MANAGING COTTON FERTILITY WITH A LEAF BLADE NITROGEN TEST AND FOLIAR APPLICATIONS OF UREA

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Abstract

Nitrogen fertilizer management is a crucial and often mismanaged part of cotton production. A fine line exists between excess and deficiency and over-fertilization is often the case. In this experiment, critical nitrogen levels determined by a leaf blade nitrogen test were used as thresholds for foliar applications of urea. Cotton plots established on Sharkey clay and Commerce silt loam were grown under five nitrogen regimes. Two fertilizer treatments in plots on each soil type included supplemental foliar applications of nitrogen based on leaf blade nitrogen levels. Nitrogen levels varied throughout the growing season with nitrogen rate, soil type and crop stage. Multiple applications of foliar urea were unable to maintain levels considered sufficient. Lint yield of cotton on both soil types mirrored our efforts to maintain adequate levels of crop nitrogen. Plots receiving the optimum soil applied nitrogen rate yielded an average of 873 and 1060 lbs. acre^{-1} for Sharkey and Commerce, respectively. Plots receiving minimal soil nitrogen along with supplemented foliar nitrogen required an average of 5.75 applications of foliar urea ($\approx$28.75 # N) and 3.1 applications of foliar urea ($\approx$15 # N) for Sharkey clay and Commerce silt loam, respectively. These foliar applications were unable to increase the yields of these treatments to levels obtained using the traditional soil applied practices.

Introduction

Nitrogen management is an important component in maximizing cotton yield and fiber quality in the Midsouth. One question that is constantly addressed is the placement and application of nitrogen fertilizers throughout the growing season. Typically nitrogen is applied before or near planting and often supplemented later in the growing season by side-dress treatments or foliar applications. The question that remains is how much of this fertilizer nitrogen is lost and how much is utilized by the plant. Additional fertilizer nitrogen is often applied to compensate for loss due to denitrification, leaching and immobilization. This additional nitrogen can lead to over-fertilization, which could promote rank growth, delayed maturity and ultimately lost profits. Recently, topics such as groundwater contamination and hypoxic areas in the Gulf of Mexico have led to a general emphasis on reducing nitrogen inputs throughout the agricultural system. Increased pressures from environmental groups and an increased emphasis on more efficient placement and use of fertilizers may lead us to develop better management practices.

The determination of optimum nitrogen rates for cotton production has always been a problem. Tradition and experience have been the primary method for determining the specific nitrogen rate for a particular cotton field. Although there is a narrow range that exists between nitrogen deficiency and excess, the possibility of nitrogen loss by leaching or denitrification generally leads to the application of more fertilizer than necessary. Because cotton is grown over a wide range of soils, climates and cropping conditions, the nitrogen requirement and efficiency can differ from location to location and year to year.

A combination of soil and plant tissue tests is often used to monitor cotton nitrogen status. The petiole nitrate test has been the most popular method used to monitor plant nitrogen status. The test estimates flow of nitrate from the root to the leaf in the transpiration stream. Because petiole nitrate levels often vary with cultivar, growth stage, soil type, weather and insect damage, the test is difficult to interpret (Keisling et al. 1995, Heitholt 1994, Sabbe and Zelinski 1990, Maples et al. 1990). Recently, Bell et al. (1997, 1998) suggested using a leaf blade nitrogen test that measures the total leaf nitrogen content. This is believed to be a direct measure of the plant's nitrogen status and provides an estimate of cumulative nitrogen uptake prior to sampling and the amount of reserve nitrogen. Like the petiole nitrate test, significant variations can occur with different cultivars, growth stage, soil type, weather and insect damage (Bell et al. 1997, 1998). Despite these caveats, results indicate that more accurate predictions of cotton nutritional status may be made. Another test that shows promise is the use of the SPAD hand-held chlorophyll meter (Minolta Camera Company) (Boquet et al. 1999, Edminsten et al. 1992). The device estimates the chlorophyll content of the leaf by measuring the difference in light attenuation at 430 and 750 nm. The advantage of this test is that sampling is non-destructive and results are instantaneous. Both tests, if used properly, could increase nitrogen fertilizer efficiency and eliminate some of the guesswork of nitrogen fertilization.

Previous research has suggested that pre-plant and sidedress nitrogen applications may not meet crop demands (Maples and Baker 1993). When this occurs, foliar applications of nitrogen have offered an alternate method of getting nitrogen to the plant. However, results from previous studies on the effects of foliar nitrogen applications have been inconsistent (Keisling et al. 1995, Smith et al. 1987, Anderson and Walmsley 1984). Recent research indicates that yield

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response to foliar nitrogen applications is not always obtained. Some explanations for this inconsistent yield increase could be decreased uptake due to leaf age and the increased surface wax content (Bondada et al. 1997). Although, many questions still exist regarding the use of leaf and petiole nitrate tests along with foliar applications of nitrogen for cotton fertility management, the concept remains promising and more research is needed. The objective of this experiment was to determine whether critical nitrogen levels and foliar application of nitrogen could be used to successfully manage cotton fertility on fine and medium textured soils.

Materials and Methods

Cotton plots were established on a moderately drained Sharkey silty clay using cv. STV 474 and a well drained Commerce silt loam using cv. SG 125. Plots were established on May 7, 1999 and May 13, 1999 for the Commerce and Sharkey respectively. Each plot consisted of eight rows 45 feet in length. Four replications of five fertilizer treatments were evaluated on each soil type. Fertilizer treatments consisted of optimum nitrogen rates for each soil type applied both pre-plant and split. Other treatments included untreated all season as well as treated and untreated with supplemental foliar applications (Table 1). With the exception of fertilization, all plots were maintained using standard production practices (i.e. insect control, tillage etc.).

Beginning at pinhead square, chlorophyll (SPAD) readings were taken weekly from ten of the upper-most fully expanded leaves. Those same leaves were removed and taken to the lab for nitrogen analysis. Midribs were removed and samples were oven dried at 80°C. Samples were then ground to pass a 40-mesh screen. Leaves were analyzed for nitrogen levels using a Leco FP-428 analyzer and total nitrogen concentration was determined (total--Kjeldahl- N equivalent)(Bell et al. 1997, 1998). Bell et al. (1997, 1998) suggest that critical nitrogen levels are approximately 4.6%, 4.0%, 3.8% and 3.3% N at pin-head square, early-bloom, mid-bloom and cut-out respectively. As with insect control recommendations, thresholds using these critical nitrogen levels along with the corresponding crop stages were established. When nitrogen levels for individual plots fell below the critical value, supplemental foliar applications were made. Urea (46% N) was applied foliarly at 5 lb. N/acre as needed. Nitrogen was applied in an aqueous solution at a volume of 10 gallons/acre using a John Deere Hi-Cycle. Plots were also monitored throughout the growing season for node above white flower and height to node ratio. End of year plant maps (COTMAP) were made at two weeks after physiological cutout. Measurements of lint yield and yield components were taken using a mechanized picker and box mapping (Jenkins et al. 1991), respectively.

Results

Leaf blade nitrogen levels throughout the growing season varied depending on crop stage, soil moisture content, and soil type. Our initial expectations were that foliar applications of urea would greatly influence the lint yield of cotton grown on clay soils. Leaf blade nitrogen results beginning at pin-head square (≈ 30 DAP) indicated a deficiency in plots receiving 0 soil applied nitrogen (Figure 1). Subsequent applications of urea throughout the growing season were unable to bring leaf blade nitrogen levels above those considered critical (Figure 1). Soil applied nitrogen rates of 40 and 120 pounds per acre (all at once or split) showed little signs of deficiency until the onset of blooming (≈ 56 DAP). As blooming occurred, foliar applications of urea were necessary in those plots receiving 0 and 40 pounds pre-plant. Those plots receiving a pre-plant application of 40 pounds of N plus foliar applications appeared to respond initially but as the sink strength (boll load) became stronger leaf blade nitrogen levels began to decline (Figure 1). On average plots receiving 0 and 40 pounds of N at pre-plant required 6.5 (32.5 # N) and 5 (25 # N) applications respectively. SPAD meter readings taken along with the leaf blades showed little promise in predicting deficiency.

On the better-drained commerce silt loam, no plots were deficient during the first two weeks of sampling (Figure 2). An extended period of dry weather (≈ 44 DAP) caused all plots to be deficient during the third week of sampling. After a foliar application of urea along with rainfall, leaf blade nitrogen levels rose above the critical level until the onset of blooming. As blooming began (≈ 58 DAP), nitrogen deficiencies began to show up in plots receiving no soil nitrogen. Although individual plots within treatments required foliar applications, on average most plots with the exception of those receiving 0 nitrogen at planting stayed above the critical level. Plots grown on the Commerce soil required fewer foliar applications during the season. On average, plots receiving 0 and 30 pounds of N at pre-plant required 3.5 (17.5 # N) and 2.75 (13.75 # N) applications respectively. This was about half of the foliar N required by the Sharkey plots. SPAD meter reading resembled those obtained in the clay test. Little differences were seen between treatments even though visible symptoms were observed in the field.

Although there was a possible blocking effect due to soil variations, lint yields in the clay plots were consistent with the leaf blade nitrogen results (Figure 3). Plots receiving 0 nitrogen for the year yielded an average of 397 pounds of lint per acre. Applications of foliar urea to plots receiving 0 soil-applied nitrogen increased yield 178 pounds for an average yield of 575 pounds of lint per acre. Plots receiving 40 pounds of nitrogen at planting along with foliar applications of urea as needed, yielded an average of 736 pounds of lint per acre (339 pounds/acre more than untreated check). Plots that received the recommended soil applied nitrogen rate of 120 pounds of nitrogen per acre (all at once or split) yielded 913 and 831 pounds of lint per acre respectively (Figure 3).

Yields in the commerce silt loam were fairly consistent among treatments. Although small numerical differences can be seen, statistical analysis of yield produced few differences (Figure 4). Plots receiving 0 nitrogen for the entire year still managed to yield an average of 792 pounds of lint per acre. When foliar urea was added to plots receiving 0 nitrogen at planting, yields were increased 116 pounds per acre for an average yield of 908 pounds per acre. Plots receiving 30 pounds of nitrogen at planting along with foliar applications of urea only boosted yields 169 pounds per acre for an average of 961 pounds of lint per acre. Recommended soil applied fertilizer treatments of 80 pounds per acre either split or all at once yielded 1065 and 1055 pound of lint per acre respectively (Figure 4).

A better understanding of yield differences was obtained by analysis of partitioned yield (Box mapping). For this paper, seed cotton from first position fruit from horizon 1 (nodes 5-8), and 3 (nodes 13-16) and first and second position fruit from horizon 2 (nodes 9-12) will be discussed. In the Sharkey clay soil, few differences were observed in any treatment for first position yield in the first horizon, although the plot receiving 40 pounds N pre-plant was slightly higher than all other treatments (Figure 5). In the second horizon, plots receiving a pre-plant application of N (40 or 120 # N) were significantly higher than those plots receiving no pre-plant fertilizer. Addition of foliar N increased first position yield over the untreated check (Figure 5). Second position yield in the second horizon were significantly higher in the plot receiving 120 pounds of N at pre-plant (Figure 5). The same is true for first position yield in the third horizon (Figure 5). It appears that first position fruit are not as affected by pre-plant applications as are fruit set later in the growing season. In fact, higher N rates early in the season appeared to slightly decrease early fruiting. However, a higher rate of fertilizer more than made up for the lack of lower fruit later in the season (horizon 2-3), which ultimately translated into higher crop yields (Figure 3).

The decreased fruiting in the lower horizons was even more pronounced in plots receiving high N rates on the Commerce soil (Figure 6). Seed cotton yield of first position fruit from horizon one in plots receiving 0 N at planting were at least significantly equal and or numerically higher to those receiving optimum N rates. The plots that received 0 and 30 pounds of N at pre-plant plus additional foliar N had significantly higher seed cotton weights than all treatments except the untreated check. However, yield at both position one and two in the second horizon were significantly higher in plots receiving at least 30 pounds of N at pre-plant. Seed cotton weights from first position fruit in the third horizon were significantly higher for plots receiving the optimal rates of N (Figure 6).

Conclusions

It was determined late in the growing season that 5 pounds nitrogen per application was insufficient to raise leaf blade nitrogen levels above the critical level. Although 5 pounds is the minimum dosage typically used, we believed that because of the potential for repeated applications, this lower rate would cause the least foliar burn. Cosmetically, plots receiving a soil application of 40% less than optimal and supplemented with foliar applications appeared to "keep up" with those plots receiving optimal N rates. However, as the boll load increased, our efforts to maintain N levels above those considered critical were unsuccessful. Based on our yield partitioning, we believe that by setting at least 1-2 more harvestable bolls per plant we can compete with optimal soil applied N rates. In order to accomplish this goal, one of two things must be done. The first is to develop new "thresholds" to trigger foliar applications. One reason our efforts may have been unsuccessful is that critical levels were too low and/or our timing was too late. The second is that a larger dose of N must be applied foliarly without significant leaf burn. This option was studied to some degree this past summer and will be researched further next season. Foliar fertilization has a place in cotton production and more research is needed to optimize it's potential.

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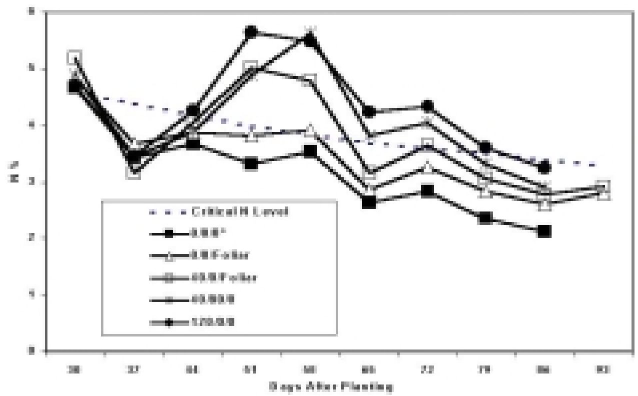
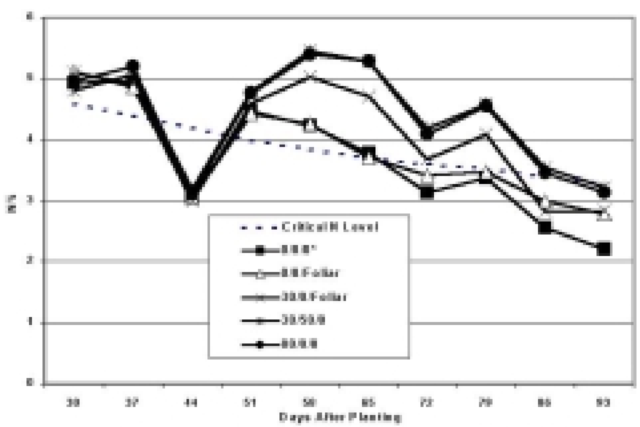
Table 1. Nitrogen rates for critical nitrogen experiment, 1999.

Sharkey Clay			Commerce Silt Loam		
Preplant	**Sidedress**	**Foliar**	**Preplant**	**Sidedress**	**Foliar**
120	0	0	80	0	0
40	80	0	30	50	0
0	0	Foliar	0	0	Foliar
40	0	Foliar	30	0	Foliar
0	0	0	0	0	0



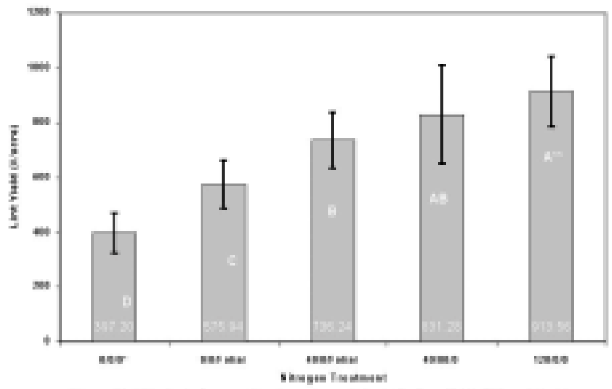
* Preplant N/Sidedress N/Follar N as needed determined by the leafblade N test

Figure 1. Seasonal change in leaf blade N% of cv. STV 474 grown on Sharkey clay, 1999.

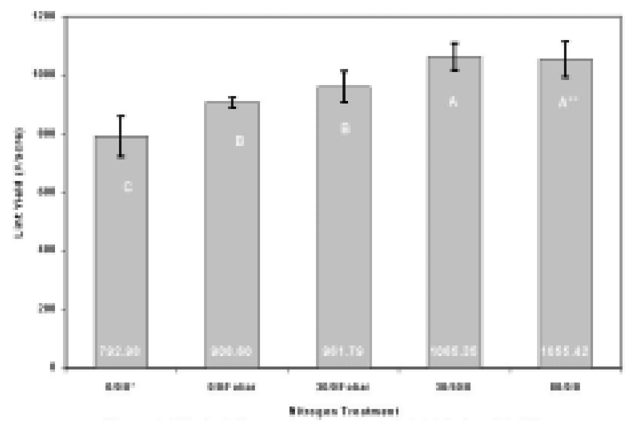


* Preplant N/Sidedress N/Follar N as needed determined by the leaf blade N test.

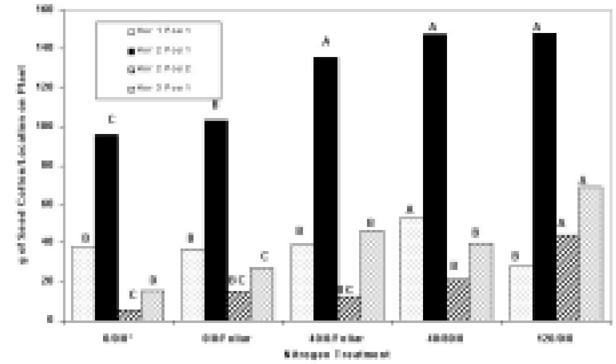
Figure 2. Seasonal change in leaf blade N% of cv. SG 125 grown on Commerce silt loam, 1999.



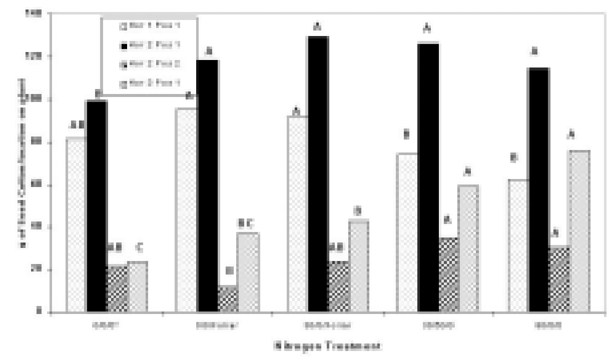
* Preplant N/Sidedress N/Follar N as needed determined by the leaf blade N test.
** Means sharing the same letter within columns are not significantly different according to LSD (a=0.05).
Figure 3. Effect of nitrogen treatments on lint yield of cv. STV 474 on Sharkey clay, 1999.



* Preplant N/Sidedress N/Follar N as needed by the leaf blade N test.
** Means sharing the same letter within columns are not significantly different according to LSD (a=0.05)
Figure 4. Effect of nitrogen treatments on lint yield of cv. SG 125 on Commerce solt loam, 1999.



* Preplant N/Sidedress N/Follar N as needed determined by the leaf blade N test.
** Means sharing the same letter within each horizon and boll position are not significantly different according to LSD (a=0.05).
Figure 5. Yield partioning in five nitrogen treatments of cv. STV 474 on Sharkey clay, 1999.



* Preplant N/Sidedress N/Follar N as needed determined by the leaf blade N test.
** Means sharing the same letter within each horizon and boll position are not significantly different according to LSD (a=0.05)
Figure 6. Yield partioning in five nitrogen treatments of cv. SG 125 on Commerce silt loam, 1999.