NITROGEN UPTAKE AND RESIDUAL SOIL N IN SAN JOAQUIN VALLEY COTTON

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Abstract

The first two years of study have been completed in a multi-location study to evaluate the response of a current California Acala cotton variety to applied N under a range of soil types, production conditions, and levels of residual soil N. Total calculated applied N plus changes in soil NO_3-N during the period from spring to fall (planting versus post-harvest) ranged from a low of 136 to a high of 252 lbs N/acre across the different N treatments and study locations. At the Westside Research and Extension Center location, the only site (in 1996) with a significant yield reduction with low N applications, average applied N plus depletion of soil NO_3-N to a depth of 8 feet averaged 164, 206, 214, and 226 lbs N/acre in the 50, 100, 150 and 200 lbs N/acre treatments in 1996. In 1996, with only one site with a significant yield reduction with decreasing amount of applied N, petiole NO_3-N levels during the flowering and boll maturing stages were within levels established as sufficient according to University of CA recommendations for petiole NO_3-N. during the entire growing season at six out of eight locations. In 1997, there was a broader range of petiole NO_3-N levels, with three out of the eight locations showing borderline sufficient or deficient levels during flowering and boll maturation. In 1997, three locations (out of eight total) showed significant yield reductions at N applications levels of 100 lbs N/acre or less.

Introduction

Although nitrogen fertilizers do not represent a large portion of the total crop budget, there are a number of reasons to improve N management to achieve a greater economic benefit from applied nitrogen. There is incentive to improve nitrogen management to reduce the chance for deficiencies that restrict yield and excess levels that encourage rank growth, influence the balance between vegetative versus reproductive growth, delay maturity and reduce effectiveness of defoliant efforts. For many years in the western U.S., cotton farmers have used irrigation, and to a lesser degree, nitrogen management to “throttle” the tendency toward rank vegetative growth, particularly when early square and boll shed are a problem. If restrictions in water and nitrogen applications are used routinely to hold back growth regardless of boll load, this can also hold back yield, so it can be a delicate “balance” to achieve the correct approach for a given situation.

Cotton requires most of its nitrogen when bolls and seeds are developing (generally in July and August in the San Joaquin Valley of CA) (Hodges, 1991; Radin et al., 1985). Nitrogen fertilizer applications for crop production should be related to yield goals. If a 3 bale/acre average is the yield goal, recent data still indicates that about 50 to 60 pounds of N/bale (165 to 180 pounds of N/acre) must come from fertilizer, irrigation water nitrate, and residual soil N carried over from previous fertilization, crop residues or legumes (Hutmacher et al., 1995; Halevy et al., 1987; Bassett et al, 1970). Large changes in yield potential due to environmental stress, management problems and pest damage will impact crop nitrogen use, fertilizer use efficiency, and uptake of other nutrients. Early-planted fields with good retention and yield potential will need close to 200 pounds total N/acre to not be limiting under good yield conditions in the San Joaquin Valley, and may benefit from petiole nitrate evaluations to determine the utility of mid-season water-run or foliar fertilization.

Plants with poor fruit retention, replanted or late-planted cotton will require less N due to lower boll loads and will be susceptible to problems with management of late-season vigor and preparation for defoliation if late-season N is too high. Consider N carryover to cotton in determining expected response to N fertilizers. If previous crops were heavily fertilized relative to crop yield and expected nutrient uptake, fertilizer requirements can be reduced, potential for deficiencies in the current crop decrease, and potential for excess N in the mid- and late-season increase. The main goals of the current study were to identify responses of the current dominant cotton variety in CA to applied N as well as the utility of soil residual nitrate-N measurements in assessing potential soil contributions to crop N requirements.

Materials and Methods

The impact of residual soil nitrogen on crop responses to applied N are under evaluation in a multiple year study on Acala cotton *(Gossypium hirsutum* L. cv. Maxxa) in the San Joaquin Valley. The 1996 and 1997 growing seasons were the first and second year in a three to four year series of experiments. These studies were conducted at the West Side and Shafter Research and Extension Centers in addition to six other locations (farm sites in all San Joaquin Valley cotton farming counties), representing a range of soil types and crop rotation schemes. All of the study sites were furrow-irrigated, with 30, 38 or 40 inch row spacing.

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In the first full year of the field studies (1996), fertilizer treatments ranged from a low of 50 lbs N/acre to 200 lbs N/acre. Four treatments of 50, 100, 150 or 200 lbs N/acre were applied in late May (prior to the first within-season irrigation). In three supplemental treatments (50, 100 and 150 lbs 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 (Table 1).

Soil nitrate-N levels in the upper two feet of the profile were converted to lbs N/acre and subtracted from the fertilizer application amounts. In this way, for example, if there was 25 lbs N/acre in the residual soil analysis for the upper 2 feet, and additional 25 lbs N/acre would be added as fertilizer to produce the 50 lbs N/acre treatment, or an additional 75 lbs N/acre to yield the 100 lbs N/acre treatment, and so on.

In 1997, the experiment was simplified down to four treatments (50, 100, 150 and 200 lbs N/acre) due to lack of significant yield responses to split fertilizer applications of 1996 (as well as prior studies of ours in 1993 through 1995, unpublished). The changes were also made in response to grower/cooperator concerns for the difficulty in putting on the second applications without sustaining damage to the plant terminal. Two of the eight sites were the same as in 1996, and in those cases, treatments were superimposed on the same field area as those treatments in the prior year in order to allow continuing evaluation of long-term effects of levels of applied N. In the six other locations, growers were unable or unwilling to accomodate continued cotton two years in a row due to concerns for disease pressure, production problems in the specific fields or changes in crop rotation needs at the farm level.

At all locations, soil NO_3-N profiles to a depth of 8 feet were sampled again post-harvest to allow calculation of total changes in soil NO_3-N during the growing season.

Results and Discussion

Soil No3-N Status

In the first year (1996), post-planting soil NO_3-N levels in the upper two feet of the soil profile ranged from an average of 8 mg NO_3-N/kg dry soil to over 40 mg/kg dry soil at two sites. In 1997, levels ranged from 9 mg NO_3-N/kg dry soil to over 35 mg/kg dry soil. These soil NO_3-N concentrations correspond with a range of 34 lbs N as NO_3-N per acre in the upper two feet of the soil profile (in a field where cotton followed wheat) to a high of more than 130 lbs N as NO_3-N/acre in the upper two feet (cotton following corn or processing tomatoes). These values represent a wide range of residual soil N potentially available to the crop. At all locations, soil NO_3-N profiles to a depth of 8 feet were sampled again post-harvest to allow calculation of total changes in soil NO_3-N during the growing season. Total calculated applied N plus changes in soil NO_3-N during the period from spring to fall (planting versus post-harvest) ranged from a low of 136 to a high of 252 lbs N/acre across the different N treatments and study locations (Figures 1, 2). While changes in soil NO_3-N alone do not represent the only form of N potentially available to the plants, it can be used as a relative indicator of the amount of N readily available within the profile. The NO_3-N form can also be readily leached and is subject to other losses, so changes do not only imply plant uptake. Efforts have been made in this study to quantify leaching losses in these studies through use of NO_3:chloride ratios determined in soil and irrigation water samples, but these analyses are incomplete at this time.

Petiole NO_3-N Levels

Across all sites, residual NO_3-N levels were generally moderate to high. In 1996, these moderate to high residual soil N levels were reflected in the petiole NO_3-N levels across sampling dates and sites. These data generally indicated minimal effect of level of applied N on petiole nitrogen status, most crop growth parameters and lint yields (data not shown). In all treatments at six locations, petiole NO_3-N levels were in the "sufficient" range established in University of CA guidelines for cotton throughout the growing season. In two locations at the lowest N application levels (including the West Side location), petiole NO_3-N levels were only borderline deficient starting about early boll-filling. In 1997, there was a broader range of petiole NO3-N levels, with three out of the eight locations showing borderline sufficient or deficient levels during flowering and boll maturation (data not shown).

Growth and Yield Responses

Out of eight field test locations in 1996, only one site (the Westside Research and Extension Center location) showed any lint yield reductions at lower N application rates (only in the 50 lbs N/acre treatment) (Figures 3, 4). It must be noted that 1996 was only a moderate year in terms of cotton lint yields and dry matter production, with less of an N requirement for seed production and growth than in many high-yield years. Lint yields in the statewide study ranged from a low of less than 1000 to over 1550 lbs lint/acre in the 1996 test sites. The lack of yield response to applied N in excess of 50 lbs N/acre in part may be due to the lower N demand under conditions of low to moderate lint yields. Prior studies we have conducted at the West Side Research and Extension Center from 1991 through 1996 indicated that approximately 50 to 60 lbs N are needed per bale of cotton produced. The results of this study do not indicate that 50 lbs N/acre is needed to produce 1200 to 1600 lbs lint/acre, but do indicate that soil residual N can serve as a major source of N in meeting crop N requirements.

In 1997, there were more locations showing significant yield reductions with N applications of 50 and 100 lbs N/acre (Figures 5, 6). The Tulare County, Merced County, and Fresno County locations showed yield reductions at the 50 and/or 100 lbs N/acre rates when compared with higher applications. Only one location showed significantly higher lint yields with increases all the way to 200 lbs N/acre. With the exception of the Tulare County location, each location with significant responses to increases in applied N had moderate to high yields compared to other 1997 sites and compared with 1996 yields. Initial (post-plant, 1997) soil NO_3-N levels in the sites with lint yield responses to increasing applied N were not uniformly low, with moderate to high levels in the surface two feet at the Tulare County and Merced County sites (data not shown). The yield response to applied N was not observed in the locations with low initial soil NO_3-N levels in 1997, regardless of the yield levels. Select soil samples in 1997 were also analyzed for NH_4-N and mineralizable N, but results from those tests are incomplete at the time of preparation of this report. As in 1996, there were many sites in 1997 with no lint yield responses across the 50 to 200 lbs/acre range of applied N. In 1997, however, soil residual NO_3-N levels alone were not a good predictor of where a yield response to applied N would be likely.

Irrigation water nitrate represents a direct source of N available to the crop. Nitrate levels in irrigation waters at all sites were relatively low, contributing a maximum of 38 lbs N/acre at one location but averaging less than 20 lbs N/acre for the entire growing season in 1997 (data not shown).

Where possible, attempts should be made to adjust fertilization practices to account for potentially-available soil N. The focus of future efforts in this study will be to analyze the petiole NO_3-N and soil N data more thoroughly to determine the utility of current plant and soil monitoring techniques in estimating potential for yield responses to applied N.

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Table 1. Nitrogen application treatments in multi-location study in 1996.

Treatment	N applied prior to first irrigation	N applied prior to second irrigation
	(lbs N/acre)	(lbs N/acre)
50*	50	0
50/50*	50	50
100*	50	0
100/50*	100	50
150*	150	0
150/50*	150	50
200*	200	0

* adjusted for beginning soil residual N as nitrate-N

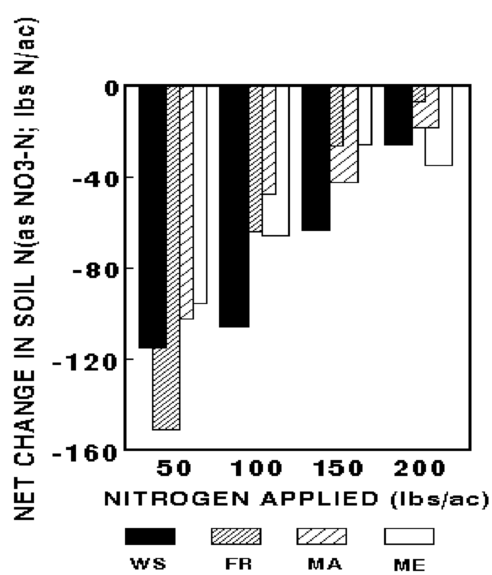

Figure 1. Change in N as NO_3-N between the spring (April or May) and the fall (October through December) soil sampling in the 8 foot deep soil profile in 1996 at four field locations as a function of nitrogen treatments. Field locations were as follows: "WS"=West Side; "FR"=Fresno Co.; "MA"=Madera Co.; "ME"=Merced Co. Values shown are accumulated totals for the entire 8 foot deep profile, with negative (-) numbers indicating a net reduction in soil N as NO_3-N from the spring to the fall period.

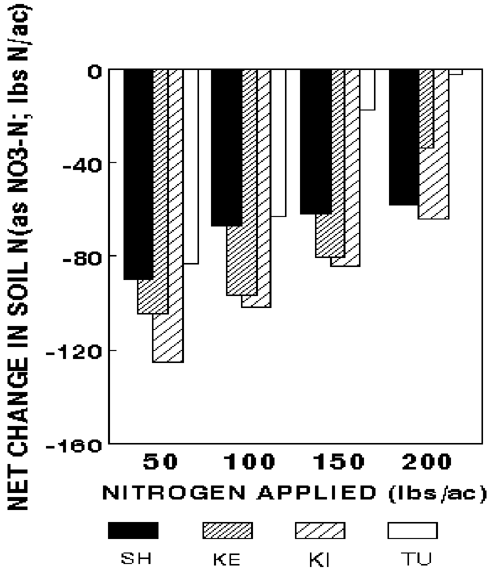

Figure 2. Change in N as NO_3-N between the spring (April or May) and the fall (October through December) soil sampling in the 8 foot deep soil profile in 1996 at four field locations as a function of nitrogen treatments. Field locations were as follows: "WS"=West Side; "FR"=Fresno Co.; "MA"=Madera Co.; "ME"=Merced Co. Values shown are accumulated totals for the entire 8 foot deep profile, with negative (-) numbers indicating a net reduction in soil N as NO_3-N from the spring to the fall period.

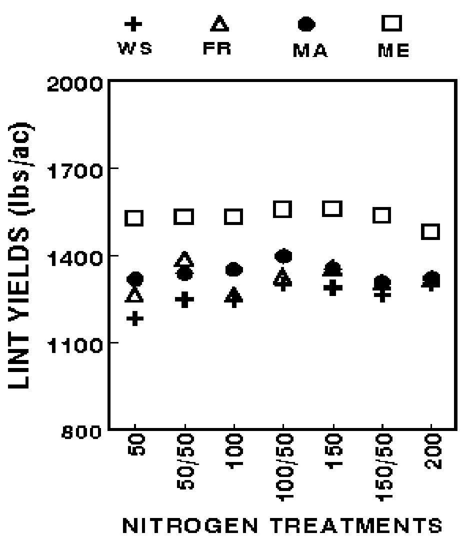

Figure 3. Lint yields in 1996 studies as a function of nitrogen treatments and study locations as follows: ("WS"=West Side Research and Extension Center; "FR"=Fresno County; "MA"=Madera County; and "ME"=Merced County.

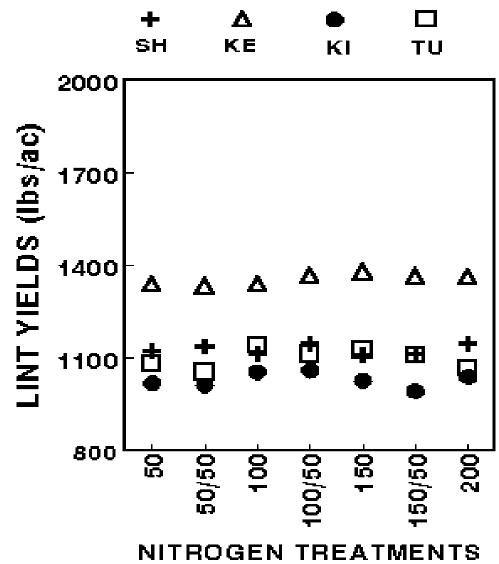

Figure 4. Lint yields in 1996 studies as a function of nitrogen treatments and study locations as follows: ("SH"=Shafter Research and Extension Center; "KE"=Kern County; "KI"=Kings County; and "TU"=Tulare County.

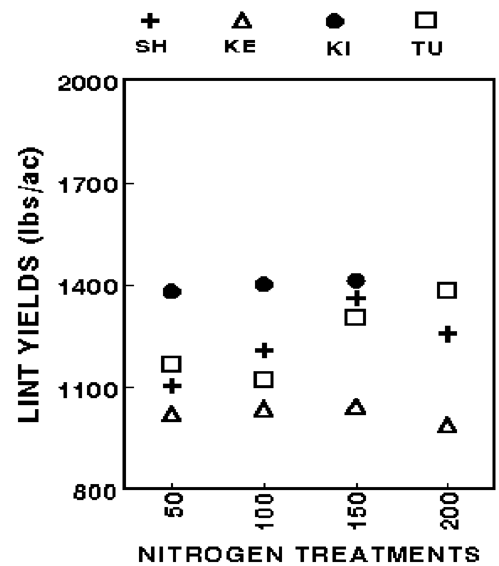

Figure 5. Lint yields in 1997 studies as a function of nitrogen treatments and study locations as follows: ("SH"=Shafter Research and Extension Center; "KE"=Kern County; "KI"=Kings County; and "TU"=Tulare County.

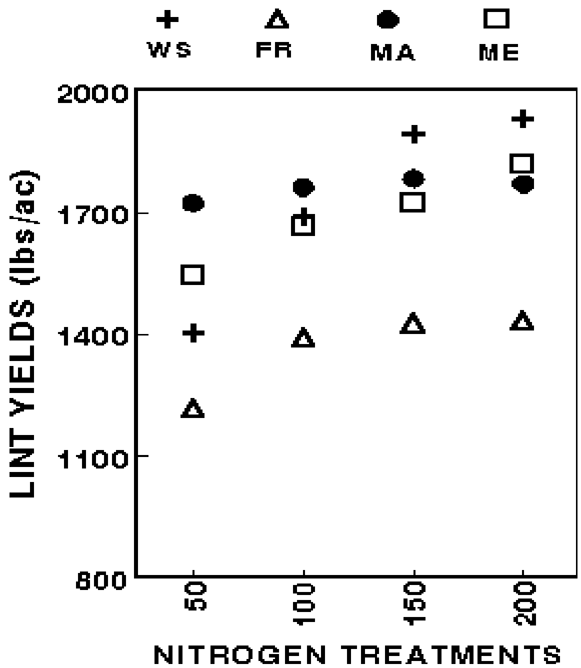

Figure 6. Lint yields in 1997 studies as a function of nitrogen treatments and study locations as follows: ("WS"=West Side Research and Extension Center; "FR"=Fresno County; "MA"=Madera County; and "ME"=Merced County.