N MANAGEMENT IN SAN JOAQUIN VALLEY ACALA COTTON: SOIL PROFILE N RESPONSES TO MANAGEMENT

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Abstract

The response of Acala cotton (*Gossypium hirsutum L.)* in California to a range of applied nitrogen treatments were investigated in a five year, multi-site experiment. Goals of this portion of the large field trial were to identify patterns of changes in soil nitrate-N status with depth within fields used in the experiments and identify the degree to which residual soil nitrogen in the soil profile could impact crop responses. Site by site analysis of soil nitrogen patterns in the soil profiles indicate varying degrees of potential for downward movement of soil nitrate N not utilized by the cotton plants during the season, and wide variation in residual soil N across sites.

Introduction

With cotton, it has been recognized for many years that mid and late-season nitrogen management has an impact on progress toward defoliation and harvest. High nitrogen levels delay harvest, can have a negative impact on the ease and costs of defoliation, and can increase problems with some late-season pests (silverleaf whitefly, aphids) that can influence lint quality. High nitrogen levels during bloom and early boll filling can also promote vegetative development at the expense of fruit retention under some conditions. An additional area of concern is the fate of nitrogen applied in excess of plant requirements. If plants grown in the rotation sequence don't have deep roots to intercept applied and residual nitrogen, its eventual movement through the soil profile can result in nitrate contamination of shallow groundwater in a wide range of conditions. Long-term field experiments were conducted across a range of soil types and cropping conditions in the San Joaquin Valley of CA to evaluate plant growth and yield responses to applied nitrogen.

Materials and Methods

The experiments were operated in University of CA Research Centers at the West Side and Shafter Research and Extension Centers plus five to six grower fields per year in Fresno, Madera, Merced, Kings, Tulare and Kern County in the San Joaquin Valley of CA. This experiment is basically described in the companion paper also in these proceedings.

Some field sites were utilized for multiple years (about 1/3 of the field sites over the five-year period), while the remaining sites were new each season due to continued changes in grower crop rotations. In all cases, soil samples were collected to a depth of 2 feet prior to planting and analyzed for beginning soil NO3-N and NH4-N. In addition, for the purposes of evaluating soil nutrient status at different times of the year, soil samples were also collected to a depth of 8 feet at two times each year in all plots. Each of three replicate plots within each treatment at each location was sampled in one-foot increments to a depth of 4 feet, and then in two foot increments to an ending depth of 8 feet, resulting in 6 separate samples per sample hole. Four locations within each plot were sampled in the first, second and third years of the study, and three locations per plot were sampled in years four and five. A Giddings soil sampling rig with a 1 ¾ inch tube was used to collect all samples.

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Soil samples were kept refrigerated until subsamples were collected for analyses. Subsamples were separated and used for gravimetric soil water content, bulk density in a limited number of samples, for a 2N KCl extract used for NO3-N and NH4-N analyses, and a subsample was air-dried for subsequent NO3-N, PO4-P, ammonium acetate exchangeable-K and other analyses as each site required. This extensive sampling was done two times each growing season, once at a time within about 1 to 3 weeks after emergence of the crop, and again after harvest and stalk shredding, but before fall cultivation in most cases. Where sampling could not be completed prior to fall cultivation, soil samples were collected in the upper two feet prior to cultivation, and then using a Giddings soil sampling rig for greater depths.

Four basic nitrogen (N) fertilization treatments were established each year at each site. The application amount used was equal to the desired N treatment level in lbs N/acre minus the calculated soil residual N value in lbs NO3-N/acre 2-ft determined using the soil samples prior to planting. If the initial amount of soil residual NO3-N was greater than 50 lbs NO3-N/acre, the residual value was used as the baseline for the 50 lb N treatment, and all other treatments were added in 50 lb increments above that baseline. Soil PO4-P and exchangeable-K were also tested on soil samples, and applications of these nutrients made as necessary to avoid P or K deficiencies in this nitrogen experiment.

In 1996, four treatments of 50, 100, 150 and 200 lbs N/acre were applied in late May (prior to the first within-growing season irrigation), and in three supplemental treatments (50, 100 or 150 lbs N/acre initially applied), a second N application of 50 lbs N/acre was applied in June just prior to the second (pre-flower) within-season irrigation. In 1997 through 2000, the experiments were simplified down to four basic treatments (50, 100, 150 and 200 lbs N/acre) due to the lack of crop growth and yield responses to split-application treatments.

Results and Discussion

Initial Soil Nitrogen Levels

In most years of the study, a wide range of soil NO3-N levels across field sites was observed. The yield data in this paper will cover all five years of the experiment, but for brevity, only a few examples of the soil N data will be discussed. Beginning soil NO3-N in the upper two feet of the soil profile were highly variable across years and sites in the experimental sites. For example, in the upper two feet of the soil profile in 1997, soil NO3-N concentrations ranged from a low of 9 mg NO3-N/kg soil dry soil to over 35 mg/kg. These soil NO3-N levels corresponded with a range of 34 lbs N as NO3-N per acre in the upper 2 feet of the soil (at a site where cotton followed wheat) to a high of more than 130 lbs N as NO3-N/acre in the upper 2 feet (cotton following corn and processing tomatoes). Soil NO3-N levels in the upper 2 feet of the profile at the Spring 1998 sampling ranged from a low of 37 lbs N as NO3-N per acre at the Shafter REC site to 103 lbs N as NO3-N per acre at the Madera County site in spring of 1998, with an 8-location average of about 65 lbs N as NO3-N/acre. Examples of beginning soil NO3-N levels in the upper two feet of the soil profile are shown for two years across all locations in Figures 1 and 2.

The range in soil sample spring nitrate levels was even greater in 1999, with the highest N site having over 200 lbs N as NO3-N available in the upper two feet of the profile (in a field where cotton planting followed corn). Soil NO3-N levels in the upper 2 feet of the profile at the Spring 1999 sampling ranged from a low of 36 lbs NO3-N per acre in the low N treatment at the West Side REC to a high of 241 lbs NO3-N per acre at the Madera County site. Most other sites in the spring upper 2-foot sampling in 1999 ranged from about 45 to 110 lbs NO3-N per acre in the upper 2 feet of soil (data not shown).

Treatment Effects

This report will focus mostly on soil test data from the 1997 and 1998 studies, but when final analyses are complete, all five years will be represented. Soil N as NO3-N was converted into lbs N/acre-foot of soil volume, and soil bulk density measured, allowing calculation of net changes in soil test N as NO3-N during the growing season (planting to post-harvest). There are recognized limits in interpreting this type of data, since values change over time with processes such as mineralization and denitrification. However, these changes in soil NO3-N over time still represent a general index of soil changes in N status resulting from crop uptake and other processes / losses during the growing season.

Data in general has indicated that most net depletion of soil NO3-N was seen in the upper four feet of the soil profile. It could be argued that this depletion could result from leaching losses as well as denitrification, but the measured presence of significant root mass at depths down to 5 to 6 feet at about ¼ to 1/3 of the sites over the five years indicated that plant uptake is another reason for net depletion even in the 4 to 8 foot zone. Most other sites had root activity primarily in the upper 3 to 4 feet of the soil profile. As levels of applied N increased at most sites, soil NO3-N levels in the 4 to 8 foot zone of the soil profile generally increased.

Average changes in soil NO3-N between the Spring (planting time) and Fall (post-harvest) soil sample timings for 1997 (Figure 3) and 1998 (Figure 4) can be used as examples of general trends identified but certainly are an over-simplification of site variation in soil NO3-N patterns. The negative numbers indicate a net "loss" or a reduction in soil NO3-N content for all the 0 to 4 foot depths in all N application treatments (50, 100, 150 and 200 lbs N/acre treatments). This can be interpreted as mostly indicating net uptake of N from that zone of the soil (although other transformations can also account for some of the changes, and these were not measured). The positive numbers seen in the 4 to 8 foot zone of the soil profile in the higher applied N treatments potentially indicate there was more NO3-N moved down into that deeper part of the soil profile during the course of the season.

Again, other transformations can also account for part of the observed changes. If the cotton or subsequent crops cannot access this N source, it would be subject to leaching losses if moved further by water moving through the soil profile. Higher beginning soil NO3-N prevailed in most sites during the 1996 trials, but similar trends were in the 1999 data (not shown). Samples were again collected in 2000 but analyses are incomplete as this report is prepared.

Due to surface infiltration characteristics, soil water storage capacity and timing of irrigations, half of the sites in this study (Shafter REC, Kern County, Tulare County, West Side REC) had relatively limited potential for significant leaching of nitrate-N into the lower profile (Shafter REC data in Figure 5). In the 1997 and 1998 studies for which soil N data is being discussed, the Fresno, Kings, Madera and Merced County sites had soil types which could allow significant downward water / solute movement under some crop, weather and management conditions. This is evidenced by higher rates of net accumulation of soil NO3-N in the 4 to 8 foot depths during the growing season (Madera County data shown in Figure 6). Careful attention to soil water storage capacity and irrigation timing and amounts could reduce potential downward solute movement beyond the 8 foot zone even in this second group of sites.

Irrigation water contributions to the N source available to the crop were monitored at all sites. In general, most sites had relatively low irrigation water NO3-N, as mountain snowmelt was a predominant irrigation water supply for many irrigation districts. Most of these sites had consistently less than 15 lbs N/acre per summer growing season that could be attributed to irrigation water sources. Again, several sites were somewhat higher in NO3-N, with 23 to 28 lbs N/acre attributed to the irrigation water in 2 sites in 1998, and three sites in 1999. No high irrigation water N sites (more than 40 lbs N/acre contribution) were used in 1998, 1999 or 2000.

Summary and Conclusions

Combined with the limited yield response to applied N at many, but not all sites, shown in the previous paper covering this long-term project, it is evident that there are reasons to make better use of information regarding residual soil N. However, in attempting to reduce applied N and make better use of residual N "reserves" in the soil, growers will need to rely even more on use of information on prior crop history and N loading, and measurements of crop N status and fruit loads to decide when likely plant needs warrant supplemental N applications. Soil N reserves can be estimated using the approach shown in this study, but most growers or consultants are only sampling the upper 2 to 3 feet. The yield penalty for deficient N in cotton dictates that a combination of management "tools" be used to determine the level to which applied N can be reduced.

Acknowledgements

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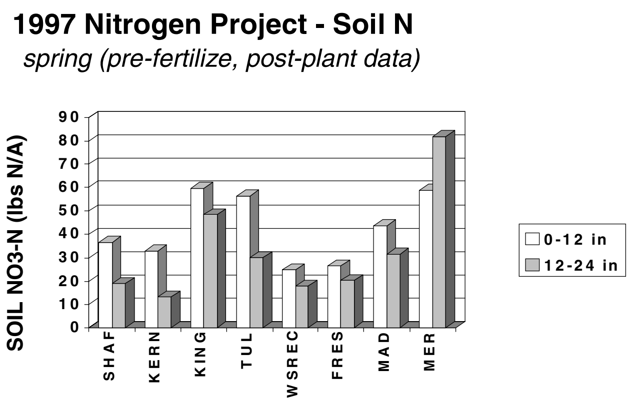

Figure 1. Soil N in the spring (pre-fertilize, within 1-2 weeks of planting) at all field research sites in N experiment in 1997. Data is expressed in lbs N as NO3-N/acre foot of soil.

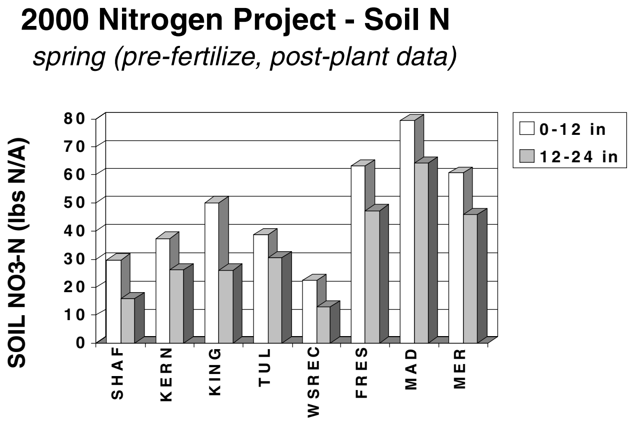

Figure 2. Soil N in the spring (pre-fertilize, within 1-2 weeks of planting) at all field research sites in N experiment in 2000. Data is expressed in lbs N as NO3-N/acre foot of soil.

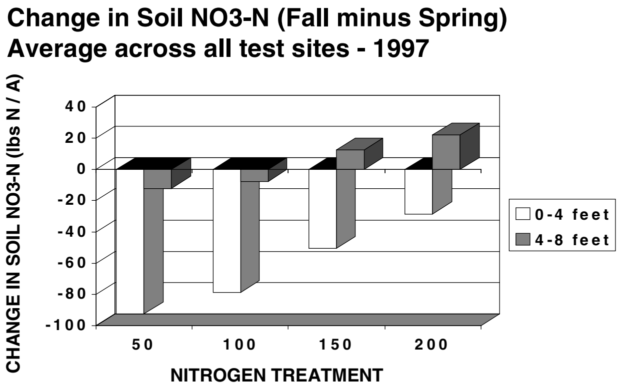

Figure 3. Change in soil NO3-N in lbs N as NO3-N per acre (in four foot increments) in 1997 period from planting (Spring) to post-harvest (fall). Data shown is the average across 8 test site locations. Negative numbers on y-axis indicate net depletion of N during the growing season, while positive numbers indicate increases in soil N in that part of the soil profile during the same period).

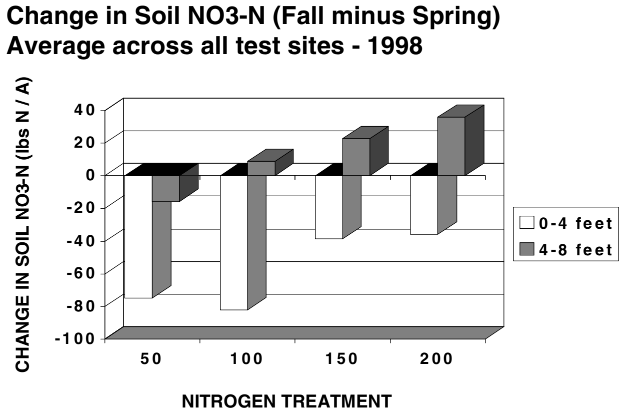

Figure 4. Change in soil NO3-N in lbs N as NO3-N per acre (in four foot increments) in 1998 period from planting (Spring) to post-harvest (fall). Data shown is the average across 8 test site locations. Negative numbers on y-axis indicate net depletion of N during the growing season, while positive numbers indicate increases in soil N in that part of the soil profile during the same period).

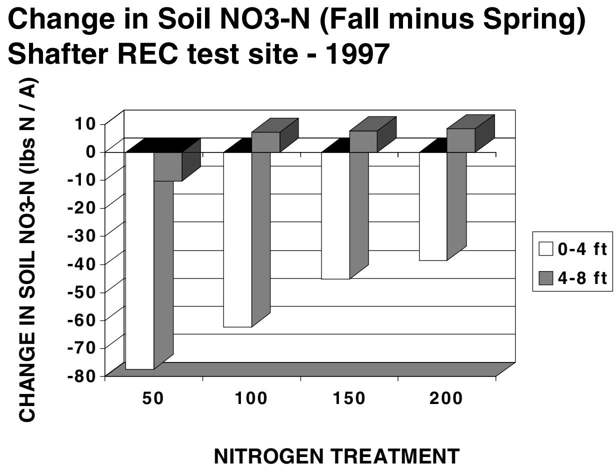

Figure 5. Change in soil NO3-N in lbs N as NO3-N per acre (in four foot increments) in 1997 at SHAFTER REC site during period from planting (Spring) to post-harvest (fall). This is a site with low soil infiltration rates, with limited chance for leaching losses after mid-season. Negative numbers on y-axis indicate net depletion of N during the growing season, while positive numbers indicate increases in soil N in that part of the soil profile during the same period).

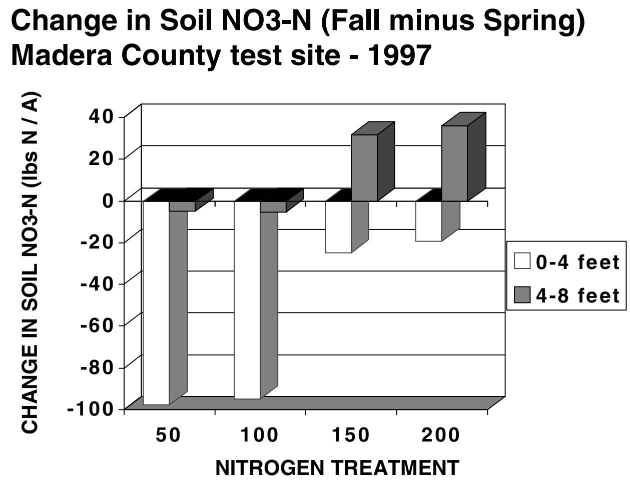

Figure 6. Change in soil NO3-N in lbs N as NO3-N per acre (in four foot increments) in 1997 at MADERA COUNTY site during period from planting (Spring) to post-harvest (fall). This is a site with moderate soil infiltration rates, with moderate to high chance for leaching losses. Negative numbers on y-axis indicate net depletion of N during the growing season, while positive numbers indicate increases in soil N in that part of the soil profile during the same period).