INTERACTION OF COTTON APHID POPULATION DYNAMICS AND COTTON FERTILIZATION REGIME IN CALIFORNIA COTTON

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Abstract

The emergence of cotton aphid as a significant pest, and secondarily the buildup of silverleaf whitefly infestations, has challenged the cotton IPM system in California. The number of insecticide applications needed for cotton production has increased from an average of 2-3 to 4-6 or more per season in recent years in many areas. A portion of this increase has resulted directly from cotton aphid applications; these treatments with non-selective materials have disrupted the biological control of other arthropod pests such as spider mites and lepidopterous larvae. Additional applications have then been needed for these pests. In 1995 and 1996, cotton yield was compromised by outbreaks of one or more of these arthropod pests. In 1997 and 1998, management of these arthropod pests was apparently good; however, the increased cost of production is problematic. Although aphid management with insecticides is presently feasible, the increased costs of production are problematic. IPM strategies which mitigate cotton aphids before they explode in the cotton field are needed and may improve the profitability of cotton production in many parts of the SJV. High levels of nitrogen fertilization appear to promote increased cotton aphid reproduction and the buildup of high in-field aphid populations. Studies were conducted to quantify this interaction and to develop nitrogen strategies to optimize cotton production while still minimizing cotton aphid population development.

Introduction

The cotton aphid, *Aphis gossypii* Glover, has developed into a significant pest of cotton in California. The importance of this pest to cotton production has changed significantly in the last 10-15 years. Prior to the mid-1980's, the cotton aphid was considered an occasional pest in the San Joaquin Valley (SJV). Beginning in ~1986, significant infestations of cotton aphids were seen on seedling cotton and on late-season cotton. Infestations on mid-season cotton (June to August) were minimal until 1992 when significant, damaging populations occurred. This trend has continued to varying degrees, particularly severe in 1994 and 1995. In 1995, cotton yield losses from cotton aphids were estimated at 3.5% (Williams 1996), in spite of management actions. This yield loss rivaled that from spider mites and lygus bugs, the established cotton arthropod pests in California. Cotton aphid outbreaks were severe and widespread in 1997 and an estimated 3.5% yield loss occurred and ~$40/acre control costs were incurred (Williams 1998). In 1996 and 1998, years without widespread high cotton aphid densities, significant costs were still incurred as preventative treatments were applied. Reasons for this shift in cotton aphid population severity are unclear; however, the yield losses and threat of contaminated lint from cotton aphid means that aphid control has become a necessary production cost for California cotton growers.

Considerable research has been conducted on this pest in California in the 1990's. The damage and treatment thresholds for cotton aphids have been defined and vary with the plant growth stage (early-season [Rosenheim et al. (1997)], mid-season [Godfrey et al. (1997), Godfrey and Wood (1998)], and late-season [Rosenheim et al. (1995)]). Biological control is an important natural control measure for several arthropod pests of SJV cotton. Predators and parasitoids effectively reduced aphid populations on pre-reproductive stage cotton (Rosenheim et al. 1997, Colfer and Rosenheim 1995). However, during the mid- and late-season, biological control of the cotton aphid is poor. In controlled experiments, green lacewings (common during the mid- and late-season) are effective predators of cotton aphids; however, the complex of hemipteran predators disrupt aphid biological control (Rosenheim et al. 1995, Rosenheim and Cisneros 1994). These hemipteran predators feed rather indiscriminately and consume potential beneficial as well as pest insects. On cotton, host plant resistance to cotton aphid is not available; the susceptibility among the approved California Acala cotton cultivars to aphid population development was found to be similar (Godfrey and Wynholds, unpl.).

Therefore, insecticides are a primary means of managing mid-season and late-season cotton aphid infestations. Organophosphate, carbamate, organochlorine, nicotinyl, and diamidide insecticides are all used to control aphids in California. Aphid control with insecticides can be very good with up to 85% control at 21 days after treatment (Wright et al. 1997). However, insecticide efficacy has often been erratic and the duration of control is often less than 10-14 days. Cisneros and Godfrey (1998) showed that agronomic and environmental factors, such as cotton foliage nitrogen level, environmental conditions, and cotton plant age all influence insecticide susceptibility. In addition, genetic-based insecticide resistance is also common in the cotton aphid (Grafton-Cardwell 1991, Fuson et al. 1995, Grafton-Cardwell et al. 1997).

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:1008-1011 (1999)
National Cotton Council, Memphis TN

Methods are needed to manage cotton aphids before they infest cotton fields or to minimize population build-up within cotton fields. The potential impact of FQPA actions along with the propensity of cotton aphids to develop resistance to commonly used insecticides highlight the importance of developing other management strategies. Nitrogen management may be one such technique for influencing cotton aphid population dynamics. Over the last 10-15 years, cotton production practices in the SJV have evolved to higher nitrogen fertilization and irrigation inputs. In the 1980's, early-season stress, accomplished with irrigation and/or nitrogen, was desired to keep the plant from accumulating too much vegetative growth. This vegetative growth was often at the sacrifice of reproductive biomass. In recent years, mepiquat chloride applications have been used to limit early-season vegetative growth. Therefore, nitrogen and water deficit conditions are minimized. These host plant conditions, including high nitrogen and adequate moisture, are generally optimal for aphid population growth and development.

Previous research, including laboratory and small plot field studies, has shown that nitrogen can influence aphid population dynamics. Rosenheim investigated the influence of plant nitrogen level on cotton aphid morph development in a laboratory study. Aphid populations on cotton plants with high compared with low nitrogen were more likely to shift to a predominance of dark morphs. This morph is more reproductive and associated with aphid outbreaks compared with the light morph (Rosenheim et al. 1994). Slosser et al. (1997) found a positive relationship between nitrogen level (0 to 88 lbs./A) and aphid density in May planted cotton but not in cotton planted in April or in June in Texas. Cisneros and Godfrey (1998) found that there were 3 times more aphids in the high nitrogen treatment (200 lbs. N/A) compared with the low nitrogen treatment (50 lbs. N/A) in studies conducted in California in 1997. Aphid populations peaked at 81 per leaf in the low nitrogen rate compared with 284 per leaf in the high nitrogen treatment. A nitrogen rate of 50 lbs. N/A is probably not feasible for optimal cotton yield, but this study has shown the potential for using nitrogen to manage cotton aphids. The typical application rate in the SJV is ~200 lbs. N/A (Hutmacher and Munk 1997). Nitrogen guidelines on Acala cotton varieties in the SJV are currently being reviewed and researched (Hutmacher et al. 1998) so this is an optimal time to quantify the effects of nitrogen on cotton aphids and to incorporate this effect into the new guidelines.

Procedures

Four studies were conducted in 1998 to further define the effects of nitrogen level on cotton aphid populations. For the first study, replicated field studies set up by the Cotton Agronomist and Cotton Farm Advisors in grower fields were utilized. 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. The 1998 cotton growing season was hindered by a cool, wet spring and therefore variable and, overall, late planting dates were common in these studies. 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 REC and in grower field near Five Points), Kings Co., Merced Co., Madera Co., and Kern Co. (Shafter REC and grower field in Buttonwillow area). 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. Aphid density, morph, and incidence of alates were recorded for each sample. Cotton petiole samples were collected from each plot during the season; a recent fully-expanded leaf was sampled and NO_3-N levels will be determined. The relationship between petiole NO_3-N level and aphid population dynamics will be examined and a quantitative relationship between these factors will be sought. The second study was similar using nitrogen rates of 50, 120, and 200 lbs./A. Plots were planted on 23 April at the Shafter REC. Plots were 300 feet long by 6 rows wide with 3 blocks. Petiole samples for plant nitrogen determination were taken every week from June to September. This site was part of the ongoing study on environmental and agronomic effects on cotton aphid insecticide susceptibility (Cisneros and Godfrey 1998).

In the third study, the interaction was examined between a pyrethroid insecticide and nitrogen level on aphid population dynamics. The pyrethroid insecticides are used for lygus bug management; they are generally the most effective registered foliar products for control of this pest, but have the drawbacks of destroying populations of natural enemies and stimulating aphid reproduction (Kidd et al. 1996, Godfrey 1998). In this study, nitrogen rates of 50, 120, and 200 lbs. N/A were used; insecticide treatments of Capture® 2E at 0.06 lbs. AI/A, Provado® 1.6F at 0.045 lbs. AI/A and an untreated were superimposed across the nitrogen treatments. Insecticide applications were made on 13 July and 18 August to plots 4 rows by 12 feet by 3 blocks. Aphid populations were quantified bi-weekly, as previously described, from 22 July to 24 September.

Cotton aphid population dynamics was studied on individual cotton leaves within several treatments by confining aphids from a laboratory colony within mesh bags made of floating row cover. At various points throughout the season, 10 aphids were placed onto a bagged 4-5 main stem node cotton leaf and the population density and aphid morph were recorded three times per week for 2 weeks. After 2 weeks, the bags and aphids were moved so as to maintain the relative leaf position. The influence of nitrogen rates was examined, 1.) no added nitrogen, ~25 lbs./A residual N, 2.) 50 lbs. N/A, 3.) 100 lbs. N/A, 4.) 150 lbs. N/A, and 5.) 200 lbs. N/A.

Results

Cotton aphid populations responded to nitrogen regime, but not to the extent seen in previous years. In addition, other factors, i.e., environmental, natural enemies, etc., generally kept aphid populations in check in 1998. In the grower field strip tests, significant aphid populations developed in only one of the eight sites. Aphid populations at the other seven sites peaked at less than 5 per leaf and were nearly 0 at most sites. At the Tulare Co. site, populations started to build on 27 July and peaked on 10 August (Fig. 1). Densities remained fairly high until defoliation in September. Plots with applied nitrogen to achieve a total nitrogen rate of 100, 150, and 200 lbs./A had significantly more cotton aphids than the lowest N rate (= 86 lbs. N/A), but populations did not separate among these three highest rates. It was interesting that the total nitrogen rate did not differ much between the 86 and 100 lb. rates, but the effect on aphid populations was significant. The nitrogen form, timing, or availability to the cotton plant may have differed between the residual nitrogen and the applied nitrogen situations. Percentage dark morph aphid was generally less than 10% and was higher in the higher nitrogen treatments compared with low nitrogen treatments, especially in the early sample dates. During years with aphid outbreaks, percentage dark morph values greater than 25% were common.

In the second study conducted at the Shafter location, aphid levels increased as the nitrogen fertility level increased (Fig. 2). Populations peaked at ~22 per leaf in the 200 lb. rate compared with 12 per leaf in the 50 lb. rate in September and continued up to ~60 per leaf in the 200 lb. treatment on 1 October. This 2x difference was less than the more than 3x difference seen in 1997 across the same treatments; densities were also much lower in 1998 as levels peaked at nearly 300 aphids per leaf in 1997. The occurrence of dark morph cotton aphids, the highly reproductive form, was much less in 1997 than in 1998.

In the nitrogen-pyrethroid study, aphid populations averaged 5.1 per leaf in the untreated, whereas aphids were controlled by the positive check, Provado, with 1.8 per leaf. The pyrethroid applications did not stimulate aphid levels with an average of 4.8 per leaf. This differs from results from previous years. There was a slight nitrogen response in this study with average populations ranging from 3.1 aphids per leaf (50 lbs. N/A) to 4.2 aphids per leaf (200 lbs. N/A). On 10 and 24 September, there were significant differences in aphid densities across the nitrogen treatments (5.2, 7.6, and 8.4 aphids per leaf for the 50, 120, and 200 lb. rates, respectively) (Fig. 3). Therefore, as with the previous studies, there was a response in aphid populations to the cotton production inputs, but it was not as pronounced as in 1997 and prior years.

The individual leaf study produced some interesting results. During the 6 to 13 July period, aphid populations did not respond to nitrogen regime (Table 1). Populations increased ~6- to 7-fold during the 7 day period. However, from 14 to 21 July, aphid populations did respond to nitrogen level; populations increased about 3-fold in the 50 to 200 lbs./A treatments and only 1.5X in the 25 lb./A treatment. There was a significant difference between the lowest and the four highest nitrogen treatments. The reason for these differences is unknown. The environmental conditions did differ significantly between these two 1-week periods. July 6 to July 13 was characterized by "cool" temperatures (average daily maximum=80.1 ^{0}F, average daily minimum=55.75 ^{0}F). This may have allowed for optimal aphid reproduction and negated the influence of plant status. July 14 to July 21 (average daily maximum=89.5 ^{0}F, average daily minimum=58.9 ^{0}F) was a period of "hot" temperatures; however, probably more typical of SJV conditions than the July 6 to July 13 period. These temperatures may have inhibited aphid reproduction and allowed the effects of the plant nitrogen status to be exhibited.

Summary

Nitrogen level still appears to be an important factor in altering cotton aphid population levels with high nitrogen promoting higher aphid populations in cotton. Other abiotic factors are undoubtedly also important and in some cases may have an overriding effect on nitrogen status. Research will continue with the goal of finding a nitrogen program in cotton that can optimize cotton lint yield without promoting cotton aphid levels.

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Table 1. Preliminary data from two sample periods from cotton aphid - nitrogen study; individual leaf study.

Cotton Aphids after 1 Week from Initial Population of 10 Adults

	Nitrogen Treatment (lbs./A)				
Sample Period	25*	50	100	150	200
July 6 to July 13	57.6 a	72.8 a	70.3 a	72.7 a	67.2 a
July 14 to July 21	14.5 b	33.1 a	31.9 a	29.5 a	26.2 a

* residual nitrogen

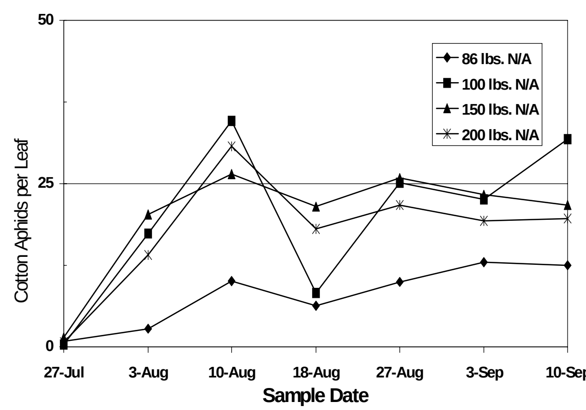

Figure 1. Cotton aphid population density from grower field test with differential nitrogen treatments; Tulare Co., 1998.

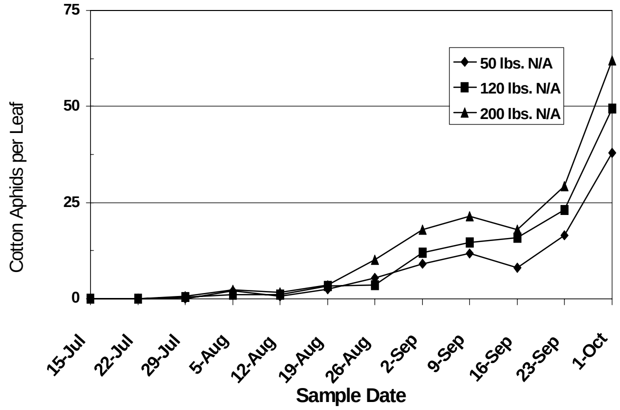

Figure 2. Cotton aphid population density from small plot test with a range of nitrogen regimes; Shafter, 1998.

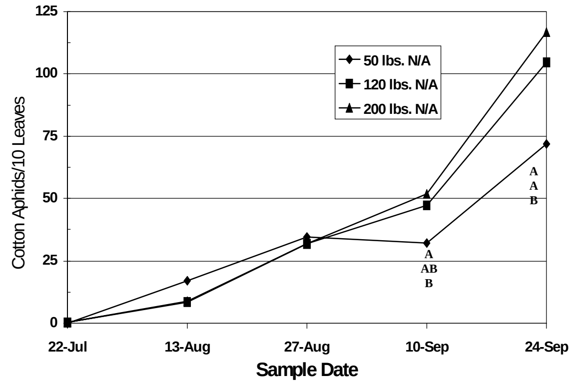

Figure 3. Cotton aphid population density by nitrogen level from pyrethroid-nitrogen test; Shafter, 1998.