INFLUENCE OF COTTON NITROGEN FERTILITY ON COTTON APHID, *APHIS GOSSYPII*, POPULATION DYNAMICS IN CALIFORNIA

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Abstract

The cotton aphid, *Aphis gossypii* Glover, has developed into a key pest of cotton in California during the 1990's. Studies were conducted to examine specific aspects of cotton aphid biology and the effects of cultural control measures on populations with the goal of incorporating these tools into robust IPM programs. Previous laboratory and small plot field studies have shown that high levels of nitrogen can increase aphid populations, therefore the possibility of using this as a cultural control measure was examined. Aphid populations in 1999 were characterized by overall low to moderate levels which developed fairly late in the season at a time when the soil nitrogen bank had likely largely been depleted/altered. Aphid levels were monitored in seven large plot grower field studies with four differential nitrogen regimes (50 to 200 lbs./A nitrogen). Low aphid populations developed late-season (Aug. and Sept.) in five of the seven fields. There was consistently a trend for more aphids in the 200 lbs./A nitrogen treatment compared with the 50 lb./A treatment with a 3-4X range across the treatments. Aphid densities in all cases were well below treatment thresholds. Detailed studies on cotton aphid population dynamics showed that generation times of aphids, from a laboratory colony placed into field cages, ranged from 12.3 to 9.3 days and the number of offspring per adult averaged 1.7 and 5.3 under 20 and 250 lbs./A nitrogen regimes, respectively. A negative effect of potassium on aphid fitness was seen and warrants further research. Finally, naturally-occurring aphid populations were monitored in plots with 0 (=20 lbs./A residual in soil), 50, 100, 150, and 200 lbs./A nitrogen. At the onset of aphid build-up, application of either a pyrethroid insecticide (Capture®) or a chloronicotinyl insecticide (Provado®) or no insecticide was superimposed. At 3 weeks following the insecticide application, in the untreated plots, aphid numbers increased slightly across the increasing nitrogen levels (10.9 to 24.8 aphids per leaf from 20 to 200 lbs./A N). Provado controlled the infestation as expected based on its activity spectrum. At 0 to 100 lbs./A N, the aphid population was 50-75% higher in the Capture-treated plots compared with untreated. However, at 150 and 200 lbs. N/A, there were 3 and 4 times, respectively, more aphids in the Capture plots compared with the untreated.

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Introduction

During the last 10 years, the cotton aphid, *Aphis gossypii* Glover, has developed from a non-pest to one of the most significant insect pests of California cotton. In 1997, cotton aphid outbreaks were severe and widespread and an estimated 3.5% yield loss occurred. The economic impact of this pest to the California industry in 1997 totaled $34 million in crop loss and $38 million in control costs (Williams 1998). Cotton aphid infestations during the late-season (mid-Aug. to Sept.) are problematic because the aphids deposit honeydew on the exposed cotton lint (Rosenheim et al. 1995). This damage reduces the value of the lint and threatens the reputation of the industry for high quality cotton. However, since ~1992 mid-season (July to mid-Aug.) cotton aphid infestations have been the most prevalent and damaging. The mid-season aphids compete with the fruiting structures for photosynthates and thereby directly reduce cotton yields (Godfrey et al., 1997 and Godfrey and Wood ,1998). Reasons for this change in pest status of cotton aphid are unclear. However, this insect pest and other traditional insect pests have contributed to the paucity of economic return for cotton production and, in part, to the decline in acreage in recent years.

One of the most noticeable changes in cotton production over the last 10 years is the use of a plant growth regulator (mepiquat chloride) instead of irrigation and nitrogen deficits to limit early-season cotton vegetative growth. This has allowed cotton production practices in the SJV to evolve to higher nitrogen fertilization and irrigation inputs. Host plant conditions including high nitrogen and high leaf water potential, i.e., adequate moisture, are generally optimal for aphid population growth and development. Cisneros and Godfrey in a small plot study in 1997 found that there were 3 times more cotton aphids on cotton in a high nitrogen treatment (200 lbs. N/A) compared with the low nitrogen treatment (50 lbs. N/A) (Cisneros and Godfrey 1998). Slosser et al. (1997) found an association between nitrogen rate and aphid numbers in Texas. These results heightened our interest in this area, as this may be a way to mitigate cotton aphid populations. A low amount of nitrogen obviously limits production, therefore this study seeks a nitrogen level optimal for plant growth but low enough to limit aphid reproduction. To this end, nitrogen guidelines on Acala cotton varieties in the SJV are currently being reviewed and researched (Hutmacher et al. 1998). The goal of this study was to investigate the influence of cotton nitrogen fertilization levels on cotton aphid populations in grower fields in the San Joaquin Valley and to conduct detailed small plot studies designed to improve our understanding of the influence of nitrogen on cotton aphid population dynamics.

With the awareness of growers to cotton aphid and the dependence on insecticides to control this pest (and impending changes in insecticide registration status), cultural control measures for this pest are needed.

Procedures

Three studies were conducted in 1999 with results contributing to understanding the nitrogen-cotton aphid interaction. These studies were a continuation of our 1998 work (Godfrey et al. 1999).

Grower Field Studies

Replicated field studies with differential nitrogen levels, set up by the Cotton Agronomist and Cotton Farm Advisors in grower fields, were utilized for the first approach. These studies were designed to evaluate the relationship between cotton nitrogen input and cotton yield and were set up as strip tests, generally 8 rows wide x the field length (up to 1/4 mile long) x 4 blocks. Target nitrogen rates in these studies were 50, 100, 150, and 200 lbs. N/A; the lowest rate utilized the residual soil nitrogen and therefore varied across locations. The three highest rates were the residual plus the appropriate amount of applied N generally in June. Field sites were located in Tulare Co., Fresno Co./West Side Research and Extension Center, Kings Co., Merced Co., Madera Co., and Kern Co. (Shafter Research and Extension Center and in a grower field). Planting dates varied across locations but were generally in mid-late April in 1999. Nitrogen was generally applied in early June. Cotton aphid populations were sampled at weekly intervals from each plot from July to September. A twenty-leaf sample, fifth main stem node leaf from the top, was used. Aphids were counted with the aid of 50X magnification. Aphid density, morph, and incidence of alates were recorded for each sample.

Nitrogen-Pyrethroid Insecticide Interaction

The second experiment was designed to study the interaction between a pyrethroid insecticide and nitrogen level on aphid population dynamics. The pyrethroid insecticides are used for lygus bug management; they are among the most effective products for control of this pest, but have the drawbacks of destroying populations of natural enemies and stimulating aphid reproduction. Several researchers have noted an increase in cotton aphid numbers following pyrethroid insecticide application. Kidd et al. (1996) and Godfrey (1998) have shown flaring of aphid populations with lambda-cyhalothrin, bifenthrin, and cyfluthrin. Therefore, in independent studies, nitrogen rate and pyrethroid applications have been shown to influence aphid numbers. In this study, nitrogen rates of 0 (actually had ~20 lbs./A N from a soil residual source), 50, 100, 150, and 200 lbs. N/A were applied on 21 June to a cotton plot planted on 5 May. Insecticide treatments of Capture® 2E at 0.06 lbs. AI/A, Provado® 1.6F at 0.047 lbs. AI/A and an untreated were superimposed across the nitrogen treatments. Insecticide applications were made on 19 Aug. to plots 8 rows by 90 feet by 4 blocks; application was delayed until aphid populations reached ~5 per leaf. Aphid populations were quantified weekly, as previously described, during Aug. and Sept. Cotton yields were quantified by harvesting the middle two rows in Oct.

Nitrogen and Aphid Population Dynamics

A manipulative field experiment, the third study, was conducted in 1999 in an acala cotton field located at UC Cotton Research and Extension Center near Shafter. The treatments were: 0, 50, 100, 150, 200, and 250 lb./A nitrogen (ammonium sulfate fertilizer). There was also a treatment of 200 lb./A nitrogen split in 4 applications (applied every two weeks), a treatment with an alternate source of nitrogen (200 lb./A of urea), and a "balanced" fertilization (200 lb./A nitrogen + 100 lb./A K_2O). Treatments, when possible, were adjusted to soil residual nitrogen (20 lb./A) and were applied on 21 June (cotton was planted on 5 May). Cotton aphids from a clonal colony (one genotype) were out planted to five plants in each plot on July 16. These aphids were enclosed in single-leaf cages (5 adults per cage) for 24 hours located on the 5th main stem leaf from the top of the plant. After this period, the adults were removed and the number of offspring produced was counted. These cohorts of aphids (first generation) were monitored and their survival, fecundity, and generation time recorded. A second cohort of aphids (second generation), the offspring of the first generation, was also monitored and their fitness factors determined. Finally, a third cohort was also monitored (third generation). In all cases, aphids were moved to new leaves every week to keep the aphids at the same position within the plant (5th leaf) and to avoid drastic changes in the leaf physiology due to the cage.

Results

Grower Field Studies

Cotton aphid populations were generally low in 1999, but levels responded to nitrogen regime. Populations generally built-up late in the season and at that time the nitrogen levels had likely largely equilibrated or at least were greatly altered compared with the treatment regimes. In the grower field strip tests, aphid populations developed in five of the seven sites (Table 1). The highest aphid density was 9 per leaf. However, at all the five sites with aphids, there was a trend with more aphids at the higher nitrogen levels; a 3-4X range was commonly seen from the 50 to 200 lbs./A treatments. Similarly, the percentage of leaves with aphids also responded positively to nitrogen level.

Nitrogen-Pyrethroid Insecticide Interaction

Cotton aphid populations were also slow to develop in the pyrethroid/nitrogen level study location. Aphid populations were generally higher in the untreated plots in the 100 to 200 lbs./A nitrogen treatments compared with lower nitrogen rate treatments during the period of aphid infestation (mid-Aug. to mid-Sept.). On 2 Sept., there were nearly 3 times more aphids in the 200 compared with 20 lbs. treatment. At 3 weeks following the insecticide applications (9 Sept.), some obvious trends were seen as shown in Fig. 1. In the untreated plots, aphid numbers increased slightly across the increasing nitrogen levels (10.9 to 24.8 aphids per leaf). Provado controlled the infestation as expected since this product has activity on lygus bugs and cotton aphids. At 0 to 100 lbs./A nitrogen, the aphid population was 50-75% higher in the Capture-treated plots compared with the untreated. However, at 150 and 200 lbs./A nitrogen, there were 3 and 4 times, respectively, more aphids in the Capture-treated compared with the untreated. Cotton yields ranged from 2145 to 3211 lbs. seed cotton per A across the 12 treatments. Yields averaged highest in the 50 lb./A nitrogen treatment and declined progressively to the 200 lb./A treatment; yields were lowest in the 0 lb./A treatment. Across the insecticide treatments, yields were ~150 lbs. greater in the Provado and Capture treatment then in the untreated. These products may have provided some lygus control, although at this late part of the season the value of lygus control is very questionable. Aphid populations did not reach damaging levels.

Nitrogen and Aphid Population Dynamics

Results from the population dynamics study showed that, for the first cohort, the aphids from high nitrogen plots, especially the ones reared on plants fertilized with ammonium sulfate only, were significantly more fecund and had a shorter generation time than the aphids from low nitrogen plots (Fig. 2, 3). Generation times ranged from 12.3 days (0 lbs./A nitrogen [=20 lbs./A nitrogen residual]) to 9.3 days (250 lbs./A nitrogen). Similarly, the number of offspring per adult averaged 1.7 and 5.3 with the low and high nitrogen regimes, respectively. Conversely, potassium seemed to have a detrimental effect on the aphid fitness. Thus, aphids from the treatment that had the "balanced" fertilization (200 lb./A nitrogen + 100 lb./A K_2O) had a lower fecundity and longer generation time than individuals from the two highest nitrogen treatments (200 and 250 lb./A of ammonium sulfate). This negative effect of potassium on aphid fitness has been observed in other systems with other herbivore species. Further studies should focus in understanding the effect of this fertilizer on the plant physiology, and its effects at the population level of this insect. No differences in aphid survival were found among treatments; however, the overall survival was low (about 33%). As in the first generation, there was a trend of higher fecundity and shorter generation time with aphids from the highest nitrogen plots; however, the differences among treatments were not statistically significant in the second generation. A similar pattern was found for the treatment that had potassium, in which the aphids showed one of the lowest fecundity and the longest generation time, though this was not significantly different from the other treatments (Fig. 2, 3). Aphid survivorship among treatments was similar (~43%) across the treatments.

Summary

Nitrogen level appears to be an important factor in altering cotton aphid population levels with high nitrogen inputs promoting higher aphid populations in cotton. Higher levels of nitrogen appear to stimulate aphid fecundity and hastens aphid development to the reproductive stages. In addition, lower nitrogen levels appear to mitigate the capacity of pyrethroid insecticides to flare aphid numbers. Unfortunately, the two years of this research (1998 and 1999) were characterized by overall low to moderate cotton aphids levels and unusual environmental conditions, especially cool, wet spring (1998) and relatively cool summer (1999). Therefore, devising sound recommendations on nitrogen effects on cotton aphid populations should await until this research is conducted during a "normal" year.

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Table 1. Response of cotton aphid populations, at the time of the peak, to applied nitrogen levels in cotton in the San Joaquin Valley, 1999.

Location/Nitrogen Treatment (lbs./A)	Aphids per leaf	% Leaves with Aphids	Date of Peak
Shafter REC - 50	0.7	20	3 Sept.
100	1.3	40	3 Sept.
150	1.7	50	3 Sept.
200	3.3	72.5	3 Sept.
Kern Co. - 50	0.05	5.0	12 Aug.
100	0.05	2.5	12 Aug.
150	0.05	2.5	12 Aug.
200	0.08	2.5	12 Aug.
Kings Co. - 50	0.3	12.5	2 Sept.
100	0.9	30	2 Sept.
150	1.4	35	2 Sept.
200	1.2	35	2 Sept.
Tulare Co. - 60	1.8	42.5	2 Sept.
100	3.2	47.5	2 Sept.
150	7.9	75	2 Sept.
200	9.0	82.5	2 Sept.
West Side REC - 50	0.7	25	15 Sept.
100	1.0	35	15 Sept.
150	1.1	40	15 Sept.
200	2.2	50	15 Sept.

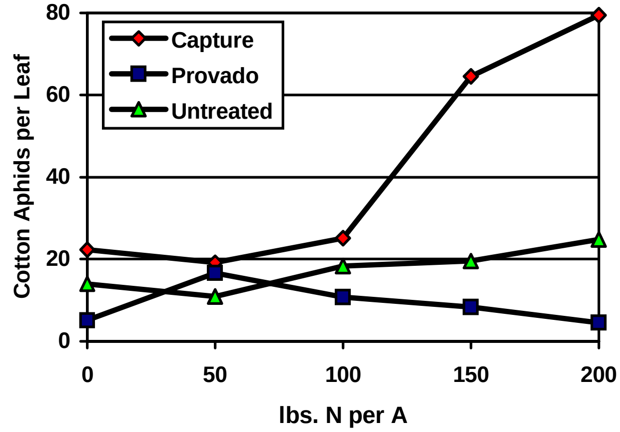

Figure 1. Interaction of insecticide application (targeted for lygus bugs) and nitrogen rate on the number of cotton aphids per leaf at 3 weeks after insecticide application (9 Sept. 1999).

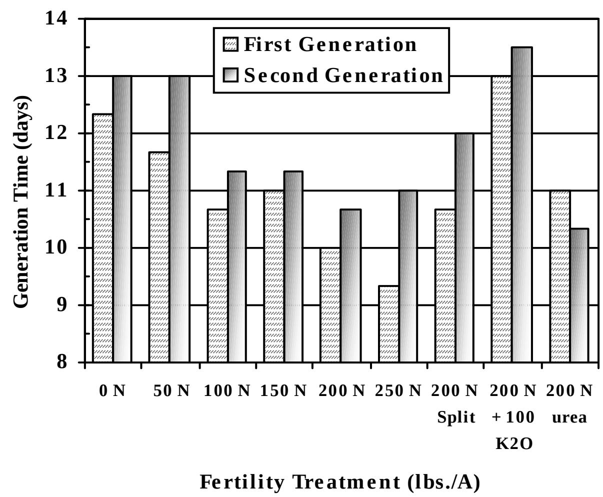

Figure 2. Effects of cotton fertility treatments on cotton aphid population dynamics – generation time, 1999.

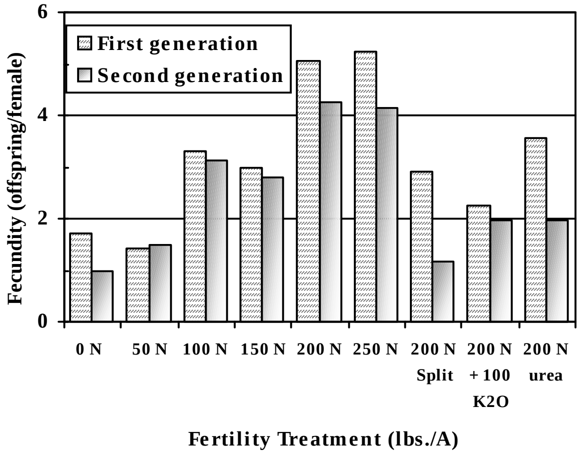

Figure 3. Effects of cotton fertility treatments on cotton aphid population dynamics – fecundity, 1999.