SUSCEPTIBILITY OF ARIZONA WHITEFLIES TO CHLORONICOTINYL INSECTICIDES AND IGRS: NEW DEVELOPMENTS IN THE 1999 SEASON

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Abstract

Whiteflies are serious pests of cotton, melons, and winter vegetables in Arizona's low deserts. Successful management of whiteflies requires an integrated approach, a critical element of which is routine pest monitoring. In this paper we report findings of our 1999 investigations of resistance of Arizona whiteflies to insect growth regulators (IGRs) and chloronicotinyl insecticides. Whiteflies collected from cotton fields, melon fields and greenhouses were tested for susceptibility to imidacloprid (Admire®/Provado®), and two other chloronicotinyl insecticides, acetamiprid and thiamethoxam, and to two insect growth regulators (IGRs), buprofezin (Applaud®) and pyriproxyfen (Knack®). Contrasts of 1998 and 1999 results indicated increased susceptibilities, on average, to both imidacloprid and buprofezin of whiteflies collected from cotton. A cropping system study showed that whiteflies collected from spring melons had significantly lower susceptibility to imidacloprid than those collected from cotton or fall melons. The opposite was found for pyriproxyfen, to which whiteflies from cotton and fall melons had lower susceptibility than those from spring melons. As in 1998, whiteflies with reduced susceptibility to imidacloprid continue to be found in certain locations, particularly in spring melon fields and greenhouses. Results of our laboratory bioassays on susceptibility of Arizona whiteflies to chloronicotinyl insecticides provided evidence of a low order cross-resistance between imidacloprid, acetamiprid and thiamethoxam. Monitoring in 1999 provided the first evidence of reduced susceptibility of Arizona whiteflies to pyriproxyfen.

Introduction

The chloronicotinyl insecticide, imidacloprid (Admire®), and the IGRs, buprofezin (Applaud®) and pyriproxyfen (Knack®), have served pivotal roles in controlling whiteflies in the unique agricultural ecosystems of Arizona's low desert (Dennehy and Williams, 1997) and other arid regions of the world (Denholm et al., 1998). Imidacloprid has provided successful season-long whitefly control in Arizona vegetables and melons since 1993, and has been used on essentially 100% of these crops since its introduction (Palumbo, 1994a, b). The IGRs, buprofezin and pyriproxyfen, were introduced to Arizona cotton in 1996, after resistance to synthetic pyrethroids and other conventional insecticides reached crisis proportions in 1995 (Dennehy et al., 1996). IGRs provided the foundation for a successful resistance management strategy, their use against whiteflies in cotton being limited to once-per-season for each buprofezin and pyriproxyfen.

Whiteflies have been previously shown to develop resistance to imidacloprid and IGRs in both laboratory and field conditions (Horowitz and Ishaaya, 1994; Prabhaker et al., 1997). Whiteflies with 50 to 102-fold resistance to imidacloprid have been selected (Prabhaker et al., 1997; Dennehy, unpublished data), and control failures have been reported in greenhouses in Spain (Denholm et al. 1998). There also have been reported problems with whiteflies resistant to buprofezin and pyriproxyfen in Israel (Horowitz and Ishaaya, 1992, 1994). Since imidacloprid is used so extensively on Arizona's vegetables and melons, the University of Arizona's Extension Arthropod Resistance Management Laboratory (EARML) began monitoring resistance development to imidacloprid in Arizona's whiteflies in 1993 (Williams et al, 1996, 1997, 1998; Dennehy and Williams, 1997). Similarly, the susceptibility of Arizona's whiteflies to IGRs has been monitored since their introduction in 1996 (Dennehy et al., 1999). Fortunately, there have been no failures of imidacloprid or IGRs reported in Arizona crops. However, monitoring whitefly susceptibility throughout Arizona has revealed populations of strikingly reduced susceptibility to both imidacloprid and buprofezin from vegetables in the Yuma area and from greenhouses in the Phoenix area (Dennehy et al., 1999). Also, statewide monitoring in last three years from cotton, a commodity with negligible use of imidacloprid, has shown successive reductions in average susceptibility of Arizona whiteflies to imidacloprid in laboratory bioassays (Dennehy et al., 1999).

As concerns for whitefly resistance to imidacloprid have mounted in Arizona, two additional chloronicotinyl insecticides, acetamiprid and thiamethoxam, have been slated for development in cotton as well as other crops. Moreover, new registrations for buprofezin and pyriproxyfen have expanded the use of these IGRs against whiteflies in greenhouses and other field crops. Because whiteflies in western Arizona typically move between the succession of vegetable, melon and cotton crops, new uses of these products are expected to exacerbate whitefly resistance overall. In this paper we report the current status of susceptibility of Arizona whitefly populations to these important insecticides, results of a cropping system study of whitefly susceptibility to imidacloprid, and cross-resistance relationships between chloronicotinyl insecticides.

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Materials and Methods

Insecticides and Whitefly Populations

We conducted a statewide survey to estimate susceptibilities of Arizona whiteflies to (1) imidacloprid (Admire®), two other chloronicotinyl analogs, (2) thiamethoxam (CGA-293343 25WG) and (3) acetamiprid (Exp-80667A) and the IGRs, (4) buprofezin (Applaud®) and (5) pyriproxyfen (Knack®). From June to November 1999, we collected 13 whitefly populations from cotton. Adult whiteflies were collected in plastic vials by vacuuming plant foliage with a Makita Cordless Vacuum® (Model 4071D). Samples were chilled and transported to the laboratory in Tucson within eight hours. Samples were released into cages containing several clean cotton plants, *Gossypium hirsutum* L. (var. DPL-50), at the five to seven true-leaf stage. Adult whiteflies were assayed approximately 36 hours after field collection. Whitefly nymphs on ornamental poinsettia and hibiscus plants were also collected from greenhouses in the Phoenix area. The infested leaves were transported back to our laboratory in Tucson and placed in cages; bioassays were conducted on emerging adults.

The climate of the low deserts of the Southwest provides whiteflies with year-round hosts. Almost 100% of fall melons in this region are soil treated with imidacloprid for whitefly control. This imposes strong pressure for resistance, therefore affecting the susceptibility of whiteflies in cotton. To study the dynamics of the susceptibility of Arizona's whiteflies in the cropping systems, we collected and assayed 11 whitefly populations from spring melons (between June 1 and July 14, 1999), 7 from fall melons (between August 15 and October 31, 1999), from the Yuma area in western Arizona and the Phoenix area in central Arizona. For imidacloprid and other insecticides used extensively in greenhouses, we collected and tested whiteflies from poinsettia and hibiscus plants that originated from Phoenix area greenhouses.

Bioassay Methods for Chloronicotinyl Insecticides

Imidacloprid (Admire®). Since imidacloprid is used as a soil treatment for whiteflies in vegetables and melons in Arizona, we adopted a systemic-uptake bioassay, previously described by Cahill et al. (1996a), that exposes whitefly adults to the chemical through their feeding on systemically-treated leaves (Williams et al., 1996). Cotton seedlings, *G. hirsutum* L. (var. DPL-50), at the second true-leaf stage of growth (18-26 days old), were cut at the mainstem soil line and placed in 200 ml of the desired concentrations (0, 1, 10, 100 or 1000 μg/ml) of Admire 2F for 24 hrs of hydroponic uptake. Leaf disks of 2.5 cm in diameter were then excised from the true leaves and placed on a thin layer of agar gel (1.3%) in 20 ml glass scintillation vials. Ten replications (vials) were prepared for each concentration. Twenty to thirty adult whiteflies were aspirated into each vial. Vials were capped with dialysis membrane (Spectra/Por*4, Baxter Diagnostics Inc., IL) and placed in an incubator at 27±1°C, 16 h photoperiod, for 48 h, after which the assays were read under a binocular dissecting microscope (Leica KL-750). Mortality was assessed by tapping vials on the counter and observing the whiteflies movement. Individuals unable to move appendages repetitively (non-reflex) were scored as dead.

Thiamethoxam and Acetamiprid. We used a leaf-dip bioassay method described by Rowland et al. (1990) for thiamethoxam and acetamiprid bioassays. Leaf disks of 2.5 cm in diameter were cut from 18-26 days old cotton plants (var. DPL-50). The leaf disks were dipped for 10 s in 50 ml of the desired concentration (0, 1, 10, 100 or 1000 μg/ml) of thiamethoxam (CGA-293343) or acetamiprid (Exp.-80667A) diluted in distilled water. The treated disks were allowed to dry before being placed, individually, on bases of agar (1.3%) in 20 ml scintillation vials. Six replications (vials) were prepared for each concentration. The remainder of the procedures, including introduction of whiteflies, assay incubation and reading, was the same as for the afore mentioned imidacloprid assay.

IGR Bioassay Methods

Buprofezin (Applaud®). We adopted the bioassay method for buprofezin from Cahill et al. (1996b). Ten pairs of adult whiteflies were aspirated into a modified polystyrene Petri dish (OPTILUX® 100 x 15 mm) where they deposited eggs for 24 h on the first true leaves of isolated 14-21 days old cotton plants. The adults were then removed, and the stem of the infested leaf was inserted in a 20 ml glass scintillation vial containing tap water. The bioassays were held at 27±1°C and a 16 h photoperiod for the duration of the assay. Eight days after the end of the oviposition period, the number of 1st instars on each leaf was counted, unhatched eggs were removed, and each leaf was dipped for 20 s in 50 ml of the desired concentration (0, 8, 100, or 1000 μg/ml) of Applaud 70 WP. Mortality was assessed 17 days after oviposition by counting live 3rd and 4th instar nymphs, and subtracting that number from the number of 1st instar nymphs counted on day eight on each leaf.

Pyriproxyfen (Knack®). The method for infestation of cotton leaves with whitefly eggs was the same as for the buprofezin bioassay. After the 24 hr oviposition period, adults were removed and the total number of eggs on each leaf was counted. Each infested leaf was then dipped for 20 s in 50 ml of the desired concentration (0, 0.01, 0.1, or 1 μg/ml) of Knack 0.86 EC and allowed to dry. The stem of each infested leaf was inserted, individually, into a 20 ml glass scintillation vial containing tap water. The bioassays were held at 27±1°C, and a 16 h photoperiod, for 7 days. Mortality was assessed by counting live 1st instar nymphs 7 days after dipping and subtracting this from the total number of eggs deposited on each leaf.

Data Analyses

Statistical differences in population responses and insecticide treatments were evaluated by ANOVA (JMP-IN, SAS institute). Probit analyses of the concentration-dependent mortality were undertaken using POLO-PC (Anon, 1987) to generate LC_{50}s, slope values, and the respective 95% fiducial limits. LC_{50}s generated for each of the chloronicotinyl insecticides tested against whitefly populations in 1999 were subjected to a log transformation, and then used for regression analyses of cross-resistance (Neter and Wasserman, 1974). ANOVA was also used to test for significance of regressions for cross-resistance.

Results and Discussions

Susceptibility of Arizona Whitefly Populations to Chloronicotinyl insecticides

Imidacloprid-Cotton. Whiteflies collected from Arizona cotton had an increased susceptibility to imidacloprid over the previous year (Figure 1). The mean corrected mortality at 1000 μg/ml imidacloprid increased significantly from 78.7% in 1998 to 92.4% in 1999. Therefore, overall susceptibility in 1999 had reverted to 1997 levels (Figure 1). However, whitefly populations from different locations varied widely in their susceptibility to imidacloprid (Table 1). Highly susceptibility populations were found in Coolidge, Casa Grande, the Maricopa Agriculture Center, and Safford, while moderately resistant populations were found in Gila Bend and the southern Dome Valley. Despite the overall increase in average susceptibility to imidacloprid from 1998 to 1999, certain locations showed consistency over the years. Whiteflies from Coolidge and Safford were highly susceptible in both 1998 and 1999, and whiteflies from the Dome Valley area were the least susceptible of field populations to imidacloprid. This was consistent with the patterns of imidacloprid use in those regions (Williams et al. 1998); there was widespread use of imidacloprid in vegetables and melons in the Dome Valley, and other areas of western Arizona near Yuma.

Imidacloprid-Cropping System. Bioassay results indicated a much lower susceptibility to imidacloprid of whiteflies from spring melons than whiteflies collected from cotton later in the season (Figure 2). The average mortality at 1000 μg/ml imidacloprid was 82.0% in spring melons, contrasted with 92.4% in cotton. A striking 20% difference in average mortality was seen in bioassays of 10 μg/ml imidacloprid. Whiteflies collected from fall melons had susceptibility similar to that of whiteflies from cotton (Figure 2). Cotton is rarely treated with imidacloprid in Arizona, and this appears to have allowed resistance levels to decline in whiteflies that migrated from spring melons onto cotton. Whiteflies on fall melons were just as susceptible as those on cotton.

Imidacloprid-Greenhouses. Whiteflies we collected from poinsettia and hibiscus plants in greenhouses and from plants being sold in retail outlets in Arizona showed strong resistance to imidacloprid. The average mortality (60%) at 1000 μg/ml imidacloprid was significantly lower than that of the field populations (Figure 3), and even lower than a laboratory population selected with imidacloprid. Collections from a cotton field adjacent to a poinsettia greenhouse were also strikingly (i.e., 80-fold) less susceptible to imidacloprid.

We cannot explain the overall increased susceptibility to imidacloprid of whiteflies from Arizona cotton in 1999. However, our data indicate that resistance to this class of chemistry is becoming commonplace in greenhouses and in some field cropping systems in Arizona. The risk of losing the many benefits we derive from chloronicotinyl insecticides will be greater than ever as acetamiprid and thiamethoxam enter the marketplace. Limiting and harmonizing use of this entire class of insecticides is critical to sustaining the success of the whitefly resistance management program in Arizona.

Thiamethoxam and Acetamiprid. In laboratory bioassays, imidacloprid was significantly more toxic to whiteflies, at the concentration of 1 μg/ml, than were thiamethoxam or acetamiprid (Figure 3). This may be the result of a greater uptake of chemical with imidacloprid as a systemic treatment than in the leaf-dip assays used for acetamiprid and thiamethoxam. Susceptibilities to thiamethoxam and acetamiprid were similar to that of imidacloprid at higher concentrations.

Cross-Resistance Study. Regression analysis (Figure 5), based on LC_{50}s, revealed the existence of statistically significant cross-resistance between imidacloprid and the other two chloronicotinyl insecticides, acetamiprid ($P<0.05$) and thiamethoxam ($P<0.01$). However, the correlations were weak, with only about 20 to 26% of the variation we observed in susceptibility to acetamiprid and thiamethoxam being explained by variation in whitefly susceptibility to imidacloprid. Similarly, a significant cross-resistance was also found between acetamiprid and thiamethoxam ($P < 0.01$). Therefore, we know that there will be at least some degree of resistance to thiamethoxam and acetamiprid conferred by resistance to imidacloprid in Arizona. Selection experiments will be conducted in the coming year to estimate the impact that use of any of these chloronicotinyl insecticides will have on the dynamics of resistance to the entire group.

Susceptibility of Arizona Whitefly Populations to IGRs

Buprofezin (Applaud®). We observed a trend of reduced susceptibility to buprofezin from 1996 to 1998. The mean mortality of Arizona whiteflies at 100 μg/ml dropped from 98.4% in 1996 to 73.3% in 1998 (Figure 6). Our 1999 statewide survey data, however, showed increased susceptibility to buprofezin (Figure 6); this is encouraging for Arizona cotton growers. The mean mortality at 100 µg/ml for 1999 was the same as in 1997. For individual locations, the lowest mortality, found in the Paloma Ranch population, was 66% at 8 µg/ml. In contrast to imidacloprid and pyriproxyfen, our cropping system study showed no difference between whiteflies from cotton and whiteflies from melons in their susceptibility to buprofezin in 1999.

Pyriproxyfen (Knack®)-Cotton. The susceptibility of Arizona whiteflies to pyriproxyfen had been high during the years 1996-98, and no reductions in susceptibility were detected (Figure 7). However, we have found, for the first time, significantly reduced susceptibility to pyriproxyfen in Arizona whiteflies in 1999 (Figure 7). The mean mortality at 0.01 µg/ml dropped from 84.0% in 1998 to 41.6% in 1999. Large variation in susceptibility to this chemical existed between populations collected from cotton (Table 2). Populations with much reduced susceptibility (<15% in mortality at 0.01 µg/ml) were found at Buckeye (Heiden), Dome Valley, and Parker Valley. For the first time we detected survivors of bioassays of 1 µg/ml and these were from the North Gila Valley collection. We continued to find highly susceptible whitefly populations in Casa Grande, Paloma Ranch, and southern Dome Valley.

Pyriproxyfen (Knack®)-Cropping System. Results of our 1999 cropping system study also suggested that whiteflies from cotton and fall melons had much reduced average susceptibility to pyriproxyfen relative to those from spring melons (Fig. 8). Significant variation in susceptibility to pyriproxyfen existed between Arizona whiteflies, with mortality at 0.01 µg/ml ranging from 10% to 100%. Overall reduced susceptibility was also confirmed by the survivors found in bioassays at 1 µg/ml of a whitefly population collected from fall melons. Whiteflies collected from poinsettia in a Phoenix area greenhouse, and those collected from a cotton field adjacent to that greenhouse, had highly reduced susceptibility to pyriproxyfen. Mortality at 0.01 µg/ml pyriproxyfen was less than 20%.

Although pyriproxyfen remains highly toxic to Arizona whitefly populations, the significantly reduced mortality at 0.01 µg/ml is a warning. Whiteflies have been found to develop severe resistance to pyriproxyfen in Israeli cotton fields and greenhouses (Horowitz et al., 1999); up to 554-fold resistance to pyriproxyfen was detected after only three applications (Horowitz and Ishaaya, 1994). Similarly, whiteflies from an Israeli sunflower field developed 450-fold resistance, while laboratory selection resulted in a 6500-fold resistance to pyriproxyfen (Devine et. al., 1999). Importantly, resistance in Israeli cotton was thought to have migrated from greenhouses. Since their introduction to cotton in 1996, Arizona has successfully managed resistance by employing the strategy of limiting both IGRs to once-per-season use. Meanwhile, pyriproxyfen has received additional registrations in greenhouses and field crops. We now must determine if their expanded use, and especially resistance emanating from greenhouses, is going to compromise whitefly resistance management efforts.

Summary

Following successive reductions in susceptibility to imidacloprid (Admire®) in 1997 and 1998, whiteflies collected from Arizona cotton exhibited increased susceptibility in 1999. Nevertheless, whiteflies highly resistant to imidacloprid have continued to be detected in Arizona greenhouses. Arizona whiteflies exhibited significant positive cross-resistance between imidacloprid (Admire®) and the newer chloronicotinyl insecticides, acetamiprid and thiamethoxam. However, it was a low order of cross-resistance; susceptibility to imidacloprid accounted for only approximately 20% of observed variation in susceptibility to acetamiprid or thiamethoxam. Arizona whiteflies exhibited increased susceptibility to buprofezin (Applaud®) in 1999. Decreased susceptibility to pyriproxyfen (Knack®) was detected for the first time in Arizona whiteflies collected from cotton in 1999. The least susceptible populations were found in greenhouses in Phoenix. There have been no reported failures of imidacloprid, buprofezin, or pyriproxyfen in cotton fields in Arizona. Continued success of whitefly control in Arizona will be challenged by: 1) increased resistance to imidacloprid; 2) expanded use of chloronicotinyl insecticides; and 3) expanded used of the IGRs, buprofezin and pyriproxyfen. It will be critical to the future success of whitefly resistance management in cotton that use of IGRs to be limited to one use per season each, and that resistance be similarly managed in vegetable and melon crops. All efforts should be made to limit movement of resistant whiteflies from greenhouse.

Acknowledgments

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Table 1. Susceptibility (% mortality ± Stdev.) of whiteflies from Arizona cotton to imidacloprid (Admire®) in 1999.

Site	Concentration Imidacloprid (µg/ml)				
	0	1	10	100	1000
Buckeye #1	4.3 (3.7)	65.6 (20.3)	82.2 (6.9)	96.1 (4.7)	92.2 (8.6)
Buckeye #2	10.8 (7.9)	68.8 (4.8)	84.0 (7.2)	98.4 (2.1)	97.9 (2.3)
Casa Grande	6.2 (5.2)	71.2 (14.5)	96.0 (4.2)	99.2 (1.8)	98.8 (2.0)
Coolidge	5.6 (5.9)	79.4 (20.7)	95.7 (4.6)	98.4 (2.1)	98.2 (4.4)
Dome Valley	2.1 (4.4)		74.6 (14.0)	94.2 (6.9)	94.1 (9.4)
Gila Bend	4.9 (5.6)	43.0 (21.9)	54.8 (14.2)	91.1 (7.8)	78.7 (10.3)
Maricopa Ag. Center	9.0 (5.6)	90.1 (4.9)	98.7 (2.1)	99.6 (1.4)	95.4 (4.7)
Marana Ag. Center	1.5 (2.4)	88.8 (9.4)	97.2 (5.6)	99.6 (1.4)	97.7 (2.7)
North Gila Valley	1.7 (2.4)	65.0 (16.0)	83.0 (10.8)	93.2 (5.9)	90.4 (6.0)
Paloma Ranch	4.9 (4.4)	74.4 (9.1)	84.0 (7.6)	95.7 (3.7)	90.1 (6.3)
Parker Valley	5.4 (5.0)	49.7 (28.1)	70.1 (19.5)	93.9 (6.9)	95.4 (6.5)
Safford Ag. Center	3.7 (5.0)	73.7 (10.3)	90.4 (8.4)	94.6 (1.8)	95.6 (3.9)
South Dome Valley	5.5 (6.6)	52.1 (16.0)	63.2 (8.6)	81.9 (9.6)	81.9 (15.6)

Table 2. Susceptibility (% mortality ± Stdev.) of whiteflies from Arizona cotton to pyriproxyfen (Knack®) in 1999.

Site	Concentration Pyriproxyfen (µg/ml)			
	0	0.01	0.1	1
Buckeye #1	5.5 (6.6)	43.9 (23.2)	99.5 (0.1)	100.0 (0)
Buckeye #2	0.0 (0)	9.1 (5.5)	84.8 (8.7)	100.0 (0)
Casa Grande	4.9 (6.2)	100.0 (0)	100.0 (0)	100.0 (0)
Coolidge	9.4 (6.5)	50.2 (17.7)	99.7 (0.8)	100.0 (0)
Dome Valley	9.1 (7.2)	10.4 (13.5)	98.4 (3.2)	100.0 (0)
Gila Bend	3.1 (4.0)	17.1 (10.6)	95.8 (6.7)	100.0 (0)
Marana Ag. Center	9.0 (4.1)	52.7 (15.0)	100.0 (0)	100.0 (0)
Maricopa Ag. Center	0.8 (1.3)	29.7 (9.4)	93.4 (7.7)	100.0 (0)
North Gila Valley	4.0 (4.7)	16.0 (13.5)	31.7 (33.1)	91.3 (6.6)
Paloma Ranch	9.5 (8.2)	93.5 (6.7)	100.0 (0)	100.0 (0)
Parker Valley	4.2 (5.5)	13.3 (15.0)	100.0 (0)	100.0 (0)
Safford Ag. Center	4.7 (7.0)	42.2 (14.7)	100.0 (0)	100.0 (0)
South Dome Valley	11.1 (14.3)	98.6 (2.2)	100.0 (0)	100.0 (0)

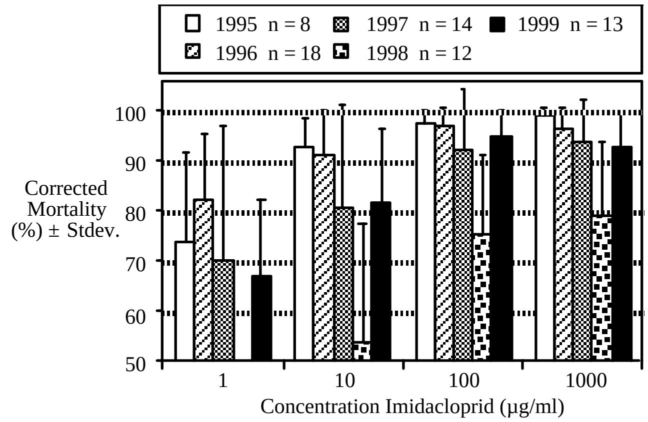

Figure 1. Changes in mean susceptibility of whiteflies from Arizona cotton to imidacloprid from 1995 to 1999.

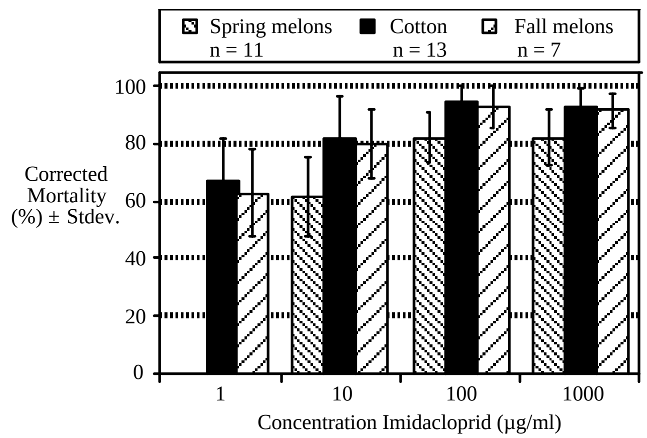

Figure 2. Comparison on mean susceptibilities to imidacloprid of whiteflies collected from different crops in central and western Arizona in 1999.

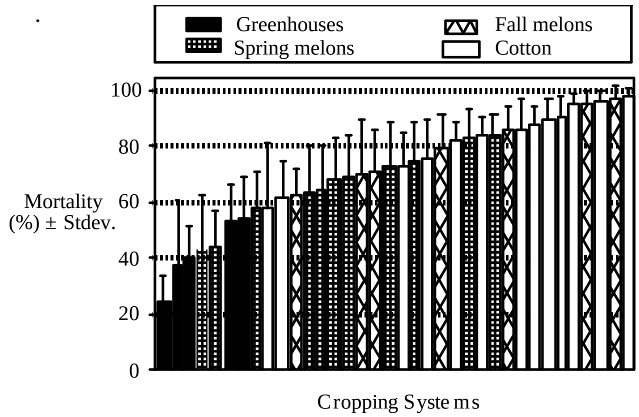

Figure 3. Distribution of mean mortality of whiteflies collected from different hosts at 1000 μg/ml imidacloprid. Whiteflies from greenhouses were least susceptible to imidacloprid.

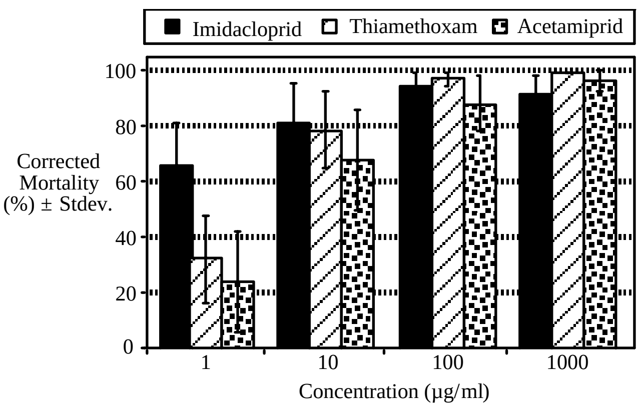

Figure 4. Comparison of mean susceptibilities to three chloronicotinyl insecticides in Arizona whiteflies collected from cotton in 1999. Imidacloprid had significantly higher toxicity than acetamiprid and thiamethoxam only at 1 μg/ml.

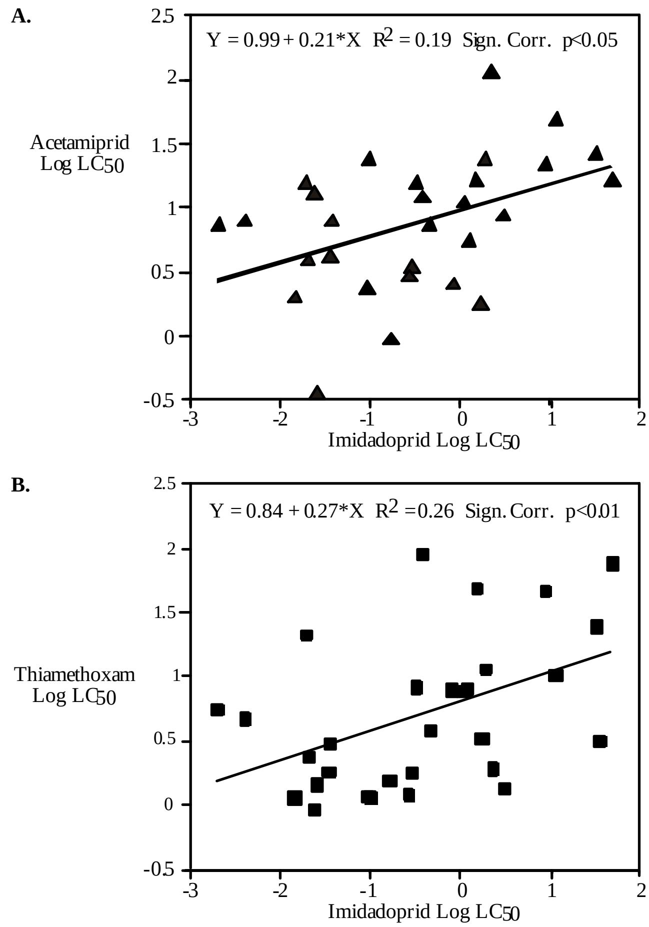

Figure 5. Results of regression analysis on LC_{50}s of three chloronicotinyl insecticides tested on all 1999 whitefly populations suggests the existence of weak cross-resistance between imidacloprid and acetamiprid (A), and between imidacloprid and thiamethoxam (B).

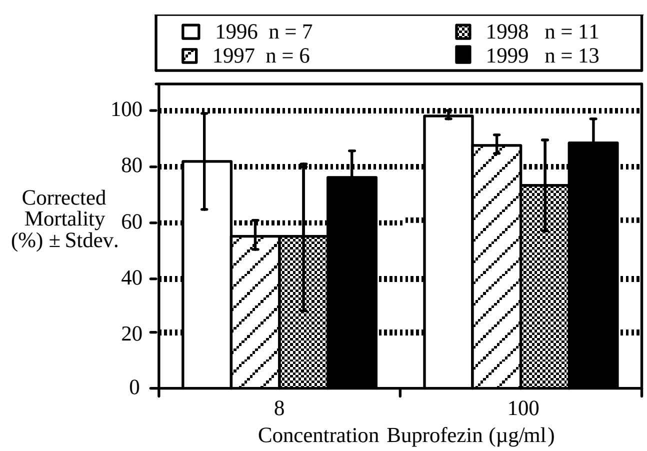

Figure 6. Susceptibility of whiteflies from Arizona cotton to buprofezin increased in 1999, after declines in the previous two years. There have been no reports of failure of buprofezin in the field.

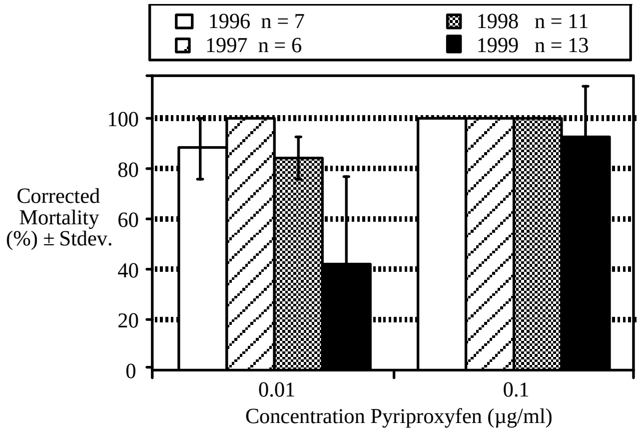

Figure 7. Since its introduction in 1996, whiteflies from Arizona cotton showed the first signs of significantly reduced susceptibility to pyriproxyfen in 1999. There are no reports of failure of pyriproxyfen in the field.

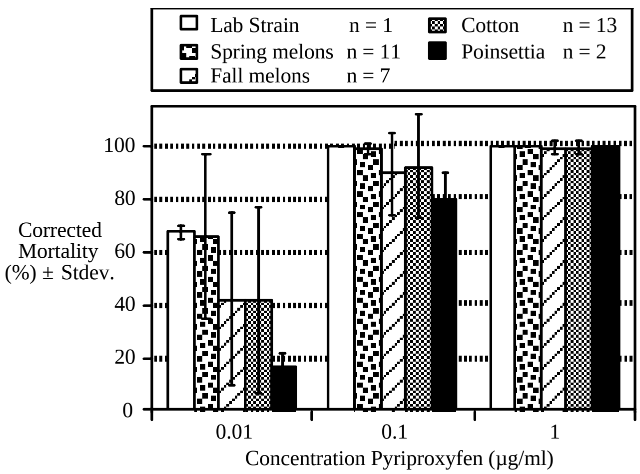

Figure 8. Whiteflies from cotton and fall melons had lower susceptibility to pyriproxyfen than those from spring melons. Greenhouse whitefly populations had the most reduced susceptibility to pyriproxyfen.