EFFECTS OF NITROGEN FERTILITY ON THE FITNESS AND THE POPULATION DYNAMICS OF THE COTTON APHID IN CALIFORNIA

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Abstract

The importance of the cotton aphid, *Aphis gossypii* Glover, as a mid-season pest in California cotton has increased since the early 1990's. Field experiments were conducted to further study aspects of cotton aphid biology and the effects of cultural control measures at the individual and population level. Previous laboratory and field studies have shown that high rates of nitrogen fertilizer can promote the build-up of aphid infestations. The goal of the present study was to determine the mechanisms behind this positive response of aphids to nitrogen. Aphid populations in 2000, at least in our study site, were characterized by overall moderate to high levels which developed during the mid-season. Naturally occurring aphid populations were monitored in 40 small plots with 10 differential fertilizer regimes. These fertilizer treatments included six nitrogen levels (0[=20 lbs./A soil residual nitrogen], 50, 100, 150, 200, and 250 lbs./A of ammonium sulfate), and four different "balanced" fertilizations (i.e.,different levels of nitrogen + K_20 fertilizers). There was a positive trend for more aphids in the 200 and 250 lbs./A nitrogen treatments compared with the 0 and 50 lbs./A treatment with a 5-7X range across the treatments. Aphid densities on the highly fertilized plots exceeded the mid-season treatment threshold. Overall, the "balanced" fertilization treatments had a negative impact on the aphid populations but aphid densities still reached the treatment threshold. Detailed studies on cotton aphid fitness showed that aphid generation times, from a laboratory colony out-planted into field cages, ranged from 7.9 to 7.1 days and the number of offspring per adult averaged from 18.5 and 44.1 under 0 and 250 lbs./A nitrogen regimes, respectively. The potassium treatments had a moderate negative effect on both the generation time and the fecundity of the aphid. Similar patterns were observed when we repeated the experiments with a second and third aphid generations. These changes in aphid fitness at the individual level may explain in part the effects of nitrogen fertility at the population level observed in the field

Introduction

The mid-season pest status of the cotton aphid, *Aphis gossypii* Glover, has changed in the last decade in the cotton production areas of California's San Joaquin Valley. Its importance has shifted from an occasional pest in California cotton in the early 1980's to become one of the key pests of Acala cotton (*Gossypium hirsutum* L.) in the 1990's. In 1995 and 1997, cotton aphid infestations were severe and widespread and cotton yield losses from aphid outbreaks were estimated at 3.5 and 3.4%, respectively (Williams 1996, 1998). Several hypotheses have been suggested to explain why cotton aphid populations in California cotton have increased over the last 10 years: the use of synthetic pyrethroids which are known to have a detrimental effect on natural enemy populations, the commercial introduction of Pima cotton (*Gossypium barbadense* L.) beginning in 1989, changes in the agro-ecosystem landscape in the San Joaquin Valley, the use of new varieties of Acala cotton, and an increase in nitrogen and irrigation inputs. Some of these hypotheses have been previously discussed (Godfrey and Rosenheim 1996). More recently, field studies in California has shown that nitrogen is a key factor influencing the population dynamics of the cotton aphid during the mid-season (Cisneros and Godfrey 1998, Godfrey et al. 2000, Cisneros and Godfrey in press), supporting the last hypothesis.

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With the commercial introduction of mepiquat chloride, a cotton plant growth regulator, in 1981 (Kerby et al. 1986) and the development of new cotton varieties with a more determinate growth pattern, the cotton production practices in the San Joaquin Valley of California have shifted to a higher use of nitrogen and irrigation inputs in the last two decades. Records from the last 20 years show that the average rate of nitrogen fertilizer used by California growers has significantly increased from approximately 110 kg N/ha in the early 1980's to about 200 kg N/ha in the mid 1990's (Fig. 1). Before the 1980's, traditional management practices relied on irrigation and/or nitrogen fertilization stress during the early vegetative development of the plant to reduce vegetative growth and to encourage fruiting. Using mepiquat chloride, growers have been able to avoid excessive vegetative growth without the use of potentially yield-limiting cultural stresses. Thus, with the increase of nitrogen and irrigation inputs by growers, cotton plants probably have higher nutrient contents than they had a decade ago. The cotton aphid may have exploited these changes in cotton production practices, resulting in a change in its pest status.

Our previous studies have focused on the effects of nitrogen fertilizer at the aphid population level. The goal of the present study was to conduct a detailed small plot study to determine the effects of nitrogen at the individual level. By identifying which fitness factors in the insect are affected by the nitrogen fertilizer our understanding of the influence of nitrogen on cotton aphid population dynamics will be improved.

Materials and Methods

Field experiments were conducted in 2000 to further study the effects of nitrogen fertilization on the fitness and the population dynamics of the cotton aphid. These experiments were a continuation of our 1999 study (Godfrey et al. 2000).

Nitrogen and Aphid Fitness

A manipulative experiment was conducted in an untreated 0.6-acre cotton field located at the University of California Cotton Research and Extension Center near Shafter, Kern County. Acala cotton cv. 'Maxxa' was planted on 6 May with 40 inch row spacing. The field was divided into 40 plots (4 rows x 46 ft each) and randomly assigned to 10 different fertilizer regimes with a total of 4 replicates or plots per fertilizer treatment. The treatments were: 0 , 50, 100, 150, 200, and 250 lb./A nitrogen (ammonium sulfate fertilizer). There was also a treatment of 100 lb./A nitrogen + 100 lb./A K_20 and three other treatments of 200 lb./A nitrogen each and different levels of K_20 added (100, 150, and 200 lb./A K20, respectively). Treatments, when possible were adjusted to soil residual nitrogen (20 lb./A) and were applied on 22 June. Cotton aphids from a clonal colony (one genotype) were out-planted to eight plants in a each plot on 10 July. These aphids were enclosed in one-leaf mesh cages made of floating row cover (5 adults per cage) for 12 hours located on the 5^{th} main stem leaf from the top of the plant. After this period the adults were removed and only one offspring produced by these females was left per cage. This cohort of aphids (eight aphids per plot, each one in a cage) composed the first generation. These aphids were monitored and their generation time (i.e.,time when aphid produces its first offspring), fecundity and survival were recorded. A second cohort of aphids (second generation), the offspring of the first generation, was also monitored and their fitness factors assessed. Finally, a third cohort (third generation) was also monitored. In all cases aphids with their cages were moved to new leaves every week to keep them at the same position within the plant (5^{th} leaf from the top) and avoid drastic changes in the leaf physiology due to the cage.

Nitrogen and Aphid Population Dynamics in the Field

The same plots used for the previous test were used for this experiment. Naturally occurring aphid infestations in these plots were monitored by taking 10-leaf samples (5^{th} main stem node leaf from the top) from each plot at weekly intervals. The sampling period went from 11 July to 5 September. Aphids were counted with the aid of a 50X magnification. Aphid density was recorded for each sample. Aphid-days were estimated for each treatment.

Results

Nitrogen and Aphid Fitness

Results from the first generation (i.e., first cohort of cotton aphids) showed aphids that were reared on plants fertilized with the highest nitrogen levels were significantly more fecund and had a shorter generation time than aphids from low nitrogen plots (Fig. 2,3). Generation times averaged from 7.9 days (0 lbs./A nitrogen [=20 lbs./A nitrogen residual]) to 7.1 days (250 lbs./A nitrogen). Fecundity (number of offspring per female) ranged from 18.5 to 44.1 in the low and high nitrogen regimes, respectively. This pattern of shorter generation time and higher fecundity on aphids that feed on highly fertilized plants is similar to the one found in our previous study in 1999 (Godfrey et al. 2000), however, overall, the generation time was shorter and the fecundity was much higher (at least 8 times more fecund) in the present study, despite using the same clonal colony. It seems that other factors (i.e., temperature) can interact with the nitrogen fertilizer affecting the fitness of this insect. Potassium seemed to have a negative impact on the aphid fitness lowering the fecundity and increasing the generation time of the insect. This detrimental effect was not, nevertheless, as strong as the one observed in 1999. Further studies should focus in understanding the effect of this nutrient on the plant physiology, and its effect at the insect population level. No significant differences were found on aphid survivorship among treatments for this generation (Fig 4).

In the second and third generations, a similar trend was found. Aphids reared on plants with the highest nitrogen regimes (200 and 250 lbs./A) showed the shortest generation time and the largest fecundity. Similarly, the potassium treatments had a detrimental effect on the aphid fitness by increasing the generation time and decreasing the fecundity of the insect. There was a trend for a lower survivorship on the aphids reared on the low nitrogen treatments, however, this trend was not statistically significant on the second generation. Potassium did not have a negative effect on the survival of the aphids in neither generation (Fig. 4). When we compare the overall fecundity of the three generations, it is noticeable that the fecundity decreased over time (i.e.,from generation to generation) paralleling the natural decrease of the plant nitrogen content. This pattern was not observed for the generation time.

Nitrogen and Aphid Population Dynamics in the Field

Results from the field population dynamics study supported our findings in the small cage experiment. Aphid populations in the highly nitrogen fertilized plots were more numerous than aphid densities in the low nitrogen plots, probably as a result of the positive effect of the fertilizer at the individual level (Fig.5). Thus, with the moderate-high aphid pressure experienced in this year, the nitrogen rate of 100 lbs./A was an effective cultural method to keep the aphid infestations below the mid-season economic threshold of 75 aphids/leaf. Although, this is half of the typical application rate in the San Joaquin Valley (~200 lbs. N/A), nitrogen guidelines on Acala cotton varieties in the SJV are currently being reviewed and researched (Hutmacher et al. 1998, Marsh et al. 2000)) showing that in some cases optimal yields can be obtained with less than the currently used nitrogen inputs. The present results corroborate our previous findings of the importance of nitrogen on the build-up of aphid infestations in the field (Godfrey et al. 2000). It is also important to note that the aphid peak occurred simultaneously in all plots (7 August), demonstrating that external factors (i.e.,factors not related to the plant) regulate the occurrence of the aphid peak (Fig. 5). The aphid densities at this peak ranged from 19.9 aphids/leaf (0 lbs./A nitrogen) to 154.2 aphids/leaf (250 lbs./A nitrogen). Similarly, the aphid-days showed a positive effect of nitrogen on the number of aphids present throughout the growing season, with more aphid-days on the plots fertilized with the highest nitrogen rates (Fig. 6). Conversely, the potassium treatments seemed to have a negative impact at the population level, with significant lower aphid densities. Nevertheless, this detrimental effect was not strong enough to keep the aphids below the mid-season economic threshold (Fig. 5).

Summary

Nitrogen level appears to be an important factor in altering the cotton aphid at the individual level with high nitrogen stimulating the aphid fecundity and hastening the insect development to the reproductive stages. These changes in the aphid fitness may promote higher aphid populations in cotton. Other abiotic factors are undoubtedly also important and in some cases may have an overriding effect on nitrogen status. The negative impact that potassium had at the aphid individual and population level observed in our study warrants further research. Research will continue with the goal of finding a nitrogen program in cotton that can optimize cotton yield without promoting cotton aphid outbreaks.

Acknowledgments

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References

Cisneros, J. J., and L. D. Godfrey. 1998. Agronomic and environmental factors influencing the control of cotton aphids with insecticides. Proceedings, Beltwide Cotton Conference. 1242-1246.

Cisneros, J.J., and L.D. Godfrey. 2001. The mid-season pest status of the cotton aphid, *Aphis gossypii* Glover (Homoptera: Aphididae), in California cotton: is nitrogen a key factor?. Environmental Entomology (in press).

Godfrey, L. D., and J. A. Rosenheim. 1996. Aphids and whiteflies in the San Joaquin valley of California in 1995. Proceedings, Beltwide Cotton Conference. 128-132.

Godfrey, L. D., J. J. Cisneros, and K. E. Keillor. 2000. Influence of cotton nitrogen fertility on cotton aphid, *Aphis gossypii*, population dynamics in California. Proceedings, Beltwide Cotton Conferences. 1162-1165.

Hutmacher, R. B., M. Keeley, R. L. Travis, and W. Rains. 1998. Nitrogen uptake and residual soil N in San Joaquin Valley cotton. Proceedings, Beltwide Cotton Conference. 654-658.

Kerby, T. A., K. Hake, and M. Keeley. 1986. Cotton fruiting modification with mepiquat chloride. Agronomy Journal. 78: 907-912.

Marsh, B.H., R.B. Hutmacher, B. Roberts, R.L. Travis, and W. Rains. 2000. Why develop new nitrogen guidelines for California cotton. Proceedings Beltwide Cotton Conferences. 1385-1386.

Williams, M. R. 1996. Cotton insect losses 1995. Proceedings Beltwide Cotton Conferences. 670-689.

Williams, M. R. 1998. Cotton insect losses 1997. Proceedings Beltwide Cotton Conferences. 904-925.

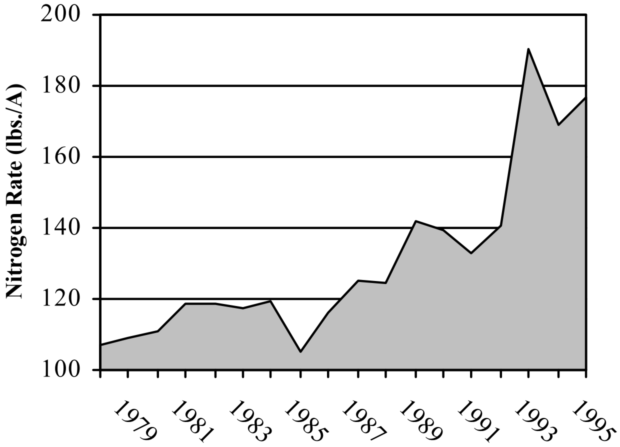

Figure 1. Nitrogen application rates used in California cotton since 1979. Data were obtained from the USDA Economics & Statistics System database (http://usda.mannlib.cornell.edu/).

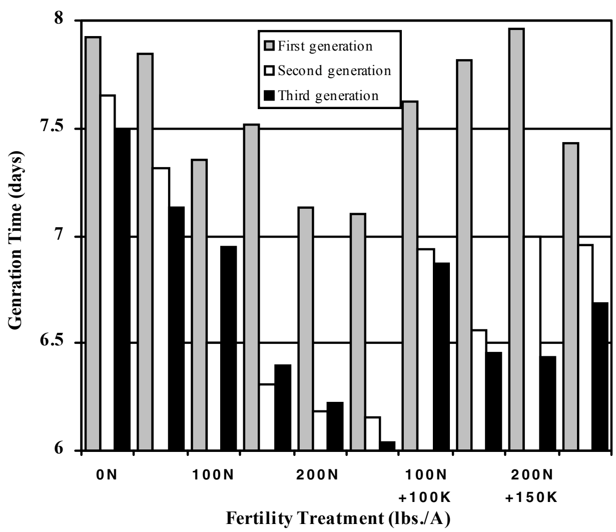

Figure 2. Effects of cotton fertility treatments on the aphid fitness: generation time, 2000.

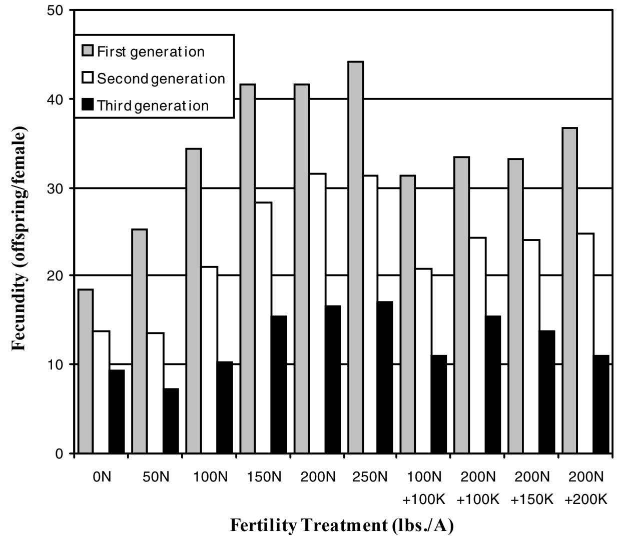

Figure 3. Effects of cotton fertility treatments on the cotton aphid fitness: fecundity, 2000.

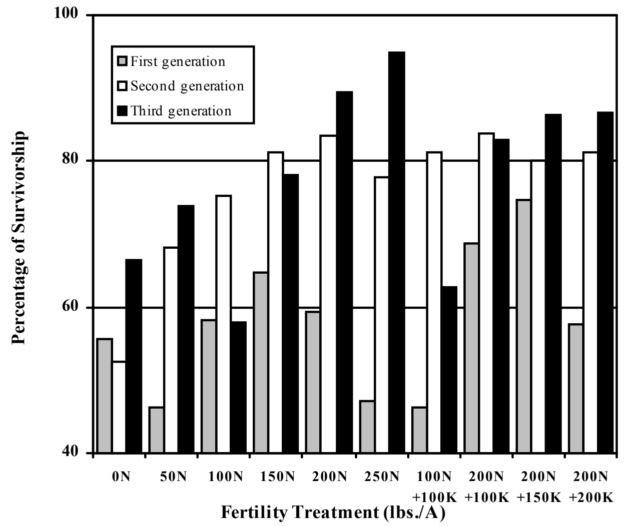

Figure 4. Effects of cotton fertility treatments on the cotton aphid fitness: survivorship, 2000.

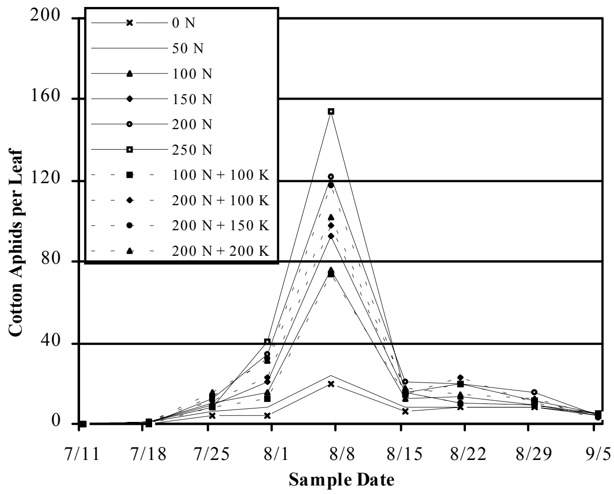

Figure 5. Effects of fertilization on the population dynamics of the cotton aphid, 2000.

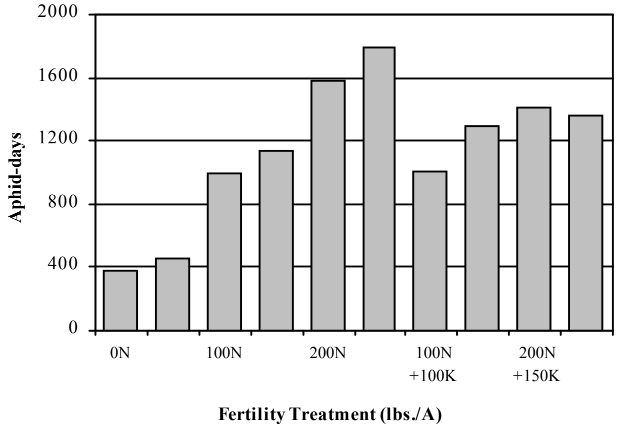

Figure 6. Effects of cotton fertility treatments on the naturally occurring aphid population: aphid-days, 2000.