INFLUENCE OF NITROGEN FERTILIZER ON COTTON HOST-PLANT QUALITY AND ITS IMPACT ON COTTON APHIDS

M. N. Parajulee
A. Hakeem
S. C. Carroll
Texas A&M AgriLife Research
Lubbock, TX

Abstract

The relationship between nitrogen fertilizer application in cotton and subsequent changes in lint and seed yield is well-understood. However, little research has been done to evaluate the role of nitrogen fertility in arthropod population abundance in cotton. Previous work suggests that there exists a non-linear relationship between soil nitrogen availability and cotton aphid abundance in cotton. However, interaction between plant-available soil nitrogen and moisture ultimately determines arthropod population dynamics, at least for the cotton aphid. Also, there is a lack of information on plant parameter values with respect to varying rates of available soil nitrogen in cotton production. A multi-year comprehensive field study was conducted to examine the effect of soil nitrogen (residual nitrogen plus applied nitrogen) on cotton agronomic growth parameters and arthropod abundances under a drip irrigation production system. Fixed-rate nitrogen application experimental plots, previously established and fixed for five years prior to the initiation of this study in 2008, consisted of five augmented nitrogen fertility levels (0, 50, 100, 150, and 200 lb/acre) with five replications. Each year, soil in each experimental plot was sampled for residual nitrogen analysis prior to planting. Rates of applied N exceeding 100 lb/acre resulted in higher residual nitrogen detection during the following season. However, variation in residual nitrogen did not significantly affect early plant growth (plant height, root length, or leaf area), except for 150 lb N/acre treatment. Increased N levels corresponded to increased leaf chlorophyll content, but leaf chlorophyll content was generally consistent across nitrogen levels exceeding 100 lb/acre. Aphid abundance was significantly lower in zero N plots versus other plots. Rates of N application exceeding 100 lb/acre resulted in the highest lint yield, but consistent numerical decline in yield beyond 150 lb N/acre in most years suggests that N application beyond 150 lb/acre may be unfavorable for cotton yield.

Introduction

Second to water, nitrogen fertility limits cotton production yields in the Texas High Plains. A three-year study was conducted near Lamesa, Texas, under a limited irrigation production system (Bronson et al. 2006) to characterize the effect of nitrogen application on leaf moisture and leaf nitrogen content in cotton and the resulting influence on cotton aphid population dynamics (Matis et al. 2008). Leaf nitrogen content did not vary with nitrogen application method (variable N versus blanket N application of an optimal amount), but both the blanket application and variable-rate application resulted in significantly higher leaf nitrogen contents than were noted in zero-augmented nitrogen plots. As nitrogen application rates were increased from zero to an optimum rate, a significant decrease in both aphid birth and death rates occurred, translating to a decrease in crowding and an increase in aphid survival (Matis et al. 2008). While these data help to characterize cotton aphid population dynamics between zero nitrogen fertility management and optimal nitrogen application rates, the population dynamics of cotton aphids and other cotton arthropods have not been examined under a full range of nitrogen fertility rates (Parajulee 2007; Parajulee et al. 2006, 2008). In particular, no known study has produced plant growth parameters or fruiting profile data pertaining to a spectrum of nitrogen application rates in cotton. The objective of this study was to evaluate, in cotton growing under a subsurface drip irrigation production system, cotton crop growth parameters and arthropod population abundance, as influenced by varying N fertilizer application rates.

Materials and Methods

The study was conducted at the Texas A&M AgriLife Research farm near Plainview, Texas. A 5-acre sub-surface drip irrigation system had been in place for six years prior to this study. Plot-specific nitrogen fertility treatments had been applied in a randomized block design with five replications since 2002. Five nitrogen application rates (0, 50, 100, 150, 200 lb/acre) had been deployed to the same experimental units consistently for five consecutive years to induce maximum discrimination among treatment plots through variation in soil residual nitrogen (Fig. 1)

0	50	200	50	200
100	100	0	100	50
200	150	50	150	0
50	200	100	200	100
150	0	150	0	150

Figure 1. Helms Farm nitrogen study experimental plot layout following a five-treatment x five-replication randomized block design. Annually, each of the 25 plots received one of the five nitrogen augmentation treatments including 0, 50, 100, 150, or 200 lbs N/acre, Hale County, TX.

The study reported herein was conducted for six years (2008-2013). Soil residual nitrogen was monitored annually by taking two 24-inch core samples from each plot Fig. 2). The 0-12 inch portions of each core were combined to form a single, composite soil sample, and likewise, the 12-24 inch portions were combined, resulting in two samples per experimental plot. Samples were sent to Ward Laboratories, Kearny, Nebraska for analysis. Regionally well-adapted cultivars were used in this study over the duration of the study: FM960B2R was planted on May 13, 2008, May 20 2009, and May 27, 2010, DP104B2RF on June 14, 2011, and FM9063B2RF on May 17, 2012 and May 23, 2013. The experiment consisted of a randomized block design with five treatments and five replications. The five treatments included side-dress applications of nitrogen fertilizer at rates of 0, 50, 100, 150, and 200 lb N/acre. Cotton was planted (56,000 seeds/acre) in 30-inch rows and was irrigated with a subsurface drip irrigation system.

Figure 2. A) Annual pre-season soil sampling of 25 sub-surface drip irrigated cotton plots; B) Annually near the time of first bloom, each plot received the same side-dressed nitrogen application treatment rate; C) Differential cotton plant growth responses are often visually apparent between plots receiving high and low N application rates, Hale County, TX.

Leaf area, plant height, and root length were measured on July 3 (2008), July 20 (2009), July 27 (2010), July 15 (2011), July 6 (2012), and July 22 (2013) to evaluate the influence of residual nitrogen on early plant growth patterns. Except for 2008, leaf chlorophyll content was also measured from 5^{th} mainstem node leaves (n=10 leaves per plot) weekly from July 30 to October 1 (10 weeks) in 2009, August 9 to September 9 in 2010 (5 weeks), July 21 to August 25 (6 weeks) in 2011, July 6 to August 2 (5 weeks) in 2012, and July 22 to September 27 (9 weeks). Soil samples were taken from the experimental plots on July 14 (2008), July 6 (2009), March 25 (2010), April 27 (2011), June 1 (2012, and June 20 (2013) for residual nitrogen analysis. Crop growth and insect activity were monitored throughout the season. Fertility treatments were applied on July 18 (2008), July 10 (2009), July 8 (2010), August 3 (2011), July 6 (2012), and July 11 (2013) with a soil applicator ground rig. COTMAN SQUAREMAN monitoring was used to monitor early plant growth, and was followed by measurement of Nodes Above White Flower (NAWF) for most study years. Pre-harvest plant mapping was used as an indicator of fruit load. Foliage-dwelling mobile arthropods were monitored weekly using a Keep It Simple Sampler (KISS; Beerwinkle et al. 1997) to collect insects from uppercanopy foliage, beginning from square initiation and ending at crop cutout, for years when arthropod activity occurred (Fig. 3a-f)

Cotton aphid populations did not develop in four (2008, 2011, 2012, and 2013) of the six years of the study, despite repeated applications of cyhalothrin intended to stimulate aphid population growth. Cotton aphid abundance was monitored weekly for five weeks from August 20 to September 17 in 2009 and from August 9 to September 9 in 2010. Hand-harvested yield samples were obtained from each plot. Fiber samples were analyzed for lint quality parameters at the Cotton Incorporated Fiber Testing Laboratory (North Carolina).

Figure 3. A) Blower sampling for arthropods, B) Processing of arthropod samples in the laboratory, C) Measuring leaf chlorophyll, D) Whole-plant sample collection for parameter estimation, E) Measuring leaf area, plant root and shoot biomass, F) cotton harvesting.

Results and Discussion

In all study years, soil residual N levels were significantly higher in plots that received the two highest application rates of N fertilizer versus plots receiving lower-rate N applications or no N augmentation, excepting plots that received 100 lb/acre N in 2012 (Fig. 4). Averaged over the six-year study period, soil residual N levels were lowest in zero and 50 lb/acre plots, although the 50 lb/acre plots had numerically higher residual N than in zero N plots. The highest N augmentation plots (200 lb/acre) had significantly highest average residual N; the year-to-year residual N was always the highest amount in this treatment, at least numerically. The two second highest N augmentation plots (100 and 150 lb/acre) resulted in significantly higher amount of soil residual N compared to that in zero and 50 lb/acre plots. Even though some year-to-year variation in leaf area, plant height, and root length was noted early in the crop season, differential amounts of soil residual N generally did not influence early plant growth, except for 150 lb/acre (Figs. 5-7). The 150 lb/acre treatment was significantly favorable for plant growth during early season contributing to the highest leaf area, plant height, and root length compared to that in other N treatments. Measured leaf chlorophyll content varied with nitrogen application level, and leaf chlorophyll contents from cotton in those plots which received 0 lb N/acre or 50 lb N/acre were significantly lower than all others (Fig. 8). Cotton in plots which received the three highest nitrogen application rates (100, 150, and 200 lb N/acre) exhibited relatively consistent leaf chlorophyll readings (Fig. 8). It is noteworthy that the leaf chlorophyll content in zero N treatment plots declined precipitously beginning in late August, when plants began allocating much of their resources to boll maturation, whereas this phenomenon did not occur in plots that received ≥50 lb N/acre. Cotton aphid activity began in late August in 2009, and densities peaked in early- to mid-September. Cotton aphid densities were significantly lower in 0 lb N/acre treatment plots compared with that in N augmented plots located only feet apart (Fig. 8). There were no significant differences in aphid densities across N augmented plots in 2009. Cotton aphid colonization occurred two weeks earlier in 2010 compared to that in 2009. While cotton aphid densities remained below economic threshold (50 aphids/leaf for two consecutive weeks) in 2009, aphid populations surpassed economic threshold in all N-augmented plots in 2010, whereas aphids remained below 50/per leaf, except for 1 week, in zero-N plots.

Nitrogen fertility level influenced boll maturity. Bolls in zero applied N plots tended to mature significantly earlier than in N augmented plots. Laboratory measurement of boll exocarp penetrability showed that bolls from zero N augmented plots required significantly greater pressure to puncture the exocarp versus that required to do so for bolls from N augmented plots. Variation in soil residual N levels, coupled with variable N application, resulted in phenotypic expression of nitrogen deficiency in cotton across treatment plots, especially between zero N plots and N augmented plots (Fig. 2). The zero N plots consistently produced the lowest lint yield for every year of the six-year study, except in 2010 when 50 lb/acre plots and zero N augmented plots had similar lint yields (Fig. 9). Overall, 150 and 200 lb/acre plots produced the highest lint yield (1,460 lb and 1,430 lb lint for 150 and 200 lb N treatments, respectively), followed by 100 (1,302 lb), 50 (1,190 lb), and zero N (960 lb) plots. Yield increased curvilinearly with each additional 50 lb N added, with the numerically highest average yield (1,460 lb/acre) occurring in augmented 150 lb N/acre treatment, but the yield numerically decreased beyond 150 lb N/acre with additional N. Consistent numerical decline in yield beyond 150 lb N/acre in most years suggests that N application beyond 150 lb/acre may be unfavorable for cotton yield.

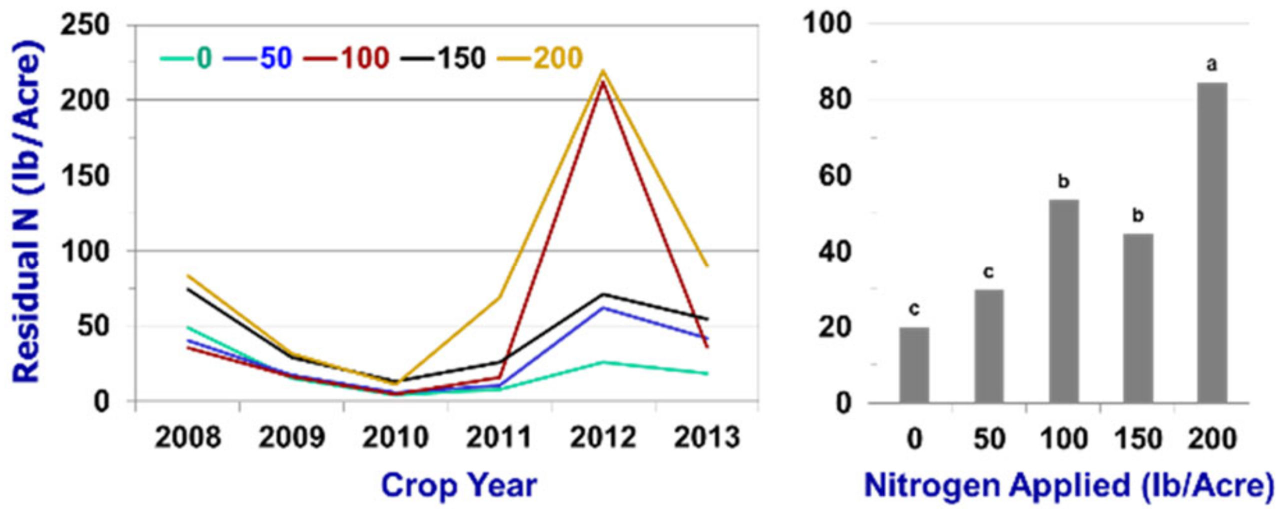

Figure 4. Effect of prior year's N application (0, 50, 100, 150, and 200 lb per acre) on residual N accumulation for the current crop year (left) and average residual N over a six-year period (right).

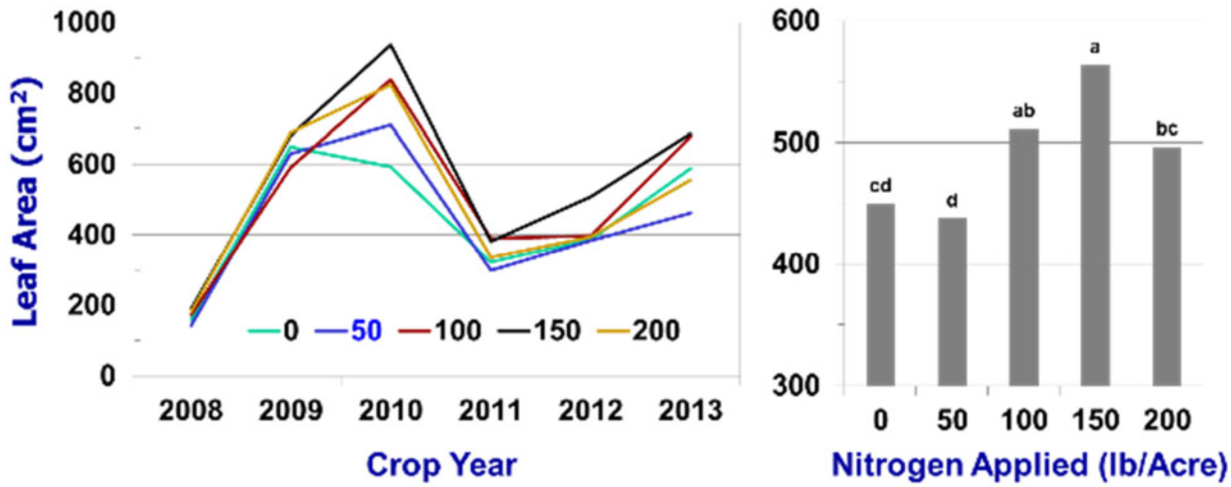

Figure 5. Effect of prior year's N application (0, 50, 100, 150, and 200 lb per acre) on residual N accumulation for the current crop year (left) and average residual N over a six-year period (right).

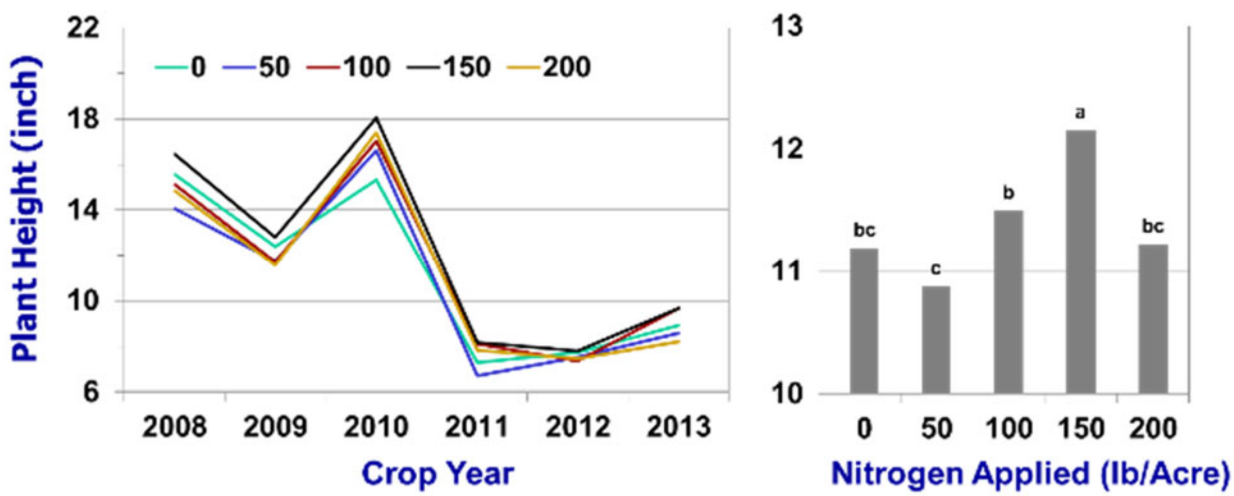

Figure 6. Effect of residual N from the previous crop year on plant height during the early crop growth period of each of the six study years (left) and average plant height over a six-year period (right).

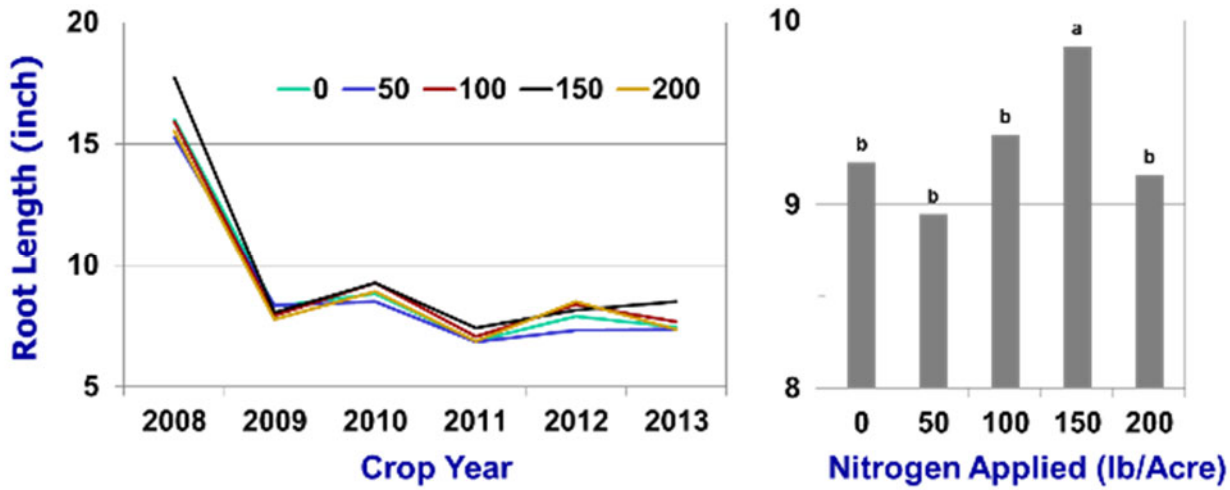

Figure 7. Effect of residual N from the previous crop year on root length during the early crop growth period of each of the six study years (left) and average root length over a six-year period (right).

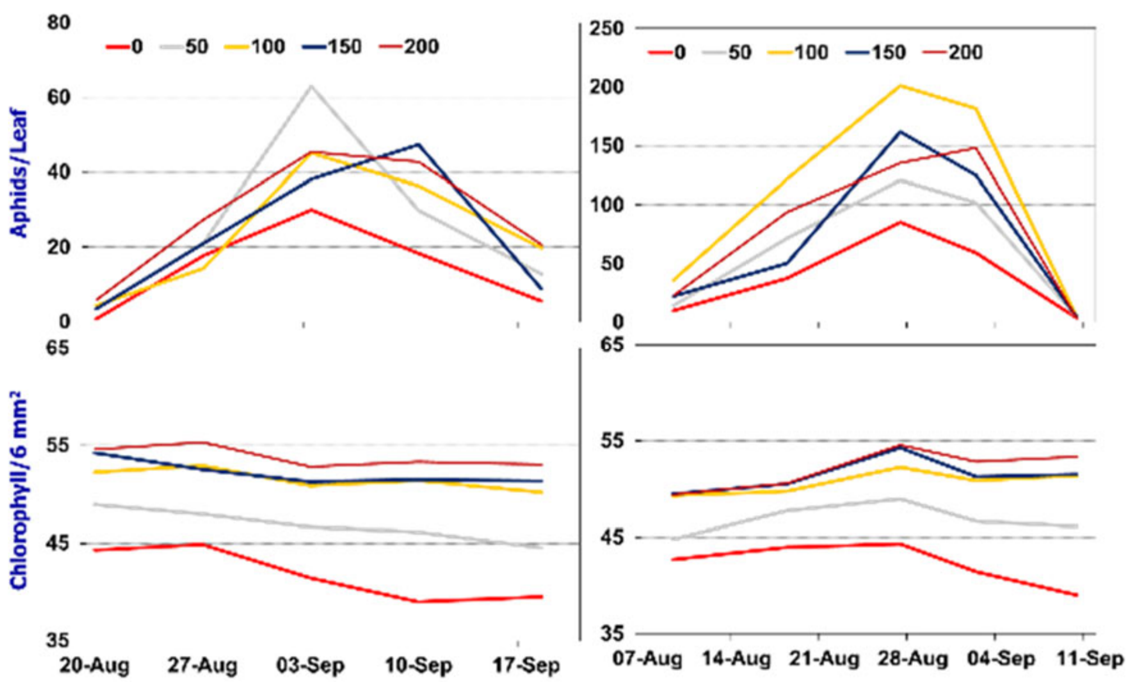

Figure 8. Temporal dynamics of cotton aphid abundance in relation to cotton leaf (5th main stem) chlorophyll content as affected by variable rates of nitrogen application (left chart – 2009, right chart – 2010).

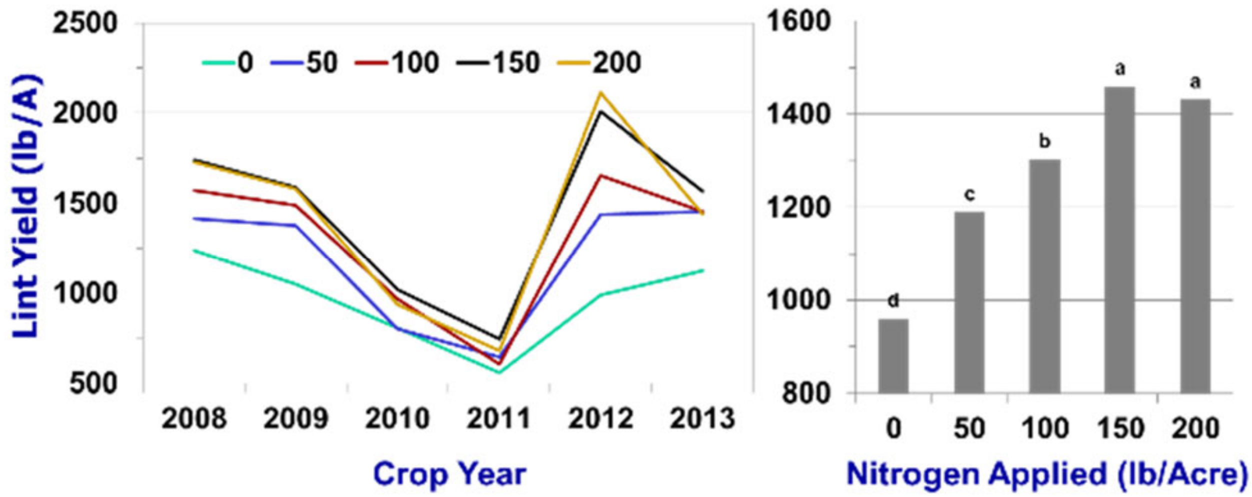

Figure 9. Year-to-year variation in the effect of nitrogen application rates on cotton lint yield (left) and average lint yield over a 6-year period (right), Helms Farm, Hale County, TX.

Acknowledgments

Cotton Incorporated Core Program and Plains Cotton Growers, Inc. have provided funding for this long-term nitrogen fertility study.

References

Beerwinkle, K. R., J. R. Coppedge, and T. M. O'Neil. 1997. "KISS" - a new portable pneumatic "keep it simple sampler" for row crop insects, pp. 1330-1333. *In* Proceedings, Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Bronson, K. F., J. D. Booker, J. P. Bordovsky, J. W. Keeling, T. A. Wheeler, R. K. Boman, M. N. Parajulee, E. Segarra, and R. L. Nichols. 2006. Site-specific irrigation and nitrogen management for cotton production in the Southern High Plains. *Agronomy Journal* 98: 212-219.

Matis, T. I., M. N. Parajulee, J. H. Matis, and R. B. Shrestha. 2008. A mechanistic model based analysis of cotton aphid population dynamics data. *Journal of Agriculture and Forestry Ecology* 10: 355-362.

Parajulee, M. N., R. B. Shrestha, and J. F. Leser. 2006. Influence of tillage, planting date, and *Bt* cultivar on seasonal abundance and within-plant distribution patterns of thrips and cotton fleahoppers in cotton. *International Journal of Pest Management* 52: 249-260.

Parajulee, M. N. 2007. Influence of constant temperatures on life history parameters of the cotton aphid, *Aphis gossypii*, infesting cotton. *Environmental Entomology* 36: 666-672.

Parajulee, M. N., R. B. Shrestha, A. K. Barman, and S. C. Carroll. 2008. Ecologically intensive pest management in cotton agroecosystems: *Lygus hesperus* as a model system. *Egyptian Journal of Agricultural Research* 86: 57-81.