Soil and Plant Recovery of Labeled Fertilizer Nitrogen in Irrigated Cotton

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Abstract

Proper timing of fertilizer N applications in relation to crop uptake can serve to improve fertilizer efficiency in irrigated cotton. Earlier research has identified an optimum application window extending from the formation of first pinhead squares to peak bloom, which corresponds well with maximum crop uptake and utilization. Field experiments were conducted at the University of Arizona Marana Agricultural Center (Grabe clay loam soil) utilizing sidedress applications of ammonium sulfate with 5-atom % 15-N at pinhead square, early bloom, and peak bloom at a rate of 56 kg N/ha. The objective was to compare relative efficiencies in terms of fertilizer N uptake and recovery among these three times of application. Results indicate that all treatments averaged approximately 80% total fertilizer N recovery. Of the fertilizer N that was recovered, approximately 40 % was taken up by the plants and 60 % recovered in the soil, primarily in the top 60 cm of the soil profile.

Introduction

There are several concepts that are key to conserving nutrients in a soil-plant system. It is important to make nutrient applications in line with crop uptake and utilization patterns. Therefore, the time (stage of crop growth), method, and rates of application are all very important in achieving optimum crop uptake and utilization of the applied nutrients.

Olson and Kurtz (1982) described plant use and efficiency of fertilizer N as a function of: 1) time of application, 2) rate of the N applied, and 3) precipitation and climate-related variables. They also related maximum fertilizer N efficiency to the latest application being compatible with the stage of crop development associated with maximum uptake. Therefore, information pertaining to crop N requirements (e.g. amount of N needed to produce a given unit of yield) and the uptake and utilization patterns for the crop in question are considered as fundamental to developing N management strategies that optimize N uptake and efficiency. With respect to cotton fertilization, McConnell et al. (1996) and Boquet et al. (1991) found that a nutrient balance approach to N management provided the best results in terms of fertilizer N uptake and recovery in both irrigated and dryland conditions. They point out the fact that over-fertilization of cotton with N can produce plants with excessive vegetative growth without gaining additional yield, in addition to providing a greater potential for loss of the N from the soil-plant system.

Uptake and utilization of N by cotton has been evaluated in a number of crop production environments and conditions (Bassett et al., 1970; Halevy, 1976; Mullins and Burmester, 1990; and Unruh and Silvertooth, 1996). Results from these and other studies have provided estimates of N utilization by cotton. Approximately 60 to 70 lbs. N (per acre) are commonly used as estimates for the production of one bale (480 lbs. lint) of both Upland (*G. hirsutum* L.) and American Pima (*G. barbadense* L.) cotton. Peak periods of uptake and utilization of N by a cotton crop commonly occur near the formation of the first pinhead square (PHS) and again near peak bloom (PB). Silvertooth et al. (1991) found that the greatest potentials for losses of NO_3^- -N in an irrigated cotton production system in Arizona occurred with pre-plant applications of fertilizer N and also with those occurring late in the season (after PB). These results were further corroborated in subsequent studies in Arizona (Navarro et al., 1997 and Norton and Silvertooth, 1998) that also demonstrated greater levels of N use efficiency with split applications. Work in several parts of the U.S. cottonbelt with long-term N management studies have also demonstrated the value

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of split applications of fertilizer N in-season for optimizing cotton fertilization (Maples et al., 1990; McCarty and Funderburg, 1990; Robinson, 1990; Tracy, 1990; Silvertooth and Norton, 1998a; Silvertooth and Norton, 1998b; Silvertooth and Norton, 1999; Silvertooth and Norton, 2000). Therefore, N fertilizer management recommendations for cotton commonly include the utilization of split applications of fertilizer N in-season.

Current N management recommendations in many cotton producing regions (McConnell et al., 1996 and Silvertooth and Norton, 1998c) include the use of split applications of fertilizer N. In Arizona, fertilizer N applications are recommended between PHS and PB (referred to as the "N application window") in relation to crop condition (fruit retention, vigor, and N fertility status) and previous amounts of fertilizer N applied in-season. Utilizing stage of growth and crop condition in N fertilization is an important application of the crop monitoring systems that are being developed in many cotton producing regions (Bourland et al., 1992; Kerby et al., 1997; and Silvertooth and Norton, 1998c). The accuracy of these crop monitoring systems in relation to stage of growth and management practices such as N fertilization, are improved markedly in many cases with the use of heat unit (HU) systems to predict crop phenology (Brown, 1989).

A field research experiment was initiated with the objective of evaluating the relative efficiencies of fertilizer N applications at several stages of growth (PHS to PB) with split applications of fertilizer N labeled with ^{15}N to cotton in irrigated cotton production systems in Arizona.

Materials and Methods

Field experiments utilizing a microplot (Silvertooth, et. al., 2001) technique were conducted during the 1994 and 1995 cotton growing season. Plots were located at the University of Arizona Marana Agricultural Center (MAR) on a Pima clay loam soil. Plots were planted to Upland cotton *Gossypium hirsutum, L.* (var. Deltapine DP20). Plots were planted on 18 April and 24 April in 1994 and 1995 respectively.

Microplots were placed within larger plots that did not receive fertilizer N. The large plots were 8, 1m rows wide and extended the full length of the irrigation run (180 m). Microplots were located in the center four rows of the 8-row macroplot and extended 1 m in length. Plots were arranged in a randomized, complete block design with four replications. Applications of labeled fertilizer N were made at three stages of growth consisting of PHS, early bloom (EB), and PB at a constant rate of application (56 kg N/ha = 50 lbs. N/acre) with a sidedress method of application. Fertilizer N applications coincided with the onset of PHS (1200 HUAP) through PB (2200 HUAP). All applications to microplots occurred using a simulated side-dress technique. A trench was cut along the side of the bed 15 cm from the center and 15 cm deep to which a rate of 56 kg N ha^{-1} in a 500 mL solution was applied and then covered immediately with soil. Each treatment received 56 kg N ha^{-1} in three individual applications for a total of 168 kg N ha^{-1}. Each treatment received one of the three applications with 5-atom % ^{15}N enriched fertilizer. Table 1 outlines treatment dates and rates for the three treatments in 1994 and 1995.

Plant and soil samples were collected at the end of the season. Above-ground portions of the plants were collected from the center two rows of each microplot in 50 cm segments resulting in a 1 m^2 area. Plant samples were dried weighed and separated into seed and stover portions. Samples were processed with a hammer mill, cyclone mill, and ball mill to obtain the proper consistency for analysis. All samples (both seed and stover) were analyzed for total N and atom % ^{15}N. Soil samples were collected from the center of each microplot to a depth of 180 cm by 30 cm increments. All soil samples were dried, ground, and analyzed for total N and atom % ^{15}N.

Total fertilizer N was calculated using the following equation.

$$X = [(TN)(c - b)] / a$$

where; X = amount of labeled fertilizer in the plant or soil (kg N ha^{-1}), TN = total N in plant or soil (kg N ha^{-1}), a = atom % ^{15}N enrichment in the fertilizer, b = atom % ^{15}N in the standard (check), and c = atom % ^{15}N in the sample. Percent of nitrogen fertilizer recovered (PFNR) was calculated

All data was subjected to analysis of variance according to procedures outlined by the SAS institute (1990) and Steele and Torrie (1980).

Results

Soil Recovery

In both 1994 and 1995 a large portion of the fertilizer N recovered was located in the top 30 cm of soil. In 1994 fertilizer N recovery levels declined dramatically below 60 cm (Figure 1). No significant differences were observed among the three application treatments with respect to soil recovery of fertilizer N.

In 1995 as much as 60% of the soil recovered fertilizer N was located in the top 30 cm of the soil (Figure 2). Fertilizer N recovered below 60 cm was negligible. Similar to the 1994 results, time of application did not have a significant effect on the recovery of fertilizer N in the soil.

Plant Uptake and Recovery

Plant recovery of fertilizer N for both 1994 and 1995 is shown in Figure 3. Plant recovery ranged from 32-36% and was not significantly affected by time of application.

Total N recovered (plant and soil recovery combined) ranged from 75-85%, which is relatively high for a cropping system of this type. Of the total fertilizer N recovered, approximately 60% was recovered in the soil. Approximately 50% of the soil recovered fertilizer N was recovered in the top 60 cm.

Summary and Conclusion

Rates of total N uptake and percent ^{15}N recovery did not differ significantly for the N fertilizations made among these three stages of growth. These results support recommendations to split applications of fertilizer N between PHS and PB to realize optimum efficiencies in irrigated cotton production systems. Results of this study further validate the current recommendation of applying fertilizer N during a specific ‘window’ of phenological time beginning at the formation of first square (PHS) through PB (Figure 4). Applying fertilizer during this application ‘window’ provides a method for realizing the most efficient uptake and use of fertilizer N for the crop.

These results also lead to the several questions regarding the fate of the fertilizer N recovered in the soil (approximately 60% of the total recovered). Such as: “What is the form of that N in the soil and how much will be available to the crop plants the following year?” and “How much of the residual fertilizer in the soil might be recovered by subsequent crops?”. A research project designed to address these questions will be initiated in Arizona during the 2001growing season.

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Table 1. Application dates and rates for each treatment, Marana, AZ, 1994 and 1995.

	Treatment 1	Treatment 2	Treatment 3
	----------kg N ha^{-1}----------		
1994			
31 May	56*	56	56
21 June	56	56*	56
11 July	56	56	56*
1995			
14 June	56*	56	56
27 June	56	56*	56
12 July	56	56	56*

*Applications made with 5 atom % ^{15}N enriched ammonium sulfate.

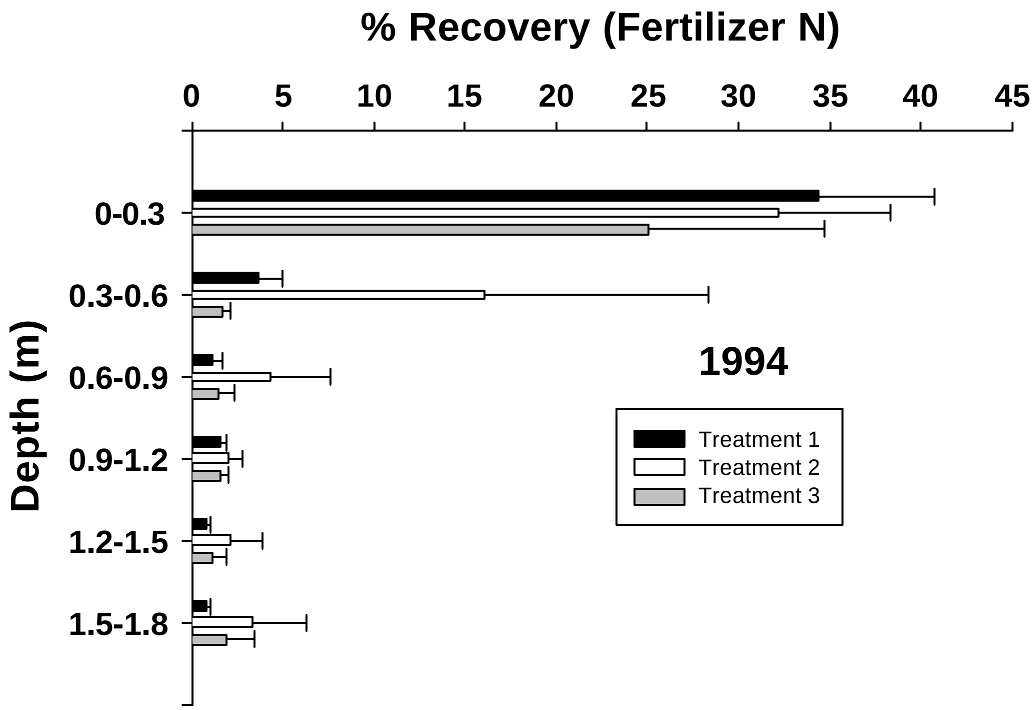

Figure 1. Recovery of fertilizer N by depth from the soil for all three treatments in 1994.

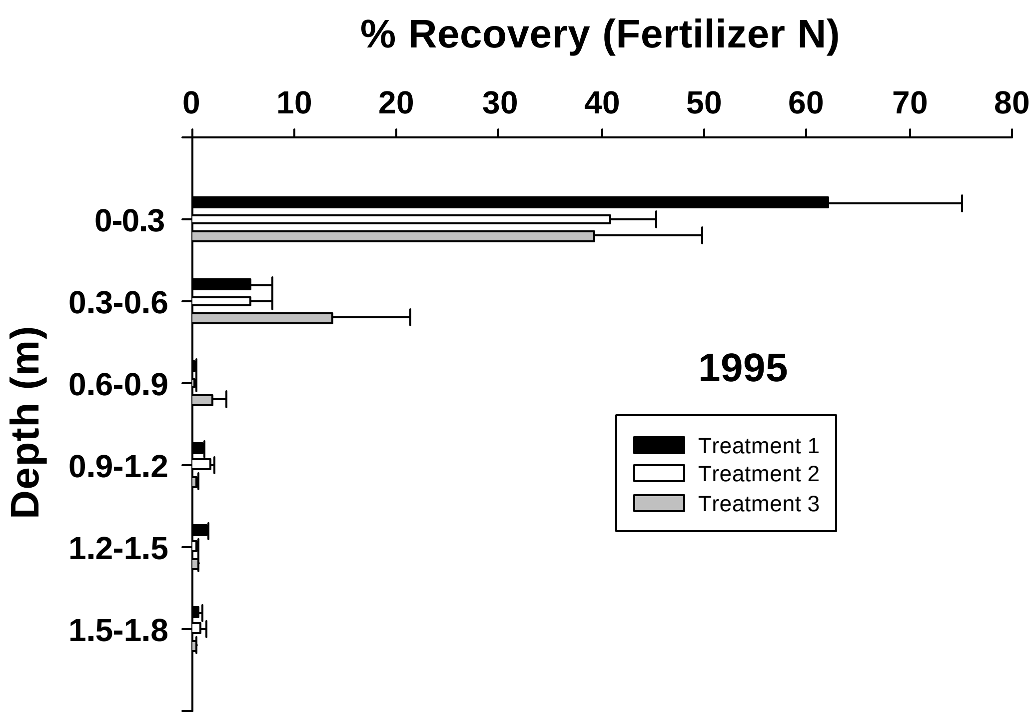

Figure 2. Recovery of fertilizer N by depth from the soil for all three treatments in 1995.

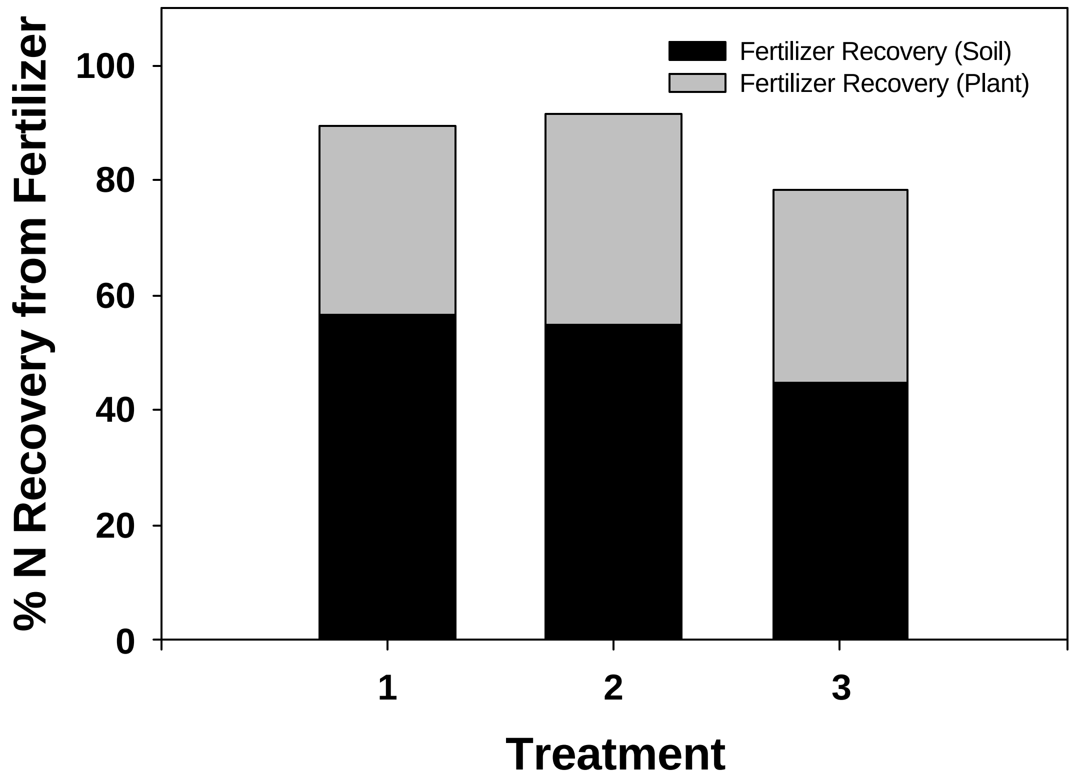

Figure 3. Total fertilizer N recovery composed of plant and soil components for all three treatments averaged over the two years (1994 and 1995).

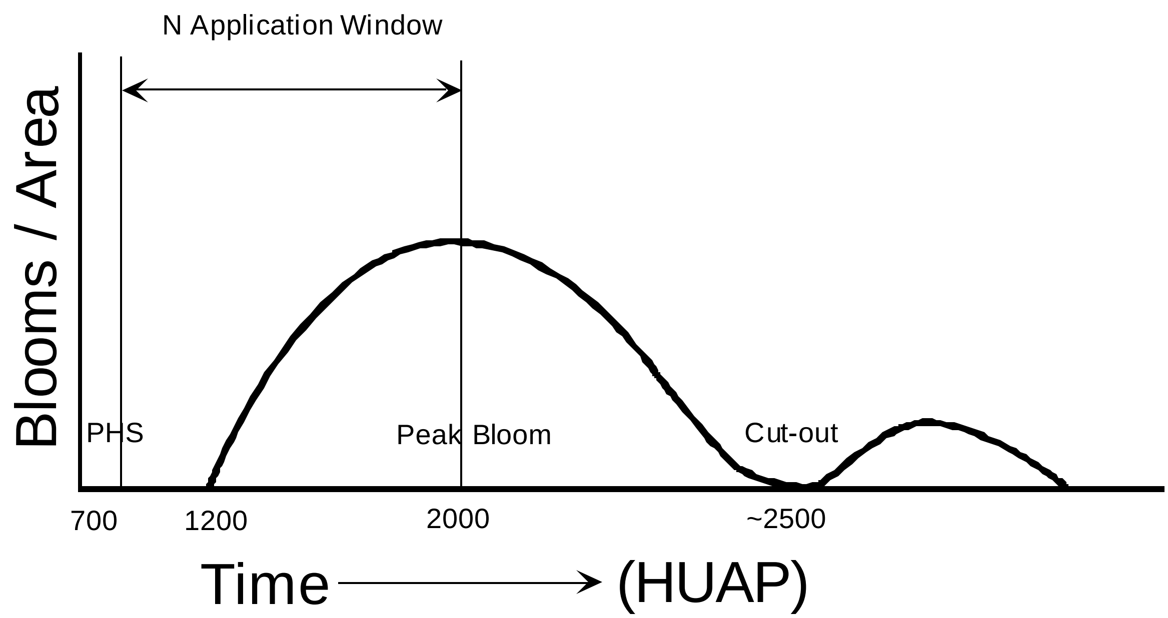

Figure 4. Depiction of the N application ‘window’ as it relates to the fruiting cycle and HUAP.