TILLAGE AND NUTRIENT SOURCE EFFECTS ON NITROGEN AVAILABILITY IN A SOUTHERN PIEDMONT SOIL

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ABSTRACT

Nitrogen availability in cropping systems using no-tillage (NT) and poultry litter (PL) may be different than in systems using conventional tillage (CT) and commercial fertilizer (CF). Water availability and organic matter contents can increase with NT and influence the rate of N mineralization and microbial demand for N. We evaluated the effects of tillage (NT and CT) and N source (CF and PL) on soil mineral N content and crop N uptake over two years for a corn (*Zea maze*) cropping system at the USDA-ARS J. Phil Campbell Sr. Natural Resource Conservation Center, Watkinsville, GA. Nitrogen was applied at 150 lb ac^{-1} as NH_4NO_3 in the CF treatment and as 5 ton PL ac^{-1} in the PL treatment (to give the equivalent N rate assuming 50% mineralization). Mineral N in the top 4 inches was measured through the corn growing season using *in situ* undisturbed soil cores. Tillage treatment did not significantly influence the total amount of soil mineral N or its distribution during the growing season. The mean soil N content for the 120 day period was near 100 lb $acre^{-1}$ for both CF and PL treatments. Maximum mineral N content was greater for the CF treatment compared to the PL treatment (203 lb ac^{-1} vs. 153 lb ac^{-1}) but the peak amount occurred 5 days later for the PL treatment and the rate of decline following the peak was slower for PL. Tillage treatments did not significantly influence corn biomass accumulation but the amount of biomass produced was greater for the PL treatment compared to the CF treatment (13,669 vs. 10,600 lb $acre^{-1}$). Maximum biomass accumulation occurred at approximately 100 DAP in both treatments. The N content of the corn biomass was greater for the PL treatment compared to the CF treatment (159 vs. 120 lb $acre^{-1}$). Maximum accumulation of N occurred at 90 DAP in both treatments. Previous research from the site showed that NT and PL combined increased corn grain yield by 31% compared with CT and CF combined. Similarly, soil water was 18% greater in NT than CT in the 0- to 4-inch depth. From our data it appears that the distribution of N from PL is more favorable to corn N demand. The increased productivity from using NT and PL apparently comes from a synergistic effect of better growing season N availability from the PL and greater water availability with NT.

INTRODUCTION

Nitrogen management in cropping systems can be influenced by nutrient source and tillage management. Poultry litter is a valuable source of nutrients readily available in the Southeast due to the large poultry production industry. Using conservation tillage and cover crops with increased residue can increase soil water availability and increase soil organic matter over time due to increased soil quality. Both water availability and organic matter content can influence nutrient availability by influencing the rate of N mineralization and microbial demand for nitrogen during the residue decomposition process. We evaluated the effects of tillage (no-till and conventional) and nitrogen source (commercial fertilizer and poultry litter) on soil mineral N content and crop N uptake over two years for a corn cropping system at Watkinsville, GA in the Southern Piedmont.

MATERIALS AND METHODS

Experimental Site and Agronomics

The research was conducted in 2004 and 2005 on the instrumented water quality facility at the USDA-ARS J. Phil Campbell Sr. Natural Resource Conservation Center, Watkinsville, GA (83°24' W and 33°54' N). The facility has 12 large (30 x 100 ft) nearly level (<1.5% slope) plots with drainage tiles in a Cecil sandy loam (fine, kaolinitic, thermic Typic Kanhapludults) (Bruce et al., 1983). Soil C is near 1.5 % at the surface (0 to 1 inch) but declines to 0.5 % below 2 inches. A majority of mineralized N therefore comes from the upper 0 to 4 inches. The research plots have been in a long term comparison of conventional tillage (CT) and no-tillage (NT) since the fall of 1991. Beginning in 1994 subplot treatments were changed from a comparison of fall planted cover crops to a comparison of spring applied commercial fertilizer (CF) and poultry litter (PL 3.3% N, 1.5% P, 2.7% K). This arrangement results in a factorial combination of treatments: CT-CF, CT-PL, NT-CF, and NT-PL arranged in a randomized complete block split-plot design with three replications, with tillage treatment as main and fertilizer treatment as sub plots. From 2001 to 2005 corn was grown and the fertilizer treatments were adjusted to meet the N demand of corn. A rye cover crop was planted in the fall and killed in the spring. Corn was planted April 12, 2004 and May 11, 2005 and harvested September 9, 2004 and October 20, 2005. Nitrogen was applied at a rate of 150 lb ac^{-1} as NH_4NO_3 in the CF treatment and as 5 ton PL ac^{-1} in the PL treatment to provide the equivalent N rate assuming 50% mineralization (Vest et al., 1994; CAES, 2007). Other agronomic activities followed routine regional practices.

Soil and Plant Sampling

Nitrogen mineralization during the corn growing season was determined using *in situ* undisturbed soil cores (4 inches height by 2 inches diameter) incubated for successive 3 week periods (Schomberg et al., 2006). Three cores were incubated at each of two locations in each plot for each three week period. The in situ cores are driven into the ground between crop rows. A mesh bag containing approximately 0.75 oz (vol) (15 g or 25 ml) of a 50:50 mixture of anion and cation exchange resins (Sybron Ionac ASB-1, C-249)[1] was placed in the lower 0.4 inches of the tube to capture NO_3^- and NH_4^+ that might leach from the soil. Six 1 inch by 4 inch (2.5 cm by 10 cm) soil samples were collected around the *in situ* cores to determine inorganic N content at the beginning of each incubation period. At the end of an incubation period, the core and resin bags were placed in separate zip lock plastic bags and transported to the laboratory. The soil and resin bags were extracted 1 M KCl and analyzed for NO3− and NH4+. New cores were established for the following incubation period. Soil bulk density, determined from core volume and soil mass, was adjusted for water content and used in converting data to an area basis. Aboveground biomass and N contents (including ears) were determined from 4 to 6 randomly selected plants per plot taken five times each in 2004 and 2005 at approximately 21 day intervals after planting. Biomass was dried for 3 to 5 days at 130 F, weighed, ground and analyzed for C and N using Near Infrared Spectroscopy.

Statistical Analysis

Statistical analysis was conducted SAS version 9.2 (SAS Inst. 2009). Mixed model analysis of variance was conducted with PROC MIXED. Replication, replication-by-tillage, and replication-by-tillage-by-fertilizer and year and its interactions with other fixed and random effects were treated as random effects in all analyses. Tillage, fertilizer source, and time (weeks or days after planting) were considered fixed effects. The BIC goodness of fit criterion was used to select the best fitting error model and structure for the analysis of variance. Unless otherwise indicated, all significant differences are given at $P \leq 0.10$. Nonlinear regression was used to estimate changes in soil and plant N contents over time using Proc Model. A logistic dose response peak function was fit to the data and differences among model parameters due to treatments were evaluated using a likelihood ratio test.

RESULTS AND DISCUSSION

Tillage treatment did not significantly influence the total amount or weekly amount of soil mineral N but there were differences between the two N sources (Fig 1). The amount of mineral N in the 0 to 4 inch soil depth increased during the first 30 days for both the CF and PL treatments. The mean soil N content for the 120 day period was similar for the CF and PL treatments (96 and 104 lb acre^{-1}, respectively). Maximum mineral N content in the CF treatments was estimated to be 203 lb ac^{-1} and occurred at 26 days after planting (DAP). Maximum mineral N content in the PL treatments was estimated to be 153 lb ac^{-1} and occurred at 32 DAP. The rate of decline of N appeared to be greater in the CF treatment compared to the PL treatment.

Corn biomass accumulation is shown in Fig 2. Similar to the results with the soil mineral N content tillage treatments did not significantly influence corn biomass accumulation. Nitrogen source did significantly influence the total amount of biomass produced during the cropping season. The amount of biomass produced was greater for the PL treatment compared to the CF treatment (13,669 vs. 10,600 lb acre^{-1}). Maximum biomass accumulation occurred at 98 DAP in the PL treatment and 102 DAP in the CF treatment but this was not different. Nitrogen concentration (%) was not influenced by any of the treatments and generally decreased over time (data not shown). The response for the N content of the corn biomass was similar to that of corn biomass (Fig 3). The amount of N in the corn biomass was greater for the PL treatment compared to the CF treatment (159 vs. 120 lb acre^{-1}). Maximum accumulation of N occurred at 90 DAP in both treatments.

Previously Endale et al. (2008) reported on yield and water relationships from this same study site for the years 2001 to 2005. They found that for the five years NT and PL increased grain yield by 11% and 18%, respectively, compared with CT and CF. Combined, NT and PL increased corn grain yield by 31% compared with CT and CF. Similarly, soil water was 18% greater in NT than CT in the 0- to 4-inch depth. Our results on mineral N in the upper soil profile provide further information about how PL is a more beneficial source of mineral N. From our data it appears that the distribution of N from PL is more favorable to corn N demand. It was surprising that we did not observe differences in soil mineral N content related to tillage even though Endale et al. (2008) showed greater water contents under NT compared to CT. The greater available water should increase N mineralization and N uptake but our data did not reflect greater amounts of mineral N in the NT treatment compared to the CT (based on the mean soil N content). One limitation to our approach is that we were only able to evaluate the upper 4 inches of soil. This is the depth of mixing of the N source in the CT treatment while in the NT treatments N sources were applied to the soil surface. This depth also is the area where most of the soil organic matter resides. In either situation (CT or NT) it appears that tillage had little impact on N availability and so the greater response of plant biomass in our study and yield reported by Endale et al. (2008) is probably a combined response due to better growing season N availability from the PL and greater water availability with NT which together produce a synergistic effect on corn production.

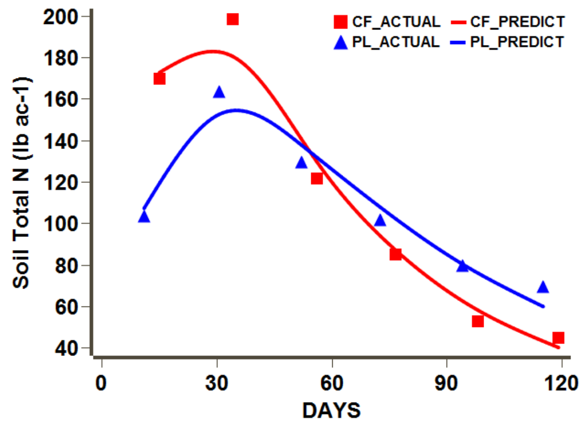

Figure 1. Influence of N source on soil total N content.

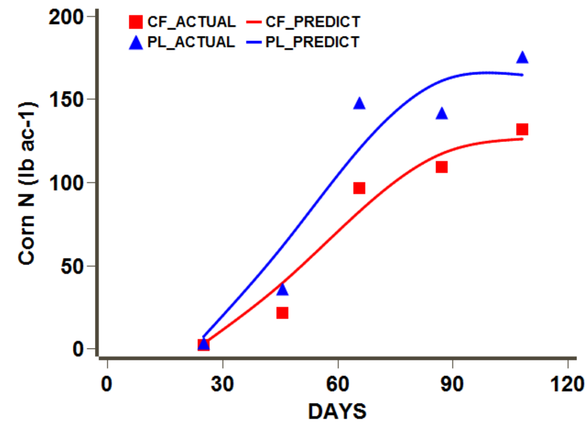

Figure 3. Influence of N source on corn N content.

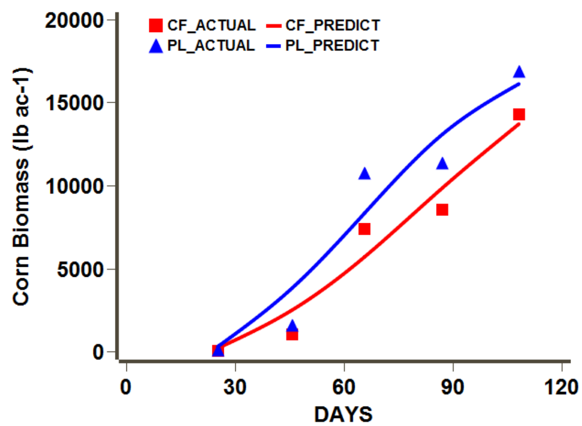

Figure 2. Influence of N source on corn biomass.

CONCLUSIONS

Our research indicates that a positive corn response to PL as a nitrogen source is related to a delay in peak N availability more so than a response to greater amount of N being applied. Availability of N from PL during the growing season apparently more closely meets the seasonal demand for N by corn in both CT and NT systems.

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