, AND PESTICIDE RESISTANCE IN SAN JOAQUIN VALLEY COTTON

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Abstract

Insecticide use escalated in the mid 1990s when outbreaks of cotton aphid occurred in response to changes in agronomic practices and an increase in insecticide resistance. Early season applications of pyrethroids for Lygus control exacerbated problems for both cotton aphid and spider mites. University of California Extension personnel conducted an educational program that outlined the problem and provided a multiple species approach to insect pest management. The essential elements of the program were an emphasis on preservation of natural enemies through a reduction of early season broad-spectrum pesticides and careful rotation of insecticide classes. Since implementation of that program, resistances to organophosphates in cotton aphid and Lygus and to an organochlorine in cotton aphid have declined. Resistance to a pyrethroid is increasing in Lygus bug, probably because of increased use of pyrethroids in its preferred host, alfalfa. Spider mites continue to show a yearly cycle of high susceptibility to major acaricides in the early season and lower susceptibility after sprays are applied. Pest problems have not been as severe since the resistance management guidelines were provided to growers. These data suggest that careful management of pesticides in cotton can maintain susceptibility for some pesticides but not others.

Introduction

Two key pests of San Joaquin Valley cotton, Lygus (*Lygus hesperus*) and cotton aphids (*Aphis gossypii*) have been controlled with organochlorine, organophosphate, and carbamate insecticides for more than 30 years. During the early 1990s, these insecticides began to loose efficacy (Grafton-Cardwell et al. 1992) and the pyrethroids were introduced. Bifenthrin was used heavily, starting in 1992, because of its efficacy against Lygus and additional activity against aphids and spider mites. At about the same time, the production habits of San Joaquin Valley growers shifted away from using nitrogen or water stress to manage plant growth and towards plant growth regulators. Greater amounts of nitrogen and irrigation were used to develop the most vigorous plant canopy during fruit production (Godfrey et al. 1999). Cotton aphids, which had previously been an early season problem kept under control by natural enemies, became a serious mid-season pest. The cotton aphid problem was greatest in 1995 and was a response to a combination of factors including weather patterns, increased irrigation and nitrogen applications for the newer cotton varieties, and increasing pesticide resistance. Cotton aphid developed resistance to bifenthrin rapidly, and by 1995, it was no longer effective for controlling aphids (Grafton-Cardwell and Goodell 1996). Resistance to bifenthrin in Lygus was also detected in 1996, however, compared to cotton aphids it was not as severe (Grafton-Cardwell et al. 1997a) or as stable (Knabke and Staetz 1997). Because the pyrethroids gave longer residual control than other insecticides, growers continued to use pyrethroids for Lygus control in spite of resistance. When pyrethroids are used for early season Lygus control, insecticide use for secondary pests such as cotton aphids, spider mites, and various Lepidoptera escalates (Godfrey et al. 1998). This is because pyrethroids are toxic to the natural enemies that control these pests. Between 1985 and 1995, pesticide use increased from 1.5 applications to up to 6 applications per season for all pests and yields were low in 1995. In response to this escalation of broad-spectrum pesticide use, University of California Extension personnel held a cotton industry workshop (Goodell et al. 1997b) to review the pest situation. One outcome of these annual insect reviews was a series of insecticide resistance management guidelines that emphasized the preservation of natural enemies by avoiding early season broad-spectrum insecticides and the careful rotation of insecticide/acaricide chemistries (Goodell et al. 1997a, Grafton-Cardwell et al. 1997b, Godfrey et al. 1997, Brazzle et al. 1997, Brazzle et al. 1998, Goodell 1999). This paper reports on the pest densities, pesticide use patterns, and pest resistance of spider mites, Lygus, and cotton aphids during 1996-1999, the period just prior to and following implementation of these resistance management guidelines.

Materials and Methods

Insecticide resistance bioassays for aphids and spider mites were prepared by treating plastic petri dishes with discriminating concentrations of pesticides mixed in ethanol. We expected to observe greater than 80% mean mortality of individuals place in these dishes if the population was susceptible to the pesticide. We could not test all insecticides and acaricides registered, and so we screened insecticides from major chemical classes. For aphids, the insecticides

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included the organophosphate Lorsban (510 ppm chlorpyrifos), the organochlorine Thiodan or Phaser (270 ppm endosulfan), the pyrethroid Capture (5 ppm bifenthrin) and the chloronicotinyl Provado (40 ppm imidacloprid). Dishes were stored in a freezer and used within 4 weeks of preparation. Twenty adult apterous aphids were placed in each dish, 3 replications were completed, and mortality was assessed after 3 hour. For spider mites, acaricides included 56.2 ppm dicofol (Kelthane), 1000 ppm propargite (Comite) and 3 ppm abamectin (Zephyr). Dishes were stored in a refrigerator and used within 4 months of preparation. Twenty adult female mites were placed in each dish, 3 replications were completed, and mortality was assessed after 24 hours. For Lygus, we treated 50 x 90 mm, plastic ziploc bags with 5 µl technical grade insecticide in acetone (Xu and Brindley 1993). For Lygus, the insecticides included the pyrethroid Capture (200 µg/bag bifenthrin), the organophosphate Metasystox-R (200 µg/bag oxydemeton-methyl) and the carbamate Lannate (40 µg/bag methomyl). Five adult Lygus bugs were placed in each bag and mortality was assessed after 8 hours. Four replications were completed for each insecticide tested. Pesticide use data was obtained from the California Department of Pesticide Regulation for 1990-1998 and summarized for Merced, Madera, Fresno, Kings, Tulare and Kern counties. Estimates of pest densities were obtained from the Cotton Insect Losses summary for the National Cotton Council (1991-1999).

Results and Discussion

Pesticide use for Lygus and aphid control between 1990-1998 in the San Joaquin Valley for major insecticide classes is illustrated in Figure 1. Endosulfan use reached a peak in 1993, organophosphate and pyrethroid use peaked in 1995, carbamate use continues to steadily increase (primarily aldicarb), and imidacloprid use was initiated in 1995. In 1995, when organophosphate and pyrethroid use in the San Joaquin Valley was at it's highest, the insecticides were not very effective in controlling cotton aphid or spider mites. The resistance monitoring program was initiated the following year (1996) in response to concerns that resistance was the cause of the aphid and mite problems.

Cotton aphid numbers were high during 1994-97. The percentage of cotton aphid populations with resistance to bifenthrin was high in 1996 (85% of populations tested) when resistance monitoring was initiated (Fig. 2). Bifenthrin resistance declined slightly in subsequent years as pyrethroid use in cotton declined, however ≥62% of populations tested responded with resistance. Thus, reduction in pyrethroid use did not bring the San Joaquin Valley cotton aphid population back to a susceptible state. In contrast, resistance to chlorpyrifos was fairly high in 1996 (40% of populations tested), but as use declined after 1995, so has the percentage of resistant populations (Fig. 3). This suggests that organophosphate resistance in cotton aphids is unstable and manageable through careful rotation of insecticide classes. A similar pattern is seen for endosulfan (Fig. 4) with 67% resistant populations in 1996 dropping to as few as 12% of populations in 1998. Imidacloprid (Fig. 5) was registered for use in 1995, and to date, no resistance to this insecticide has been detected. At least a portion of the reduction in organophosphate and pyrethroid use in the late 1990s was due to the introduction of this new insecticide class (chloronicotinyl). Continued rotation of these different insecticide classes with any insecticides that become registered in the future is recommended. There is a continued need for selective insecticides that allow the aphid natural enemies to survive.

Lygus bugs become a key pest in cotton fields as foothill vegetation dries and as neighboring alfalfa fields are harvested (Goodell 1998). Although pyrethroid use declined in cotton after 1995, use in alfalfa has dramatically increased (Fig. 6). Recent registration of pyrethroids for alfalfa weevil control and use for other pests of alfalfa has greatly escalated pyrethroid use in this crop. In 1996, Lygus bug susceptibility to bifenthrin in the early season was observed, suggesting that resistance to this insecticide could be managed (Knabke and Staetz 1997). However in 1997-98 resistance surveys, resistance to bifenthrin in Lygus bugs increased to ≥80% of populations tested at all times of the season. This may be an example of neighboring crop pesticide use influencing pesticide resistance in a pest of cotton. If the heavy pyrethroid use in alfalfa continues, we are likely to see bifenthrin resistance in Lygus continue to increase. Use of pyrethroids in cotton increased in 1998 (Fig. 1), possibly in response to the increasing level of resistance in Lygus. Resistance to the organophosphate oxydemeton-methyl fluctuated, as did use of this insecticide and other organophosphate insecticides. Resistance of Lygus to methomyl has only been measured for two years, but showed a significant increase from 0% to 39% in 1999. Although too early to tell if this is a trend, the increased use of carbamates (especially aldicarb) may be the cause of the observed increase in carbamate resistance. All of the insecticides registered for Lygus control are fairly broad-spectrum. There is a great need for development of selective insecticides for Lygus control in order to allow the natural enemies of the other pests to survive.

Figure 7 shows the pesticide use patterns for abamectin, dicofol, and propargite use for spider mites in the San Joaquin Valley from 1990-98. Peak use of all three acaricides occurred in 1995, the year when cotton aphid populations were out of control and broad-spectrum pesticide use was at it's highest (Fig. 1). Spider mites are generally a problem in years when broad-spectrum insecticides are applied early for Lygus and cotton aphids. Spider mites have many natural enemies that aid control and if left undisturbed control most populations. The observed pattern of pesticide resistance in spider mites is different than insects. Each year, spider mite populations are initially quite susceptible to all three acaricides (Fig. 8). This is because populations consist primarily of fully susceptible strawberry mite (*Tetranychus turkestani*) and because resistance declines in *T. urticae* and *T. pacificus* during the winter. Acaricides are applied during June and July and these applications select for resistance. This pattern has been observed for dicofol and propargite since the mid 1980s (Grafton-Cardwell et al. 1987). In 1998, resistance to abamectin was observed for the first time in *T. urticae* and *T. pacificus* infesting cotton. However, resistance declined by the subsequent spring. Many factors result in yearly subsiding of acaricide resistance levels in cotton spider mites including, selectivity of acaricides favoring natural enemies, high movement of spider mites between crops (Grafton-Cardwell et al. 1991), natural rotation of acaricide classes, and recessive inheritance of resistance. The result is that dicofol and propargite remain efficacious as early or mid season sprays in most cotton fields in spite of nearly 20 years of documented resistance. There has been a tendency in recent years for cotton growers to increasingly rely on abamectin for spider mite control (Fig. 7). For resistance management purposes, rotation of abamectin with other acaricides is continually advised (Goodell et al. 1999).

Summary

Pesticide bioassays were useful for detecting trends in resistance to major groups of insecticides and acaricides. The data indicate that pyrethroid resistance in Lygus and cotton aphids is quite high, suggesting that pyrethroid usefulness may be approaching an end. In contrast, resistances to organophosphates, organochlorines, and acaricides occur, yet the level or frequency of resistance fluctuates in response to pesticide use. There is greater potential for maintaining susceptibility to these pesticides if their use is limited.

The education program emphasized the concept that pesticide resistance cannot be managed in one pest without managing it in the other pests. Use of insecticides for either Lygus or cotton aphids selects for resistance in both insects. Heavy use of early season broad-spectrum pesticides for Lygus disrupts biological control resulting in increased use of acaricides for spider mites and insecticides for aphids. In addition, cotton pests are influenced by insecticide use in neighboring crops. Escalating insecticide use in alfalfa is a likely cause of increased pyrethroid resistance in Lygus infesting cotton. The best resistance management program is one that reduces all pesticide use and the University of California Resistance Guidelines help the growers follow that strategy.

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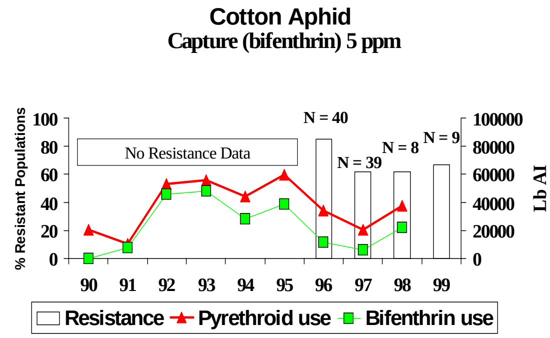

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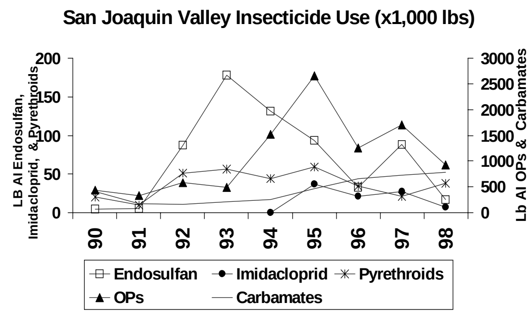

Figure 1. Insecticide use (lb AI) during 1990-98 in San Joaquin Valley Cotton.

Figure 2. Bifenthrin and pyrethroid use (lb AI) during 1993-98 and the percentage of bifenthrin-resistant cotton aphid populations of total (N) tested during 1996-99.

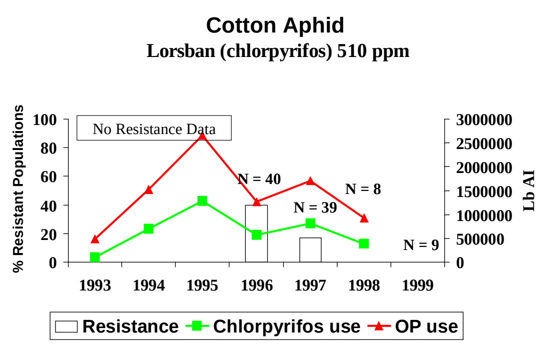

Figure 3. Organophosphate and chlorpyrifos use (lb AI) during 1993-98 and the percentage of chlorpyrifos-resistant cotton aphid populations of total (N) tested during 1996-99.

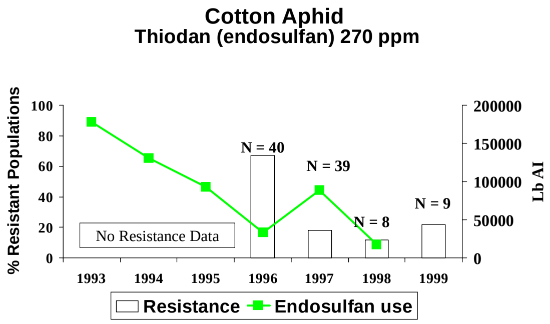

Figure 4. Endosulfan use (lb AI) during 1993-98 and the percentage of endosulfan-resistant cotton aphid populations of total (N) during 1996-99.

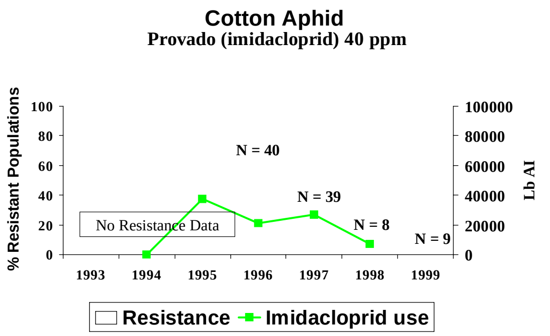

Figure 5. Imidacloprid use (lb AI) during 1995-98 and the percentage of imidacloprid-resistant cotton aphid populations of total (N) tested during 1996-99.

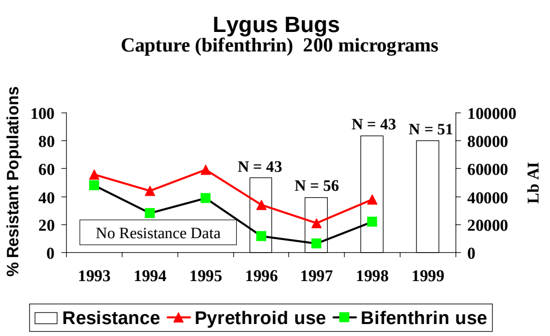

Figure 6. Bifrenthrin and pyrethroid use during 1995-98 and the percentage of bifenthrin-resistant Lygus population of total (N) tested during 1996-99.

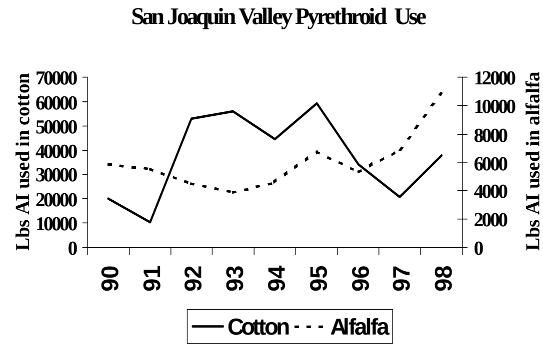

Figure 7. Pyrethroid use (lb AI) during 1990-98 in San Joaquin Valley cotton and alfalfa.

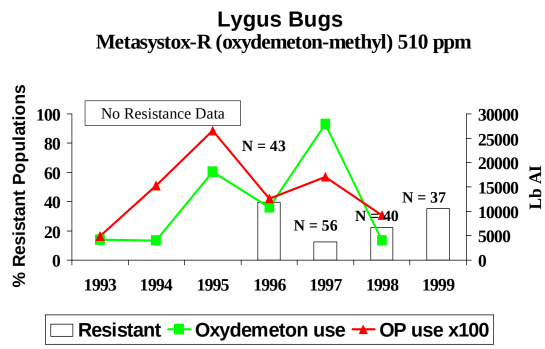

Figure 8. Oxydemeton-methyl and organophosphate use (lb AI) during 1995-98 and the percentage of oxydementon-methyl-resistant Lygus populations of total (N) tested during 1996-99.

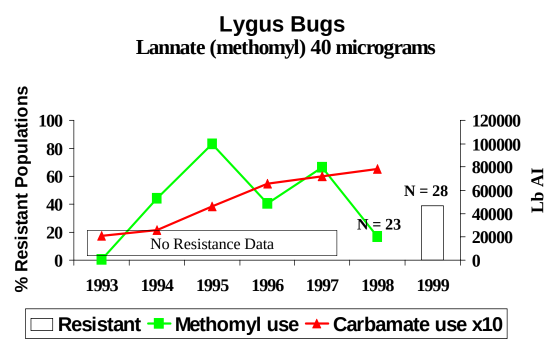

Figure 9. Methomyl and carbamate use (lb AI) during 1995-98 and the percentage of methomyl-resistant Lygus populations of total (N) tested during 1998-99.

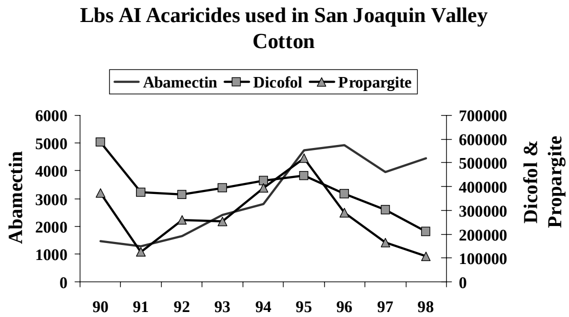

Figure 10. Acaricide use (lb AI) during 1990-98 in San Joaquin Valley cotton.

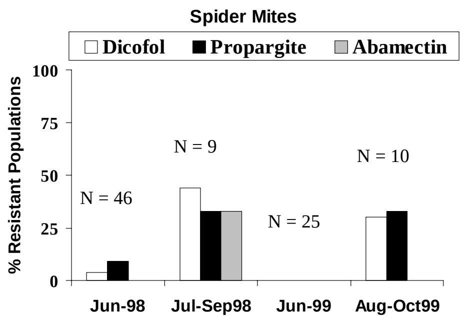

Figure 11. The percentage of dicofol-, propargite-, and abamectin-resistant spider mite populations of total (N) tested during 1998-99.