Interaction of Cotton Nitrogen Fertility Practices and Cotton Aphid Population Dynamics in California Cotton

2000 Final Report

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Objective

During the last 10 years, the cotton aphid (*Aphis gossypii*) 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 industry in 1997 totaled $34 million in crop loss and $38 million in control costs. Cotton aphid infestations during the late-season (mid-Aug. to Sept.) are problematic because the aphids deposit honeydew on the exposed cotton lint. 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. Reasons for this change in pest status of cotton aphid are unclear. This insect pest and other traditional insect and mite pests have contributed to the lack of economic return for cotton production in recent years. One of the most noticeable changes in cotton production over the last 15 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). This amount of nitrogen (50 lbs. N/A) is probably not optimal for cotton production as yields will likely be reduced. However, these results have stimulated our interest in this area, as this may be a way to mitigate cotton aphid populations. Results from this project in 1999 were interesting and supported the earlier studies. Naturally-occurring populations of cotton aphids were generally low to lacking in 1999, which hindered this aspect. This points out that other factors besides nitrogen and plant quality, i.e., environmental factors, are also important in this system. The controlled studies in 1999 produced some compelling results. This study seeks to investigate the influence of cotton nitrogen fertilization levels and cotton aphid populations in grower fields in the San Joaquin Valley. Nitrogen levels optimal for plant growth but low enough to limit aphid reproduction are sought. With the awareness of growers to cotton aphid and the dependence on insecticides to control this pest (and impending changes in insecticide registration status), we believe growers will adapt new practices if they are designed. The efforts of the Agronomy Cooperative Extension personnel to redefine the nitrogen use for cotton, the "squeeze" being put on growers to reduce costs of production (and therefore insecticide inputs), and the possible loss or restriction of commonly used aphid insecticides (such as Lorsban®) through the Food Quality Protection Act all provide a framework for developing and introducing alternative management tools.

Project Objectives:

1.) Study the influence of cotton nitrogen fertilization practices on cotton aphid population dynamics and seasonal buildup in cotton.

2.) Identify specific crop carbohydrate and N status associated with higher aphid densities during specific crop growth stages.

Summary:

The cotton aphid, *Aphis gossypii*, has developed into a key pest of cotton in California during the 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 goals of the present study were to verify the existence of the nitrogen-aphid interaction under grower field conditions and to determine the mechanisms behind this positive response of aphids to nitrogen. Aphid populations in 2000, at least in our study sites, were characterized by overall moderate to high levels which developed during the mid-season. In 1999, aphid levels were overall low. Aphid levels were monitored in seven large plot grower field studies with four differential nitrogen regimes (50 to 200 lbs./A nitrogen) during both 1999 and 2000. There was consistently a trend for more aphids in the 200 lbs./A nitrogen treatment compared with the lower treatments. In 2000, populations were similar in the 50, 100, and 150 lbs. nitrogen/A treatment (~32 aphids/leaf) and in the 200 lbs./A nitrogen treatment, populations averaged ~75/leaf. In addition, the interaction between nitrogen level and pyrethroid application (a common production practice used to manage lygus bug populations) was examined. At the onset of aphid build-up, application of either a pyrethroid insecticide (Capture®) or a chloronicotinyl insecticide (Provado®) or no insecticide was superimposed. With the high nitrogen treatments (150 and 200 lbs./A nitrogen), there were 3 to 6 times more aphids in the Capture-treated plots compared with the untreated. The flaring effect was mitigated in the low nitrogen treatments. 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_2$0 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.

Work Description:

TASK 1: Nitrogen and Cotton Aphids in Grower Field Plots

Subtask 1.1: Sample residual soil N in perspective field plot sites.

Completed spring 2000.

Subtask 1.2: Field sites for experimentation will be chosen based on the data collected under above sample.

Completed spring 2000.

Subtask 1.3: The following nitrogen treatments will be established 1.) 50 lbs. N/A, 2.) 125 lbs. N/A, 3.) 175 lbs. N/A, and 225 lbs. N/A with applied N adjusted to account for soil residual N.

Completed by 7/00. Replicated field studies with differential nitrogen levels, 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. Target nitrogen rates in these studies were 50, 100, 150, and 200 lbs. N/A; the lowest rate utilized the residual soil nitrogen, determined in Subtask 1.1, and therefore varied across locations. The three highest rates were the residual plus the appropriate amount of applied N generally in June. Field sites in grower fields were located in Tulare Co., Fresno Co., Kings Co., Merced Co., and Madera Co in 2000. Two Univ. of California Research and Extension Centers were also utilized. There was one "large plot" field site at each of the Shafter [Kern Co.] and one site at West Side [Fresno Co.]) RECs and the row lengths were ~300 ft. at these two locations. Planting dates varied across locations, but most were in early April. At the Shafter REC, two smaller plot sites were also included. The first site (referred to as the entomology site) will be reported under TASK 1 and included nitrogen rates of 0, 50, 100, 150, and 200 lbs./A applied to 300-foot long rows. The lowest rate was, in actuality, a 20 lb./A treatment considering the soil residual nitrogen. This study was planted on 6 May; the late date was preferred because this favors the build-up of aphid populations. Fertilization occurred in mid-June immediately before irrigation. The ammonium sulfate was shanked into the soil on both sides of the rows.

Subtask 1.4: Naturally-occurring cotton aphid populations will be sampled at weekly intervals from each plot.

Plots described under Subtask 1.3 were used for this aspect. 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 on the leaf in the laboratory under 50x magnification. If populations reached levels too high to reliably count, we washed the aphids from the leaves onto a sieve and then back-washed that material into ethanol for safe storage and later counting. Aphid density, morph, and incidence of alates were recorded for each sample.

In 2000, aphid populations were higher than in 1999 and developed earlier in the season. Averaging all seven locations with April planting dates, levels peaked in mid-August in 2000 (compared with an early September peak in 1999). Populations were similar in the 50, 100, and 150 lbs. nitrogen/A treatment and averaged ~32 aphids/leaf (Fig. 1). In the 200 lbs. nitrogen/A treatment, populations averaged ~75/leaf. The percentage aphid-infested leaves responded weakly to nitrogen rate. Aphid populations in individual fields responded clearly to nitrogen level. A field located in Merced Co. showed a clear delineation of the aphid populations by nitrogen treatment (Fig. 2). Populations peaked at 217 aphids/leaf in the 200 lb./A treatment compared with 50 aphids/leaf in the 50 lb./A treatment. At the Shafter REC site which utilized the May planting date in 2000, treatments for lygus bugs were superimposed across the nitrogen treatments. Although this aspect was outside the scope of this project, it is a common practice to apply one or two insecticide applications for this pest. These applications are known to be disruptive to cotton aphid populations. In the untreated plots on 16 Aug. (3 weeks after the insecticides were applied to the treated plots), aphid numbers increased across the increasing nitrogen levels (0 to 36 aphids per leaf from 0 to 200 lbs./A nitrogen) (Fig. 3). Provado controlled the infestation which is in agreement with its activity spectrum. At 100 and 150 lbs./A nitrogen, the aphid population was 2X higher in the Capture-treated plots compared with untreated and it was 6 times higher (Capture compared with untreated) in the 200 lbs./A nitrogen treatment. Therefore, these factors clearly interact to further exasperate the aphid population density.

Subtask 1.5: Cotton petiole and leaf blade samples will be collected.

Cotton petiole and leaf blade samples were collected from each plot at 3 points during the season. A recent fully-expanded leaf was sampled and NO_3-N levels will be determined. The relationship between petiole/blade NO_3-N level and aphid population dynamics will be examined and a quantitative relationship between these factors will be sought. Previous results from 1998 showed a promising relationship between petiole nitrogen and aphid numbers. Petiole levels are a commonly measured and accepted method by growers and may have relevance in terms of aphid populations. Data have been collected; however, summarization and analyses are not completed. Petiole nitrate data from TASK 2 studies are summarized and included below

Subtask 1.6: Evaluate cumulative plant growth responses to treatments using final plant mapping.

Final plant map data were collected from each field - the seven grower fields and the entomology site at the Shafter REC. Ten plants per each field replicate were evaluated. Data were summarized using CottonPro program which calculates retention by position, the 95% zone, etc. As an example of the results, the harvestable boll by node position charts are shown in Fig. 4 and 5 for the 0 lbs./A and 200 lbs./A nitrogen by Provado and Capture treatments from the entomology field site. These should represent the extremes of the treatments with regard to nitrogen fertility and aphid populations, i.e., Provado should control the aphids and Capture application generally facilitates the infestation. There were not significant differences in the fruiting patterns among the treatments. The 200 lbs. treatments set fruit about 1 node lower on the plant compared with the 0 lbs. treatment.

Subtask 1.7: Evaluate yield responses to treatments and HVI lint quality components.

Seed cotton yields were evaluated with a commercial cotton harvester from the middle two rows of each field replicate. Data summarization and analyses from the grower field sites are ongoing. Seed cotton yields from the Shafter REC entomology site ranged from 1369 (Provado with 20 lbs./A nitrogen) to 2826 lbs./A (untreated with 200 lbs./A nitrogen) (Fig. 6). Across the insecticide treatments, yields were numerically highest with 100 lbs./A nitrogen (2650 lbs./A seed cotton) and fell off slightly with more nitrogen (200 lbs./A produced 2469 lbs./A seed cotton) and less nitrogen (20 lbs./A nitrogen produced 1733 lbs./A seed cotton). Seed cotton yields varied only slightly across the insecticide treatment main effects. These products may have provided some lygus control, although at this late part of the season the value of lygus control is very questionable.

Subtask 1.8: Analyses, interpretation, interim report and invoice.
Complete 12/00.

TASK 2: Nitrogen and Cotton Aphids - Detailed Studies

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. Cotton aphid population dynamics were studied on individual cotton leaves within each treatment by confining aphids from a laboratory colony within mesh bags made of floating row cover. Through this research, we can develop an understanding of the mode through which nitrogen influences this pest. Naturally-occurring aphid population levels were also quantified in a manner similar to that described in Subtask 1.4.1 Completed: 12/00.

Subtask 2.1: Plots design.

The established 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 K_20, respectively). Treatments, when possible were adjusted to soil residual nitrogen (20 lb./A) and were applied on 22 June.

Subtask 2.2: Cotton aphid population dynamics will be studied on individual cotton leaves. Cotton aphids from a clonal colony (one genotype) were out-planted to eight plants in 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 5th 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, fecundity and survival 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 (5th leaf from the top) and avoid drastic changes in the leaf physiology due to the cage.

Results from the first generation (i.e., first cohort of cotton aphids) showed that 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. 7 and 8). 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 1999; however, overall, the generation time was shorter and the fecundity was much higher (at least 8 times more fecund) in 2000 than in comparable treatments in 1999, despite using the same clonal colony. It appears 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 fertilizer 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 9). In the second and third generations, similar trends were found. Aphids reared on plants with the highest nitrogen regimes (200 and 250 lbs./A) showed the shortest generation time and the highest 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. 9). 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. Petiole nitrate levels during the time this study was conducted are shown in Fig. 10. At the onset, there was excellent separation in petiole nitrates among the N rate treatments (15,000 to 2,500 ppm). Additionally, interpretation and analyses may provide some more insights into this interaction.

Naturally-occurring 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.11). Thus, with the moderate-high aphid pressure experienced in 2000, 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. The present results corroborate our previous findings of the importance of nitrogen on the build-up of aphid infestations in the field. 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. 11). 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). Conversely, the potassium treatments seemed to have a negative impact at the population level, with significantly lower aphid densities. Nevertheless, this detrimental effect was not strong enough to keep the aphids below the mid-season economic threshold (Fig. 11).

Subtask 2.3: Split fertilizer application studies.

Complete by 9/00. The split fertilizer studies in 1999 clearly showed no promise, i.e., the aphid population dynamics in the split treatment paralleled that in the comparable full treatment. Therefore, this aspect was discontinued in 2000 and the potassium studies were enhanced as this aspect showed more promise based on the 1999 results.

Subtask 2.4: Analyses, interpretation, interim report and invoice 10/00.

TASK 3: Extending Results to End-Users

Results collected under Tasks 1 and 2 were presented to clientele in several ways. Completed:12/00

Subtask 3.1: Presentation of results at Shafter Cotton Field Station and/or West Side Research and Extension Center Cotton Field Days.

Oral presentations were made at the Cotton Field Days at the Shafter and West Side Research and Extension Center in September 2000. Twenty-minute presentations were made to ~125 and 150 participants at Shafter and West Side, respectively. A handout detailing this and other work was prepared and given out (copy included). An oral presentation was made at the Fertilizer Research and Education Program Conference in November 2000; a proceedings article was also written.

Subtask 3.2: Presentation of results at UC Cotton Work Group meeting.

Completed by 12/00. An oral presentation was made to the Cotton Workgroup; a handout which mentions a portion of this work is included.

Subtask 3.3: Preparation of articles for commodity and trade magazines.

Completed by 12/00. An oral presentation was made highlighting the results of this project at the Beltwide Cotton Conference in 1/2001. Several thousand individuals associated with the cotton industry US-wide and internationally attend this meeting. The proceedings of this conference are published and pre-press copy of this article is included. A summary of ongoing research on the cotton aphid was published in California Agriculture (Nov.-Dec. 2000, pp. 26-29). The aphid-nitrogen aspect is mentioned in a portion of this article. A copy is included.

Subtask 3.4: Interim report and invoice 12/00.

Project Evaluation:

Any sort of cost:benefit analyses is impossible to do at this time until all the data have been collected. Aphid management is only one part of cotton production so this analysis may not apply. The results of the Hutmacher portion of the project, i.e., yield, is, of course, critical. I'm sure we will do this, but to-date we have not synthesized all the results.

Outreach Activities:

1. 8 January, 2000. Influence of Cotton Nitrogen Fertility On Cotton Aphid, *Aphis gossypii*, Population Dynamics in California, presented by L. D. Godfrey J. J. Cisneros, K. E. Keillor, and R. B. Hutmacher, Beltwide Cotton Conferences; oral presentation and proceedings article (pp. 1162-1166).
2. 19 Sept. 2000, "Cotton Arthropod Pest Research - Management Influences on Pest Populations", Shafter Cotton Field Day, Shafter REC; 100 participants, growers, PCAs; oral presentation and handout.
3. 21 Sept. 2000, "Agronomic Management Factors Impacting Aphid Populations", West Side Research and Extension Center Cotton Field Day, West Side REC; 150 participants, growers, PCAs; oral presentation.
4. 14 November 2000, "Interaction of Cotton Nitrogen Fertility Practices and Cotton Aphid Population Dynamics in California Cotton", Proc. Fertilizer and Education Program, pp. 54-57; oral presentation and proceedings article.
5. 30 November 2000, "Management of Cotton Arthropod Pests with Insecticides and Acaricides", UC Cotton Workgroup meeting, Kearney Ag. Center, 60 participants, growers, PCAs, other academics; oral presentation and handout.
6. 13 January 2001, "Effects of Nitrogen Fertility on the Fitness and the Population Dynamics of the Cotton Aphid in California", presented by J. J. Cisneros, L. D. Godfrey, K. E. Keillor, and R. B. Hutmacher, Beltwide Cotton Conferences; oral presentation and proceedings article (in press).

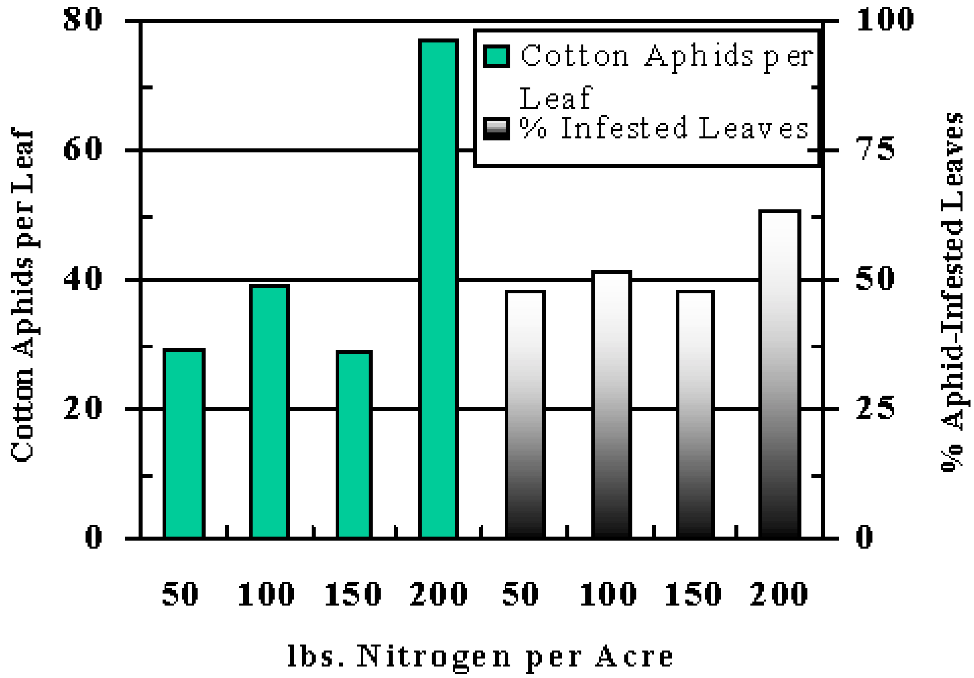

Figure 1. Cotton aphid peak population and incidence of infested cotton leaves across nitrogen levels - average of seven locations across San Joaquin Valley, 2000.

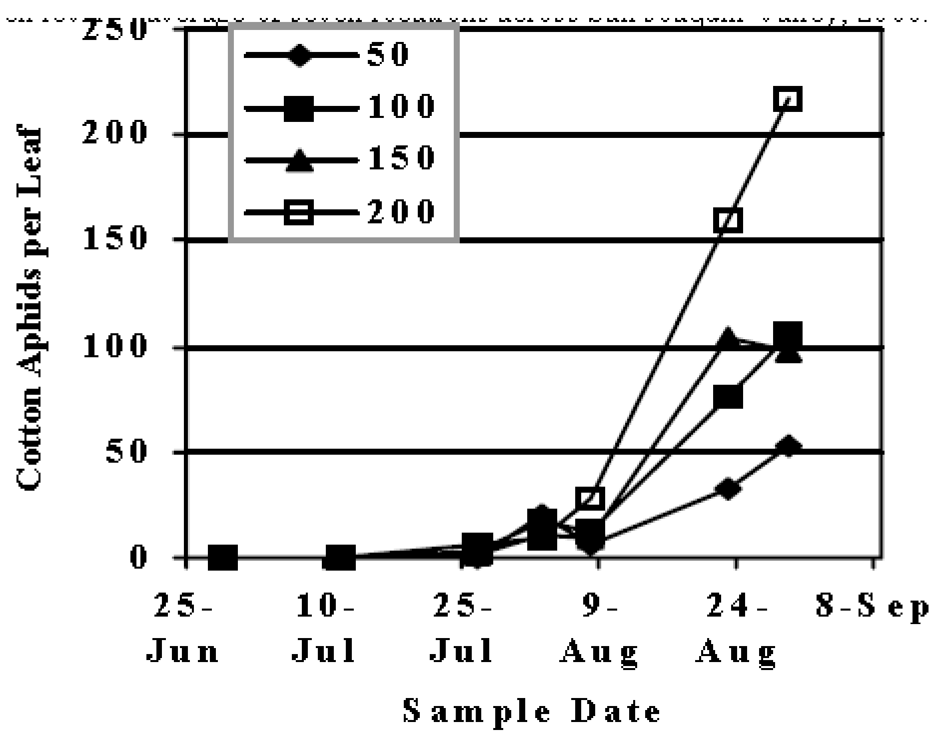

Figure 2. Cotton aphid population level across nitrogen regimes from a grower field site in Merced Co., 2000.

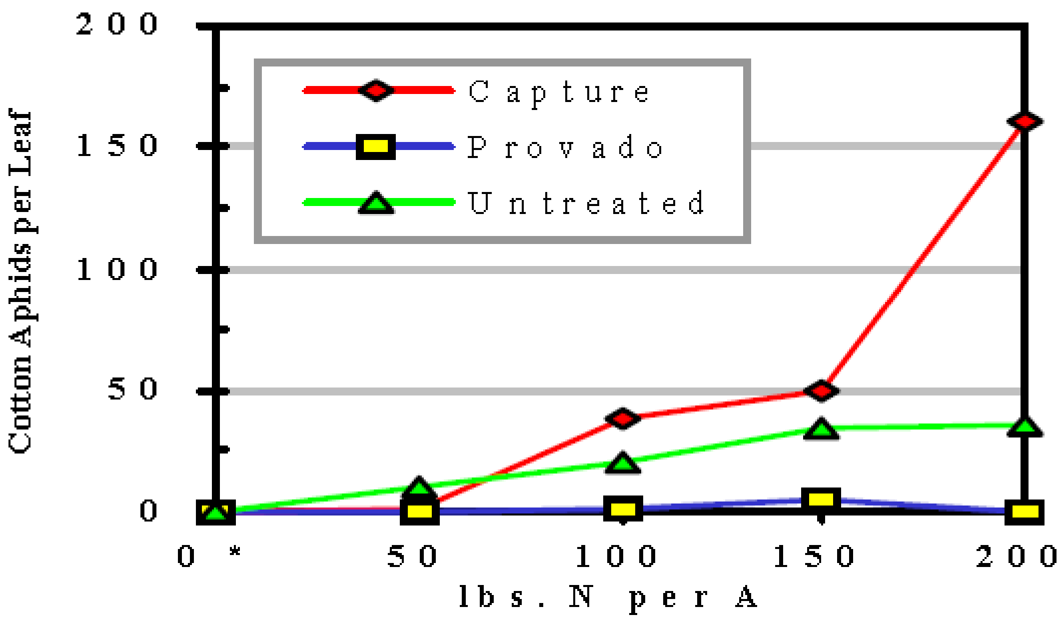

Figure 3. Cotton aphid population level as effected by nitrogen level and insecticide treatment for lygus bugs in 2000. Data collected 3 weeks after insecticide application. * =20 lbs./A residual soil nitrogen.

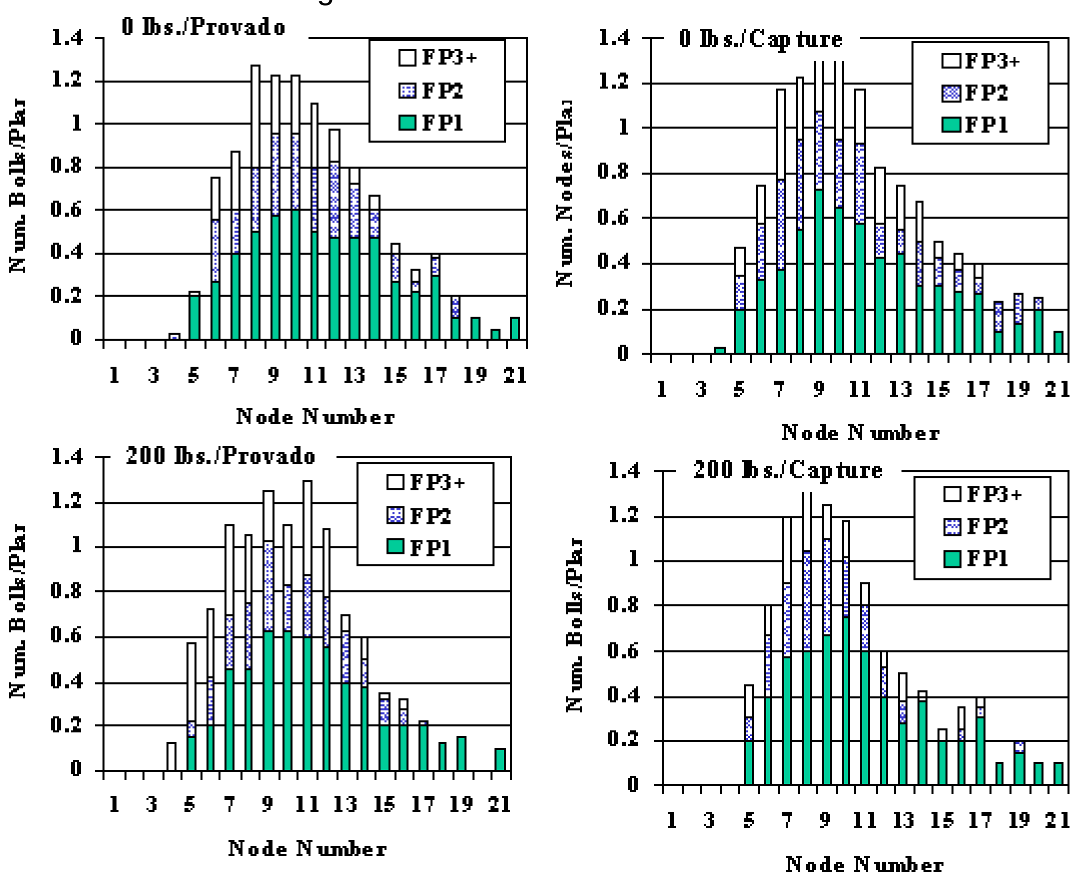

Figure 4. Plant mapping data summary from entomology field site; Shafter REC, 2000.

For additional figures (figures 5 through 11), contact FREP.