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RESIDUAL SOIL NITROGEN EVALUATIONS IN IRRIGATED SOILS OF THE DESERT SOUTHWEST

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Abstract

A series of studies were conducted in the central region of Arizona from 2001 through 2004 to examine the effects of residual fertilizer nitrogen (N) on plant growth and development, yield, fiber quality, and soil NO_3^--N levels. Residual N projects were initiated at the University of Arizona Maricopa (MAC) and Marana (MAR) Agricultural Centers in 2001 following 10 (1991-2000) and 7 (1994-2000) years at Maricopa and Marana respectively of N management studies involving a control and three different N management regimes. Soil NO_3^--N levels in all four treatments at both locations declined dramatically, particularly in the 0-30cm level after 2001 with the cessation of fertilizer N applications. Soil NO_3^--N levels have approached a steady level of less than 5 parts per million (ppm) in all treatments at both locations. Lint yield response differed at the two locations. Lint yield at MAC fell precipitously over the course of the four-year residual N project. Lint yield levels averaged near 1500 kg ha^{-1} at the initiation of the residual study. After four years of no fertilizer N applied lint yields had fallen to 900 kg ha^{-1}. Lint yields at MAR however, have remained higher. At the initiation of the residual study lint yield levels were near 1200 kg ha^{-1}. After four years of no fertilizer N applied lint yields still have remained near 1200 kg ha^{-1}.

Introduction

Cotton production systems in the low elevation deserts of Arizona are typically high input and high yielding systems. Water and N are the most critical inputs, beside crop protection, needed in this type of production system with N being the most commonly supplied nutrient through fertilization. Of all the nutrients added to the production system N is the most dynamic. The dynamic nature of this nutrient in the soil plant system makes the development of recommendations for N fertilizer applications more difficult. Fertilizer N applied to the system has several potential fates including some that render the nutrient unavailable to the plant. These processes include immobilization, denitrification, soil fixation, and leaching of nitrate. These processes diminish, in some cases temporarily, the availability of applied fertilizer N. Other soil processes have the opposite effect on N availability. The process of mineralization, which includes ammonification and nitrification, releases organic soil N making it available for crop uptake and utilization. The process of immobilization/mineralization or the conversion of inorganic N (available) to organic (unavailable) forms of soil N is a complex process that makes the development of N management strategies more difficult.

Research investigating mineralization/immobilization in soils around the U.S. has revealed some interesting results. Westerman and Kurtz (1972) used labeled N fertilizer to investigate the residual effects of applied fertilizer after two sequential cropping seasons of sorghum-sudan hybrid (*Sorghum sudanense* L.). At the end of the second season 22-26% of the initial applications of N remained in the soil. McCracken et. al. (1989) utilized plots from a long-term field experiment to evaluate the effects of fertilization history and winter annual cover cropping on corn grain yield and N uptake. Results from their study indicated that a history of N fertilization increased both N uptake and grain yield. Similar results were obtained with the leguminous annual cover crops. The influence of residual fertilizer applications on subsequent crops can be both organic and inorganic N due to the potential immobilization of applied fertilizer N (Olson and Swallow, 1984). Olson and Swallow (1984) found that the effect of residual organic N is lessened with higher application rates of fertilizer N. They also concluded that mineralization of immobilized fertilizer N occurs over a period of several years. Allen et al. (1973) found that 50% of the applied fertilizer was still present as organic material in the soil 5 years later.

Research has been conducted at several locations throughout Arizona in an effort to develop and refine N fertilizer recommendations for cotton production. These projects included four different N management treatments that are outlined in Table 1 (Silvertooth et. al., 1990-1995; Silvertooth and Norton 1996 and 1997; Silvertooth and Norton

1998; Silvertooth and Norton 1998b; Silvertooth and Norton 1999; Silvertooth and Norton, 2000; Silvertooth et al., 2001). The results of the long-term N management studies have indicated an ability of the desert soils to supply a substantial amount of N through mineralization even though the soils at the two locations where these research projects were conducted have less than 1% organic carbon. There is little information available directly investigating the mineralization and immobilization potential of irrigated desert soils.

The main objective of this project was to evaluate the effects of fertilization history on subsequent yield of cotton at two low-desert locations in Arizona.

Materials and Methods

Long term nitrogen management studies were established at the MAC and MAR in 1991 and 1994 respectively with similar N management treatments as outlined in Table 1. Table 2 outlines the soil characteristics and elevation of the two sites involved in the N management projects. Total amounts of fertilizer N added each year ranged from 0 in the control to over 330 kg N/ha in the most aggressive treatment. Plots were established at each location consisting of 8, 1m rows wide that extended the full length of the irrigation run (180 m). Plots were arranged in a randomized complete block design with 4 replications. Each year of the N management study Upland cotton (*Gossypium hirsutum* L.) was planted and the four N management treatments were imposed. All other cultural inputs and pest control were managed in an optimal fashion.

Tissue samples were collected each year to monitor current NO_3^--N levels in the plant and to schedule fertilizer applications for the feedback treatments. A complete set of plant measurements were also collected over the course of the season on 14-day intervals to monitor plant growth and development as affected by N management treatments. Lint yield estimates were made by harvesting the center four rows of each plot and weighing the seedcotton. Sub-samples were collected for percent lint and fiber quality determinations.

In 2001, all N applications were terminated and a residual N project was initiated to examine the effects of the fertilization history on subsequent growth and yield. All plots were kept intact during the four years of the residual N study. Plant measurements were collected each year to monitor plant growth and development but tissue samples were not collected due to the fact N fertilizer applications were not being scheduled. Pre-season soil samples were also collected prior to the beginning of each season to a depth of 120cm by 30cm increments. These samples were analyzed for soil NO_3^--N. Yield estimates were made again by harvesting the center four rows of each plot with sub-samples collected for fiber quality and percent lint estimates.

All data collected from the residual N studies were subjected to analysis of variance. This analysis was performed for each site-year to determine differences among residual N treatments for all dependent variables including lint yield, soil NO_3^--N levels, and fiber quality parameters. All statistical analysis was performed according to procedures outlined by the SAS Institute (2002).

Results and Conclusions

Statistical analysis revealed no significant differences among treatments in any given year with respect to any of the dependent variables tested including lint yield, fiber quality, soil NO_3^--N, and plant growth and development indices. However, interesting trends were observed between the two locations with respect to yield response after the initiation of residual N treatments in 2001.

Soil NO_3^--N trends are shown in Figures 1 and 2 for MAC and MAR respectively. Similar trends were observed between the two locations with decreasing levels of NO_3^--N, particularly in the top 30 cm of the soil profile. After the third year soil NO_3^--N levels approached a steady level of less than 5 ppm at each depth for all treatments at both MAC and MAR.

Lint yield results provided an interesting comparison contrast between the two locations. Relative lint yield (to the control) is shown in Figures 3 and 4 for MAC and MAR respectively. At the MAC location relative lint yield rapidly approached unity (1) with the cessation of fertilizer N applications (Figure 3). At MAR, a significant amount of variation in relative yield continued past the initiation of the residual N project (Figure 4). The response in lint yield at MAC (Figure 5) showed a significant decline after the initiation of the residual N study. Yield levels averaged near 1500 kg lint ha^{-1} through 2000. Since the initiation of the residual treatments lint yields have dropped to near approximately 800 kg lint ha^{-1} (Figure 5). Lint yield response at MAR was quite different (Figure 6). No significant differences among treatments were detected but average lint yield levels did not decline as dramatically as those observed at MAC (Figure 6). Average lint yield, prior to initiation of the residual treatments in 2001, was near 1200 kg lint ha^{-1} and have remained near that level into the fourth year.

Considering the fact that no fertilizer N has been applied to these plots since the 2000 season, the majority of the N taken up by the crop had to be derived from native soil N through mineralization. Additions of N through the irrigation water were also negligible (data not shown). The fact that lint yields have remained at a sustained level at MAR would indicate the soils' greater potential for mineralization of native soil N and/or a greater reserve.

Based on the assumption (Mullins and Burmester, 1990; Unruh and Silvertooth, 1996) that approximately 75 kg N ha^{-1} are required to produce one bale of lint (~280 kg), the 2004 crop extracted ~160 kg N ha^{-1} at MAR and ~120 kg N ha^{-1} at MAC. This is a significant amount of N supplied through mineralization from soils with organic carbon levels of less than one percent.

Additional Related Work

In an effort to better understand the mineralization potential and the effects of fertilization history on irrigated desert cotton production a separate study was initiated in 2001 utilizing ^{15}N enriched fertilizer as a means of tracing the fate of applied fertilizer over a period of four years. This study was initiated at the Safford Agricultural Center (SAC) which has a very similar soil to the MAR location.

The study was established with four separate treatments randomized in a complete block design with four replications. A microplot ($2m^2$ plots) (Silvertooth et al., 1997) design was utilized within an existing N management study. The ^{15}N microplots were placed in the control plots where no additional fertilizer N was applied. An application of ^{15}N labeled fertilizer was made during the 2001 season. Figure 7 outlines the four treatments that were employed in this study.

This design will allow for an investigation into the fate of applied fertilizer N through an explicit measurement over a period of 4 years. Both soil and above ground plant material have been were collected each year from the microplots. Depending on the treatment, the material was either returned to the soil or utilized to measure uptake and recovery (Figure 7). The results of this series of studies are currently being investigated and will hopefully serve to help better understand the immobilization/mineralization process in irrigated desert soils.

Table 1. General N management outline for treatments used during the studies conducted at MAC (1991-2000) and MAR (1994-2000).

Treatment Number	Fertilizer N Management Regime
1	Control (No fertilizer N)
2	Standard – Preplant and sidedress (in-season)
3	Feedback approach (soil and petiole NO_3^--N analysis)
4	2x rate from soil and petiole NO_3^--N feedback

Table 2. Soil classification and elevation information for the two sites for the N management and residual N studies.

	Maricopa Agricultural Center (MAC)	Marana Agricultural Center (MAR)
Elevation	360m	610m
Soil Series	Casa Grande fine sandy loam	Grabe silty clay loam
Soil Family	Fine-loamy, mixed, hyperthermic	Coarse-loamy, mixed, thermic
Soil Subgroup	Typic Natrargid	Aridic Cumulic Haplustoll
Soil Order	Aridisol	Mollisol

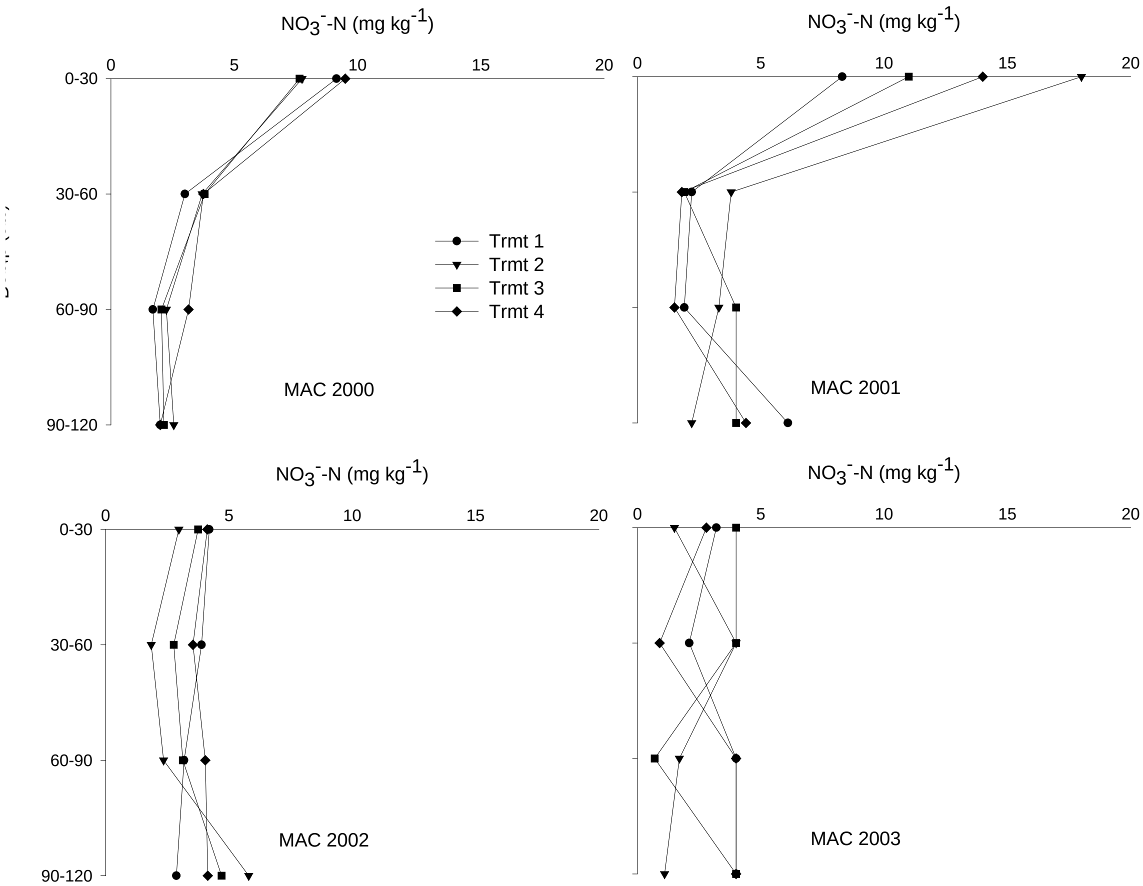

Figure 1. Soil NO_3^--N profiles from pre-season soil samples for each treatment and depth collected during the residual N study at MAC (2000-2003).

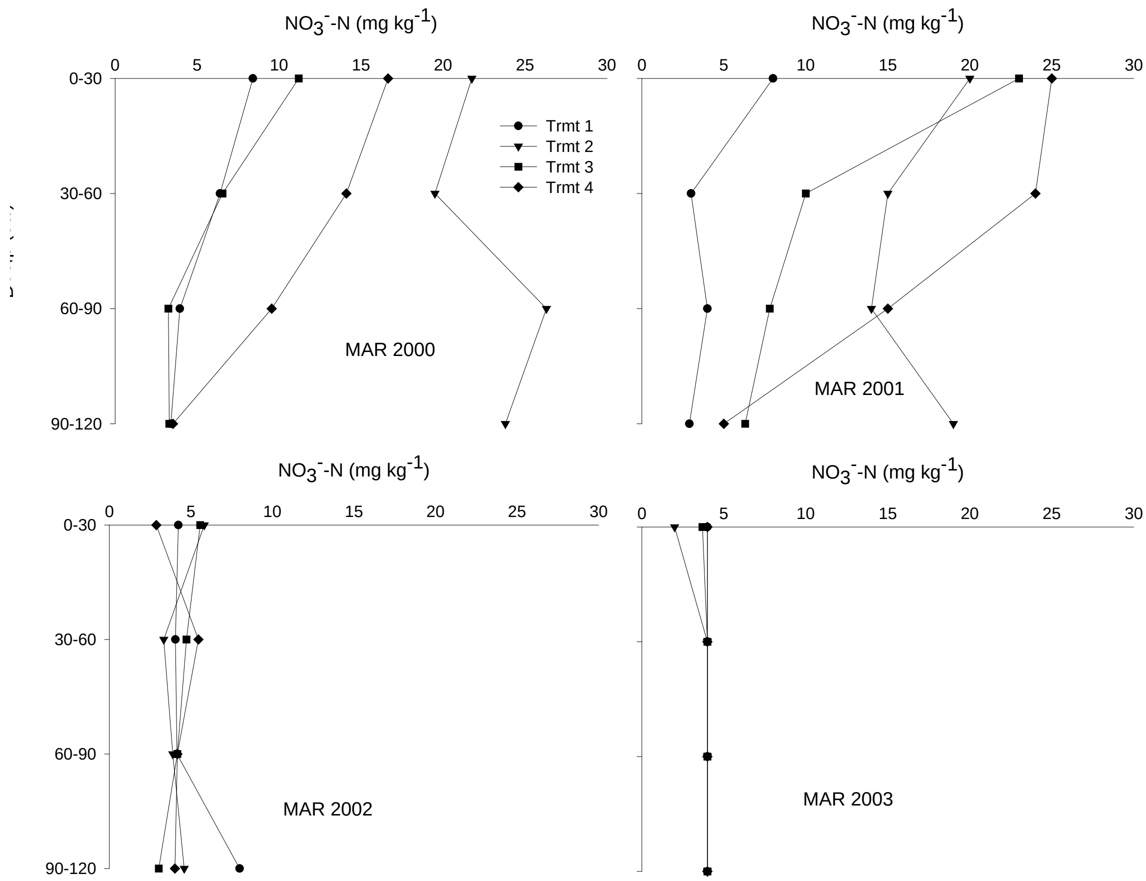

Figure 2. Soil NO_3^--N profiles from pre-season soil samples for each treatment and depth collected during the residual N study at MAR (2000-2003).

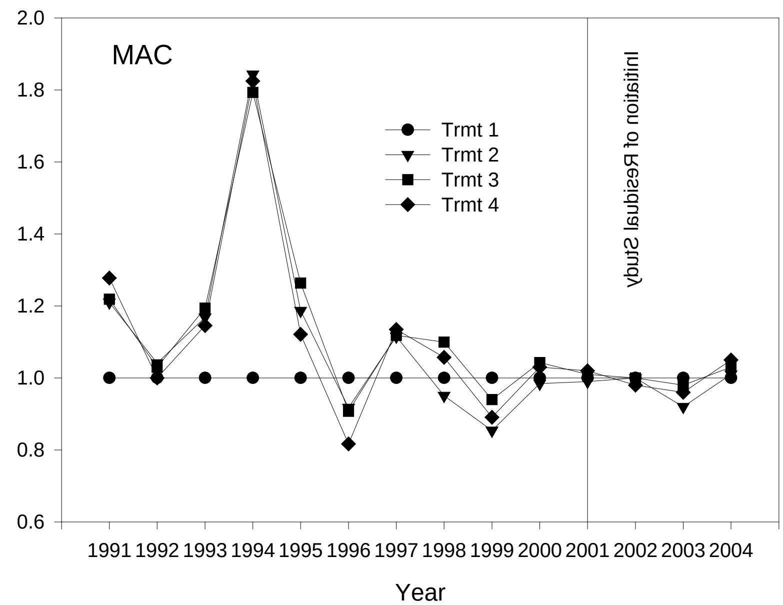

Figure 3. Relative lint yield (control) for each treatment from the initiation of the N management studies (1991) through the completion of the residual study (2004), MAC.

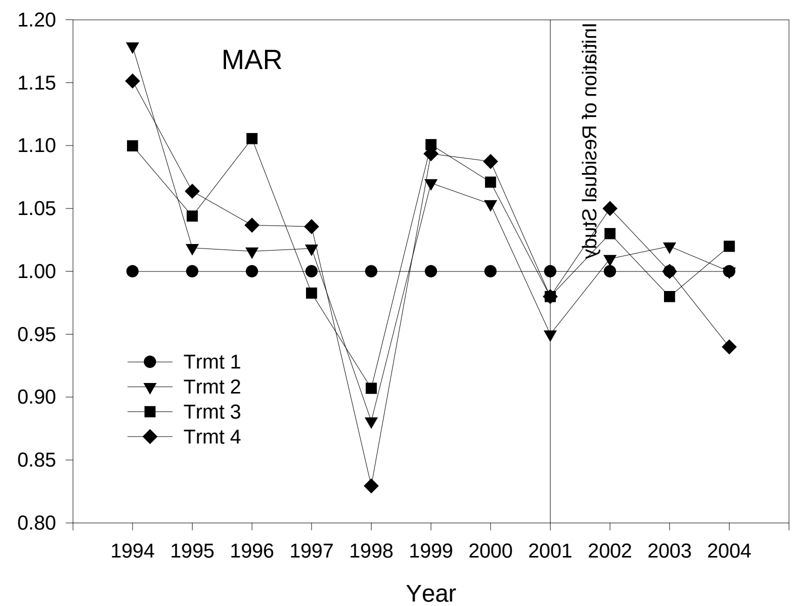

Figure 4. Relative lint yield (control) for each treatment from the initiation of the N management studies (1994) through the completion of the residual study (2004), MAR.

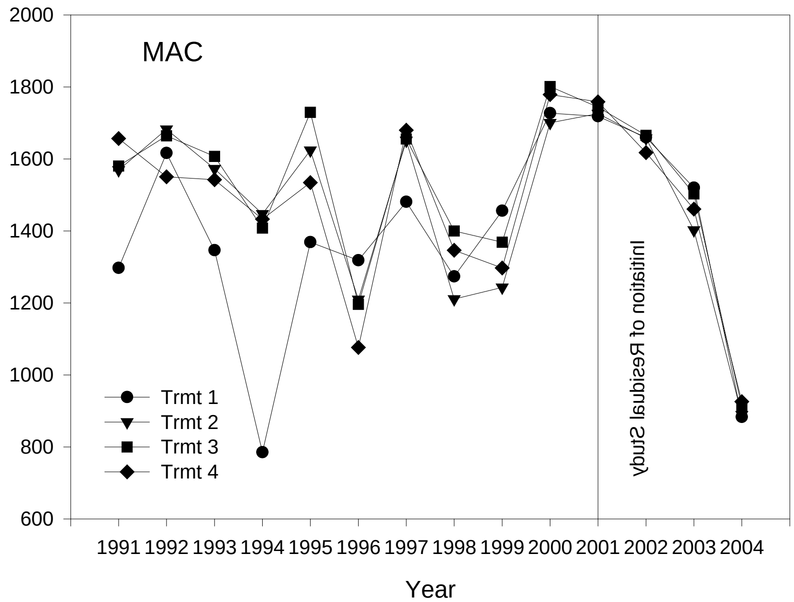

Figure 5. Lint yield estimates for each treatment from the initiation of the N management studies (1991) through the completion of the residual study (2004), MAC.

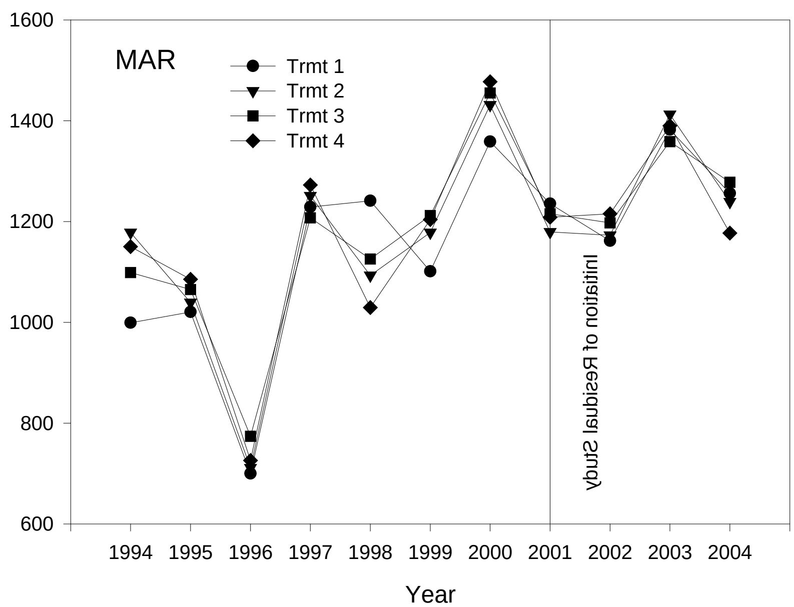

Figure 6. Lint yield estimates for each treatment from the initiation of the N management studies (1994) through the completion of the residual study (2004), MAR.

	Treatment 1	Treatment 2	Treatment 3	Treatment 4
2001	Harvested Uptake and Recovery	Harvested and Returned	Harvested and Returned	Harvested and Returned
2002	--	Harvested Uptake and Recovery	Harvested and Returned	Harvested and Returned
2003	--	--	Harvested Uptake and Recovery	Harvested and Returned
2004	--	--	--	Harvested Uptake and Recovery

Figure 7. Treatment scheme for the ^{15}N residual fertilizer study conducted 2001-2004 at SAC.

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