AGRONOMIC AND ENVIRONMENTAL FACTORS INFLUENCING CONTROL OF COTTON APHIDS WITH INSECTICIDES

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Abstract

Some agronomic and environmental factors were studied under field conditions to determine their effect on the insecticide susceptibility of the cotton aphid, *Aphis gossypii* Glover. In all experiments, a rapid petri-dish bioassay technique was used to characterize the aphid response to Capture 2E (bifenthrin), Lorsban 4E (chlorpyrifos), Phaser 50W (endosulfan), Furadan 4F (carbofuran), and Provado 1.6F (imidacloprid). Dark aphids were less susceptible to most insecticides (Capture, Lorsban, Furadan, and Provado) than the light morphs. Aphids from late-planted cotton were less susceptible to all five insecticides than the aphids from the early planting, however, the difference in their response to Capture was not statistically significant. Nitrogen levels significantly affect the insecticide response for cotton aphids. Aphids from high nitrogen plots were less susceptible to Capture and Provado but more susceptible to endosulfan than the aphids from low nitrogen plots. Nitrogen also affected the population dynamics of naturally occurring aphids with higher densities in plots with higher levels of nitrogen. These changes in susceptibility may explain in part the erratic control with insecticides observed in the field.

Introduction

The importance of the cotton aphid, *Aphis gossypii* Glover, as a pest in the California cotton production area, has increased since the late 80's. Even though aphid populations can be present at any time of the growing season, only mid- and late-season infestations are usually damaging to cotton production. Mid-season outbreaks have been shown to cause direct damage by reducing the cotton yield (Andrews and Kitten, 1989; Godfrey *et al*., 1997). Late-season infestations can cause indirect damage by reducing the quality and value of the lint. The honeydew produced by aphids can contaminate the lint of open bolls (a situation known as sticky cotton), and makes the cotton difficult to harvest and gin.

Researchers have been working on finding tactics to manage the mid- and late-infestations of the cotton aphid (e.g., biological control, cultural control, etc.), but presently, insecticide control is still the primary method used by growers and often the only viable tactic. Unfortunately, in the last few years, chemical control of this pest has become very erratic and unpredictable. Development of genetic-based insecticide resistance has been pinpointed as one possible explanation for this phenomenon. Moderate to high levels of cotton aphid resistance to organophosphates, carbamates, organochlorines, and pyrethroids have been documented throughout the cotton belt over the last 15 years (Grafton-Cardwell, 1991; Grafton-Cardwell *et al*., 1992; O'Brien *et al*., 1992; McKenzie *et al*., 1994; Fuson *et al*., 1995; Knabke *et al*., 1995; Grafton-Cardwell and Goodell, 1996). However, genetic-based resistance may not be the only explanation for field insecticide failure. Various factors/observations indicate that this insecticide resistance may be influenced (i.e., induced) by several agronomic and environmental factors. Researchers have noted that cotton aphid resistance to some pesticides used in California cotton, especially organophosphates, generally declines throughout the growing season (Grafton-Cardwell, 1991; Fuson and Godfrey, 1995; Knabke *et al*., 1995; Grafton-Cardwell and Goodell, 1996). The opposite result would be expected if the resistance is correlated with insecticide-based selection pressure, i.e., insecticide usage. In addition, the cotton aphid morphs (dark vs. light morphs), which are affected by environmental conditions (Wilhoit and Rosenheim, 1993; Rosenheim *et al*., 1994), may also influence the susceptibility of the cotton aphid to insecticides (Saito, 1991; Xiwu and Bingzong, 1992; Godfrey, personal communication). The results of these studies on aphid morph response to insecticides, however, have been variable. Finally, host plant species can change the cotton aphid response to insecticides, as shown by McKenzie and Cartwright (1994), and Fuson and Godfrey (in review). These researchers demonstrated that cotton aphids reared on cotton were less susceptible to insecticides than those from melons.

All these studies point toward the hypothesis that agronomic and environmental factors may affect the resistance of the cotton aphid to insecticides. The extremely plastic phenotype of cotton aphids provided an ideal model system to test this hypothesis. Our study has attempted to pinpoint some of the factors that influence the response of this insect to insecticides. Through an understanding of these factors, the resistance may be better managed and field control improved.

Materials and Methods

A known Capture-resistant clonal aphid colony was used in all experiments. The first female aphid of this colony was obtained from a aphid colony collected from the San Joaquin Valley (Christiansen, personal communication). For all experiments, insecticide dose response curves from this pyrethroid-resistant clonal aphid colony were obtained by using a modified rapid bioassay petri-dish technique developed by McKenzie *et al* (1994). This technique consisted of placing adult cotton aphids into 50 mm petri-dishes which inner surfaces have been coated with serial dilutions (at least 4 doses) of parts-per-million (ppm)

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concentrations of Capture 2E (bifenthrin), Lorsban 4E (chlorpyrifos), Phaser 50W (endosulfan), Furadan 4F (carbofuran), and Provado 1.6F (imidacloprid). A total of 20 aphids was placed into each petri-dish and mortality determined after 3 hours of exposure. Four replicates (dishes) for each dose/insecticide combination were used. Mortality was recorded when the aphid was unable to either walk at least one body length in a directed manner or to right itself after being turned over. Natural mortality was taken into account by the use of controls (i.e., petri-dishes without insecticides).

Aphid Morph Effects on Insecticide Susceptibility

Aphids from the clonal, pyrethroid-resistant colony were reared on Acala cotton seedlings under greenhouse conditions. A range of morphs was obtained naturally. Dark and light morphs were selected to test their response to the above insecticides (bioassay conducted on 8/14/97). At least four replications (dishes) were used for each morph/dose/insecticide combination. For each insecticide, dose response curves for dark and light morphs were obtained and statistically compared using probit analysis (Polo PC software).

Planting Date Effect on Insecticide Susceptibility

Acala 'Maxxa' cotton was planted on 4/4/97 (early planting), and 5/30/97 (late planting) in field plots located at the UC Cotton Research Station near Shafter, CA. Each treatment (planting date) had 4 plots (replicates) that were arranged in a randomized block design. Each plot consisted of 4 rows. Four weeks after emergence of the second planting date, the 4-5th main stem node leaves (from the top) of many cotton plants in all the plots were infested with aphids from the known pyrethroid-resistant clonal colony. After infesting the leaves, the aphids were enclosed with cages made from floating row cover material. This material allows ~90% light transmittance and only minimal (~1-2ºC) temperature elevation while retaining the clonal aphids and excluding predators and wild aphids. Aphids were kept in the cages for 3 weeks allowing them to go through at least 3 generations. Cages with the aphids were relocated to new leaves every 3-4 days in order to keep them at the same main stem node position within the plant. Fertilization and irrigation schedules were adjusted so these factors were constant between planting dates at the time of aphid infestation. Cotton aphids reared under these conditions were collected from these cages (7/29/97) and their insecticide susceptibility was characterized using the bioassay petri-dish technique described above. From each plot, one replication (petri-dish) was used for each dose/insecticide combination. Probit analysis was used to compare the aphid dose responses for each insecticide between treatments. Plant nitrogen levels were monitored with petiole analyses, and plant growth/development with plant mapping evaluations.

Nitrogen Level Effect on Insecticide Susceptibility

Two nitrogen regimes (treatments) were established within field plots at the UC Cotton Research Station. Each nitrogen regime had 4 plots (replicates) with 4 rows of Acala 'Maxxa' cotton per plot planted on 4/4/97. The nitrogen regimes applied to the plots were 0 (low nitrogen) and 160 lb. of nitrogen/acre (high nitrogen). Soil samples taken from these plots, previous to the fertilization, showed that the residual nitrogen in the soil was ~50 lb. N per acre. The irrigation schedule was constant in both treatments. The plots were arranged in a randomized block design. Plants within each plot were infested with aphids from the known pyrethroid-resistant clonal colony on 7/1/97 and kept in cages as in the planting date experiment. Cotton aphids reared under these conditions were collected from some of the cages after 3 weeks and their susceptibility to Capture was characterized using the bioassay petri-dish technique described above (bioassay conducted on 7/23/97). Three weeks later a second bioassay (8/13/97) was conducted with the five insecticides using the rest of the cages. For both bioassays, the cages were relocated every 3-4 days to keep the aphids at the same position within the plants. Probit analysis was used to compare aphid response to the insecticides between the two nitrogen treatments. One replication (petri-dish) for each dose/insecticide combination was taken from each plot. Plant nitrogen levels were monitored with petiole analyses.

Nitrogen Level Effect on Natural Aphid Population Dynamics

The naturally occurring cotton aphid populations from plots of the nitrogen level experiment (two nitrogen levels with 4 plots each) were monitored at weekly intervals from 16 June to 20 August. Leaf samples (20 fifth main stem node leaves from each plot) were taken and the aphids counted in the laboratory within the following hour. Dark and light morphs were counted separately as well as apterous and alate forms.

In addition to the bioassays conducted with the aphids enclosed in the cages, a petri-dish bioassay was conducted on aphids naturally occurring in the field on 7/24/97. The aphids used were collected from the plots described above. The chemicals used in the bioassay were Capture and Lorsban.

Results and Discussion

The cotton aphid shows phenotypic plasticity to different traits. Its fecundity and morphology are affected by nutrient availability, temperature, photoperiod, and host plant (Miyazaki, 1989; Wilhoit and Rosenheim, 1993). The present study showed that the environmental, aphid-based or plant-based factors may not only affect easily observable characteristics such as color, size, generation time, and fertility but also the insect response to different insecticides.

Aphid Morph Effects on Insecticide Susceptibility

The effects of the aphid morph on the insecticide susceptibility of the known pyrethroid-resistant clonal colony can be seen in figure 1. Dark aphids were less susceptible to Capture, Lorsban, Furadan, and Provado than the light morphs. There was not enough evidence to conclude that dark and light morph response to endosulfan was significantly different. These results seem to agree with the study of Xiwu and Bingzong (1992) who found that the dark aphids were more tolerant to some pesticides than the light ones. This difference in insecticide susceptibility could be a result of size. Dark aphids are usually larger in size than the light morphs. Being larger, it may be reasonable to suspect that the dark-morph aphids may also have larger amounts of all type of structural proteins and enzymes, including detoxifying enzymes, which can make these aphids less susceptible to the insecticides. In addition, the ratio of exposed surface to volume decreases with size, therefore, the relative dose exposure may decrease for the dark morphs.

Planting Date Effect on Insecticide Susceptibility

Figure 2 shows the susceptibility to five insecticides of the known pyrethroid-resistant clonal colony of aphids reared on cotton plants that were planted at two different dates. Aphids from the late planting date plots were less susceptible to Lorsban, Furadan, Provado, and endosulfan than the aphids from the early planting date. The same trend was observed for Capture, however, the difference was not statistically significant. These results seem to be contradictory to the study by Fuson *et al* (1995). These researchers found, using direct insecticide applications to field plants, a trend towards better control by some insecticides within later planted cotton, even though this trend was not statistically significant. Fuson *et al.* (1995) concluded that part of their results may be related to a change on spray coverage (i.e., later-planted cotton treatments had less foliage and therefore better insecticide coverage).

Nitrogen Level Effect on Insecticide Susceptibility

Figure 3 summarizes the effect of the nitrogen levels on the susceptibility to five insecticides of the known pyrethroid-resistant clonal colony. In the bioassay conducted on 8/13/97, aphids from the plots with high nitrogen were less susceptible to Capture and Provado than the aphids from the low nitrogen plots. The opposite result was found for endosulfan. No significant differences were found in the insecticide response to Furadan and Lorsban. This study supports the field study done by McKenzie *et al*. (1995), which demonstrated that natural populations of aphids on cotton showed decreased pyrethroid susceptibility when cotton plants had increased levels of nitrogen. Figure 4 shows that the susceptibility to Capture changes over time. Comparing the same treatments (e.g., high nitrogen in the first bioassay vs. high nitrogen in the second bioassay), aphids were more susceptible in the second bioassay than in the first one. However, in both bioassays aphids from the high nitrogen plots were less susceptible to Capture than the aphids from the low nitrogen plots. This change of susceptibility over time is in concordance with the decline of insecticide resistance throughout the growing season observed in the field by other researchers (Grafton-Cardwell, 1991; Grafton-Cardwell *et al*., 1992; O'Brien *et al*., 1992; McKenzie *et al.*, 1994; Fuson *et al*., 1995; Knabke *et al*., 1995; Grafton-Cardwell and Goodell, 1996). This change in susceptibility over time may be linked to changes in nitrogen availability within the plant (e.g., leaf nitrogen availability decreases throughout the growing season). Despite the changes in Capture susceptibility of the pyrethroid-resistant clonal colony in both bioassays, these aphids were still less susceptible to Capture than a known susceptible clonal aphid colony used as comparison (Figure 4).

Nitrogen Level Effect on Natural Aphid Population Dynamics

Figure 5 shows the effect of the nitrogen levels on the population dynamics of naturally occurring aphids. Aphids from plants in the high nitrogen plots were present in higher numbers than the ones in the low nitrogen plots. Rosenheim *et al*. (1994), in laboratory experiments, showed that the growth rate of cotton aphids increased when the plants that harbor the aphids were fertilized with nitrogen. Our results also corroborated the field results obtained by Slosser *et al*. (1997) who found a positive linear correlation between aphid density and nitrogen fertility in cotton.

Figures 6 & 7 show that the nitrogen levels also had an effect on the susceptibility to Capture and Lorsban of the naturally occurring aphid population. The naturally occurring cotton aphids present in the high nitrogen plots were less susceptible to Lorsban and Capture than the ones in the low nitrogen plots.

Summary

Presently, insecticides are a major tool used to control cotton aphids in cotton. However, in recent years, insecticide control in California has become erratic and unpredictable. More frequent applications and tank-mixes are commonly needed to achieve acceptable control. The present study shows that some agronomic and environmental factors can influence the response of the cotton aphid to different insecticides, which could explain in part the insecticide failures observed in the field. The dark vs. light aphid morph experiment indicated that the dark-morph aphids possessed a significantly lower susceptibility to most insecticides than the light morphs. In addition, the planting-date experiment showed that aphids reared on late-planted cotton were less susceptible to most insecticides than the aphids reared on early-planted cotton. Finally, the nitrogen-level experiment suggests that meanwhile aphid susceptibility to some insecticides may decrease with higher levels of nitrogen on the plant, the opposite result was observed with at least one of the insecticides. Our study also shows that nitrogen may also affect the population dynamics of aphids. Additional work is needed to test if any of these changes in insecticide susceptibility are significant in a field situation, and also to determine the physiological mechanisms behind these changes. By a better understanding of the role that agronomic and environmental factors play in the insecticide susceptibility of this aphid, an increase in the predictability and effectiveness of insecticide control could be achieved (i.e., best time of application, best choice of insecticide, modification of cultural practices, etc.). This may lead not only to more effective control but also to a reduction in the number of insecticide applications.

Acknowledgments

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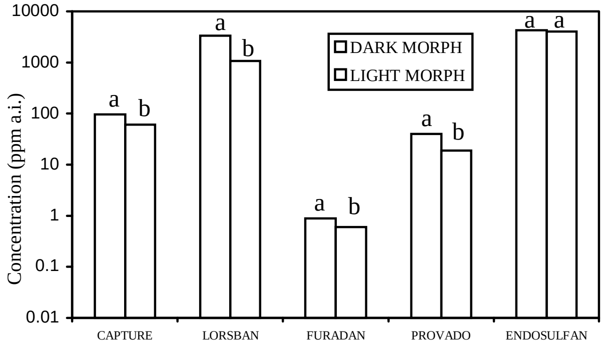

Figure 1. Influence of aphid morph on the susceptibility of a clonal pyrethroid-resistant cotton aphid colony to different insecticides. Shown are the LC_{95} values from dose response curves obtained for each chemical.

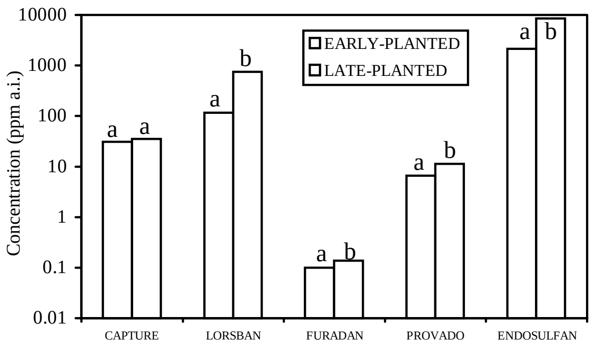

Figure 2. Influence of planting date on the susceptibility of a clonal pyrethroid-resistant cotton aphid colony to different insecticides. Shown are the LC_{95} values from dose response curves obtained for each chemical.

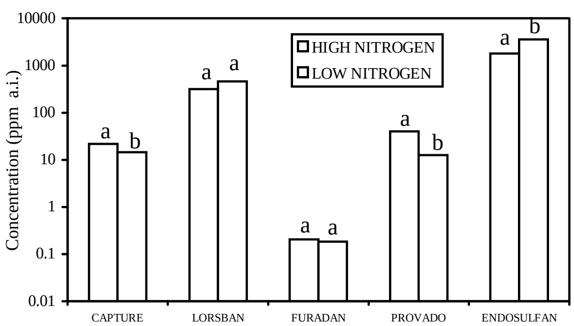

Figure 3. Influence of nitrogen level on the susceptibility of a clonal pyrethroid-resistant cotton aphid colony to different insecticides. Shown are the LC_{95} values from dose response curves obtained for each chemical.

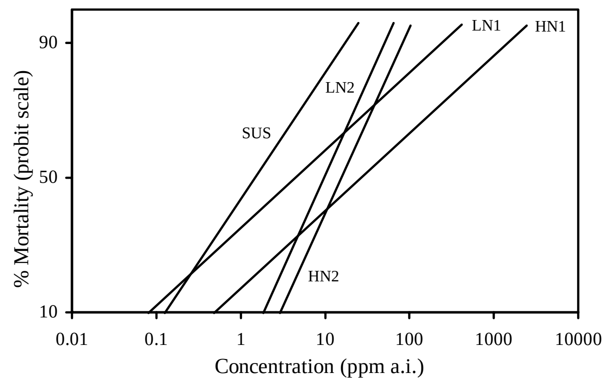

Figure 4. Change in the susceptibility of the cotton aphid to Capture (bifenthrin) over time. LN1 and HN1 are dose response lines from a first bioassay (7/23/97) with pyrethroid-resistant clonal aphids reared on plants with low (LN) and high (HN) levels of nitrogen respectively. LN2 and HN2 are dose response lines from a second bioassay (8/14/97) with the same clonal aphids and treatments. SUS=dose response line from a susceptible clonal aphid colony (bioassay: 8/14/97).

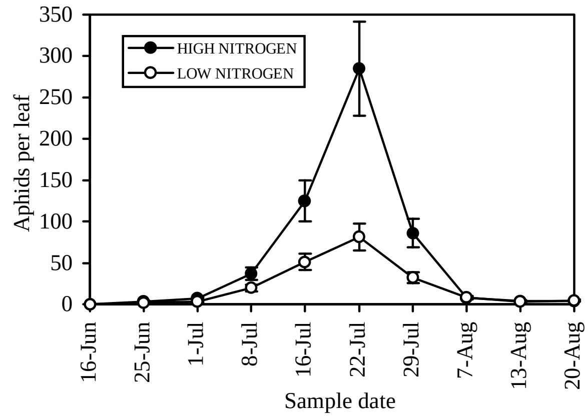

Figure 5. Naturally occurring cotton aphid population density (dark + light morphs) from plots with high and low levels of nitrogen. Cotton planted on 4/4/1997.

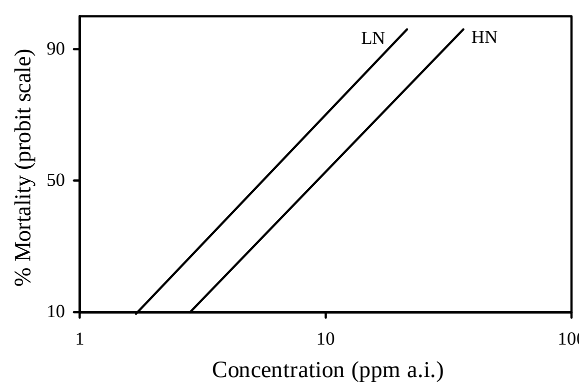

Figure 6. Change in susceptibility to Capture of a naturally occurring cotton aphid population present on plots with high (HN) and low (LN) levels of nitrogen. Bioassay was done on 7/24/97.

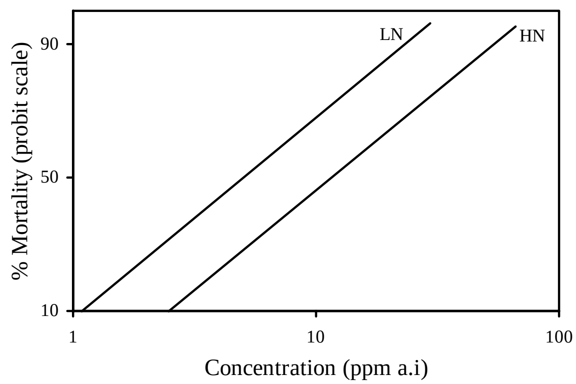

Figure 7. Change in susceptibility to Lorsban of a naturally occurring cotton aphid population present on plots with high (HN) and low (LN) levels of nitrogen. Bioassay was done on 7/24/97.