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TILLAGE AND BEEF CATTLE MANURE EFFECTS ON SOIL NITROGEN IN A DRYLAND ROTATION

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ABSTRACT

Minimum tillage practices used in dryland cropping systems that reduce soil water evaporation and erosion may also decrease efficiency of manure nutrient utilization. We initiated a study in 1997 to investigate the effects of surface-applied stockpiled and composted beef cattle (*Bos taurus*) manure on soil N and sorghum [*Sorghum bicolor* (L.) Moench] and wheat (*Triticum aestivum* L.) yields and N-uptake within a wheat-sorghum-fallow dryland crop rotation. Paired terraces with no-tillage (NT) and stubble-mulch tillage (ST) systems were main plots of a single rotation phase. Stockpiled manure, composted manure, or commercial fertilizer (urea + ammonium phosphate) were applied prior to sorghum planting to supply estimated N and P requirements of sorghum and wheat for a 3-year period. Phosphorus-based manure or compost treatments also received supplemental urea. Unfertilized treatment checks were included for yield and nutrient comparisons. Sorghum grain yield in 1999 exhibited a significant ($P < 0.05$) response to tillage and fertilizer treatments. Plots receiving urea had 22% greater yield and 16% greater N-uptake than manure and compost amended plots. Moreover, manure and compost sorghum yields were no different or slightly lower than those of the unfertilized plots. Wheat was a good scavenger of residual N accumulated throughout the fallow period although grain yield was not affected by N treatments and tillage. Residual NO_3^--N after harvest and N-uptake were significantly greater under ST as compared with NT. Tillage may be required to maintain higher mineralization rates and permit a more efficient use of manure N.

INTRODUCTION

In many regions dominated by animal-based agriculture, confined animal feeding operations generate large quantities of manure and animal-by products that must be properly managed to minimize or avoid offsite impacts to water bodies. Land application is the most economically viable alternative to utilize manure and manure by-products. Manure utilization as a nutrient source for crops is hampered because its fertilizer equivalency may change over time and the nutrient availability depends on the manure and soil characteristics as well as biological and chemical transformations within the soil system. Moreover, prolonged applications of manure with low N:P ratios can lead to P loading and increase the potential for excessive loss of P in surface runoff.

Difficulties with manure use for dryland crops in semiarid environments may be further compounded by shallow or no-tillage practices employed to retain surface residues and conserve stored water for crop production. Incorporation of solid manures using inversion tillage may improve the efficiency of manure nutrient utilization but forfeit benefits associated with minimum tillage practices such as reduced evaporation, soil erosion, and runoff (Jones et al. 1994). Alternatively, manure that is spread and left unincorporated will elevate soil phosphorus levels near the soil surface and increase the likelihood of excessive P losses into surface waters (Smith et al., 2001).

We initiated a study in 1997 to investigate the long-term effects of surface-applied stockpiled and composted beef cattle manure on soil nitrogen and phosphorus, grain yield, and crop uptake within a wheat-sorghum-fallow dryland crop rotation under NT and ST environments. We present results pertaining to the tillage and manure effects on soil N and plant uptake of N for all rotational phases in 1999 and 2000.

MATERIALS AND METHODS

The study was established in 1997 on six contour-farmed level terraces on Pullman clay loam (fine, mixed, superactive, thermic Torrertic Paleustoll) near Bushland, TX with an average annual precipitation of 476 mm. Terraces have been cropped under a wheat-sorghum-fallow rotation since 1988. The terraces are managed under no-tillage (NT) or stubble-mulch tillage (ST) (Jones and Popham, 1997) such that all phases of the rotation are present under each tillage treatment every year. The study area had a baseline 8.35 (NT) and 8.13 (ST) g kg^{-1} organic carbon for the 0-30 cm soil depth increment with C:N ratios averaging 10.3.

Six fertility treatments were established within a randomized split plot design with three replications within each tillage × rotation phase combination. Experimental plots (13.5 × 30 m) within each terrace interval were subdivided with earthen berms perpendicular to the slope to prevent runoff from entering plots. Fertilizers were applied once for each cycle of the rotation in June prior to sorghum establishment. The six treatments were: (1) beef feedyard manure applied to provide 134 kg total N ha^{-1} (MN); (2) beef feedyard manure applied to provide 16 kg total P ha^{-1} plus supplemental urea (MP) (3) composted beef feedyard manure applied to provide 134 kg total N ha^{-1} (CN); (4) composted beef feedyard manure applied to provide 16 kg P ha^{-1} plus supplemental urea (CP); (5) urea and ammonium phosphate applied at rates to achieve 108 kg N ha^{-1} and 20 kg P ha^{-1}, respectively (CF); and (6) check with no commercial fertilizer or manure applications (CK).

Manure and compost applications were made using a modified dry fertilizer drop spreader. Stockpiled beef feedyard manure and commercially composted manure from the same feedyard were collected in the spring of each year. Organic materials were ground using a tub grinder to improve material uniformity and improve uniformity of spreader applications. Applications were not incorporated, however, some shallow (< 10 cm) incorporation was attained on ST plots with sweep tillage necessary to control weeds after sorghum harvest and later in the rotation. Urea fertilizer was broadcast on the MP, CP, and CF plots at the same time as manure and compost applications. Monoammonium phosphate (11-52-0) was applied with urea to achieve the desired N and P rates in the CF plots. Application rates for each treatment averaged across terraces and years are shown in Table 1.

Sorghum (DeKalb 39Y) was sown in late June or early July at a rate of 84 000 seed ha^{-1} and a row spacing of 0.76 m with a vacuum seeder. Winter wheat (TAM 107) was sown in late September or October at a rate of 40 kg ha^{-1} in 0.30 m rows with a hoe-drill. Weed control and seedbed preparation in the ST plots were achieved using a sweep plow with one 1.5-m blade and two 1.8-m blades. Herbicide applications were used to control weeds in the NT plots. Immediately prior to grain harvest, sorghum was hand harvested from two 3-m rows and wheat was hand harvested from two 1-m rows. Hand samples were dried in a 70° C oven and weighed to determine grain yield and aboveground biomass. After crop harvest or in August for the fallow rotation phase, eight soil samples were collected from each experimental plot and composited across the 0-5, 5-10, 10-20, and 20 to 30-cm depth increments. All soil and plant sampling began in 1999.

Table 1. Average nitrogen and phosphorus application rates by source and fertilizer treatment, 1997-2001.

Treatment	N Source		P Source	
	Manure kg N ha^{-1}	Commercial kg N ha^{-1}	Manure kg P ha^{-1}	Commercial kg P ha^{-1}
Manure, N-based (MN)	134		45	
Manure, P-based (MP)	49	88	16	
Compost, N-based (CN)	134		58	
Compost, P-based (CP)	38	103	16	
Commercial Fertilizer (CF)		108		20

Total N and C in manures, plant tissues, and soils were determined by dry combustion. Soil samples were analyzed for 2*M* KCl extractable NO_3^--N and NH_4^+-N (Keeney and Nelson, 1982). Ammonium in extracts were determined using the salicylic analog of the indophenol blue blue method (EPA, 1983). Nitrates and nitrites in the extracting solutions were determined using the autoanalyzer - cadmium reduction procedure (EPA, 1983).

Mixed linear model analysis (Littell, 1996) with fertilizer treatment and tillage as fixed effects and plot replicates as random effects were used to analyze plant and soil data. The different phases of the rotation represented by three sets of paired terraces were analyzed separately because treatments were not applied at the same time. Orthogonal contrasts were used to determine differences between groups of treatments and effects with $P \leq 0.05$ were declared significant.

RESULTS AND DISCUSSION

Yield and Plant Uptake of Nitrogen

Wheat grain yield did not exhibit any response to tillage or fertility treatments in 1999 and 2000 (Fig. 1). However, CF, MP, and CP plots receiving urea two years earlier had greater plant uptake of N (Fig 2) principally due to significantly higher nitrogen contents in the grain. In addition, stubble mulch tillage (ST) plots yielded grain with, on average, 19% greater nitrogen contents than no-tillage (NT) plots.

Sorghum grain yields on NT plots were significantly greater than ST plots in 1999 and 2000. In 1999 sorghum grain yield exhibited a significant response to fertilizer treatments (Fig. 1). Plots that received urea (CF, MP, and CP) had 22% greater yields than MN and CN plots (P=0.0002). However, the relative yield response due to fertilizer source was 7% greater under NT as compared to ST plots. An exceptionally dry growing season in 2000 (~100 mm) caused soil water to be limiting and likely offset any yield responses due to fertilizer treatments. Total N-uptake by sorghum in 1999 was also significantly influenced by tillage. Averaged across fertilizer treatments, N-uptake in stubble mulch tillage plots averaged 31% greater than no-tillage plots (Fig. 2) despite the fact that grain yields in no-tillage plots were greater. In 2000, sorghum uptake of N was not influenced by tillage. In both years, however, plant uptake of N in MP, CP, and CF plots receiving urea was 21%

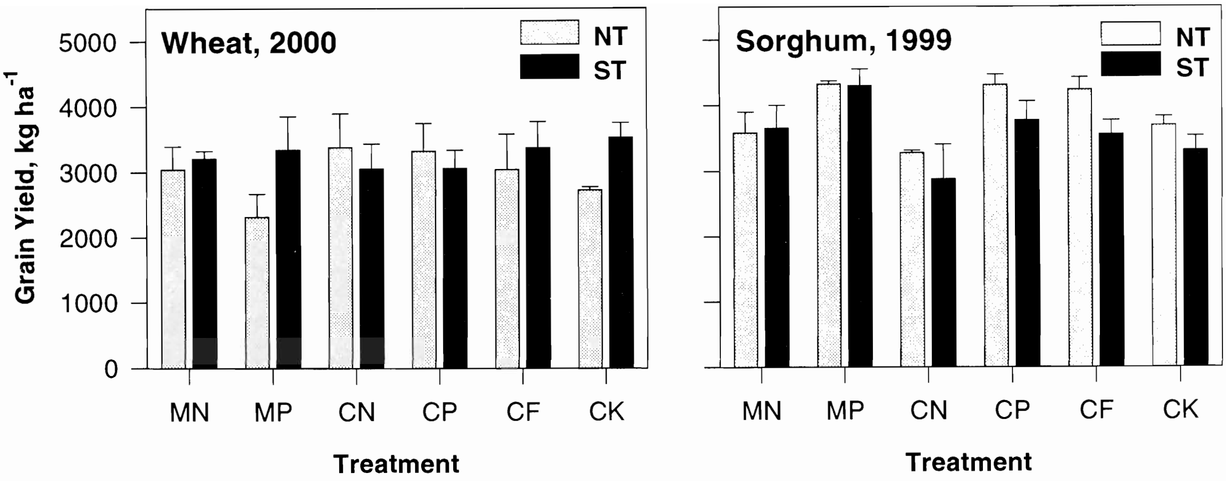

Fig. 1. Mean wheat and sorghum grain yields (dry weight) for the manure, compost, and fertilizer treatments under no-tillage and stubble-mulch tillage. Bars are standards errors.

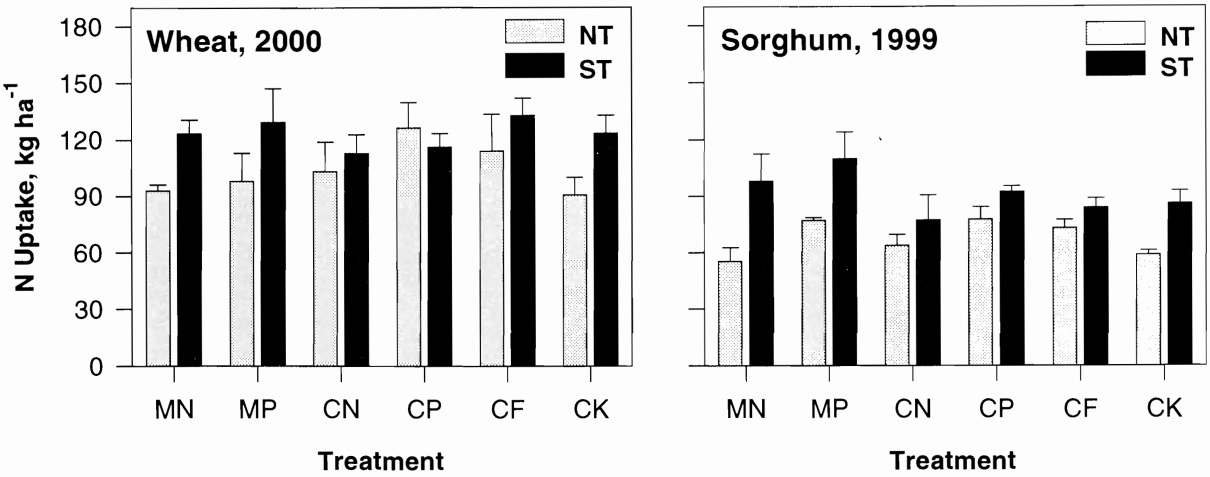

Fig. 2. Mean uptake of N by wheat and sorghum from manure, compost and fertilizer treatments under no-tillage and stubble mulch tillage. Bars are standard errors.

greater ($P = 0.033$) than N-uptake in MN and CN plots. The differential N-uptake among fertility treatments was approximately four-times greater under NT as compared to ST for these two years.

Soil Nitrogen

Total soil nitrogen was governed principally by soil depth and tillage. When integrated over 30 cm, however, total C and N for each tillage treatment were essentially equivalent. Soil NH_4^+-N was not significantly influenced by tillage and fertility treatments. The overriding effect of tillage and fertility treatments on soil N were their influence on NO_3^--N levels. Residual NO_3^--N was consistently and significantly greater in ST plots as compared with NT plots for all three terraces throughout the duration of the study (Fig. 3). In plots receiving urea (MP, CP, and CF) residual NO_3^--N was consistently greater than levels in plots that receiving exclusively organic N sources (MN and CN). Comparison of NT and ST residual NO_3^--N levels in manured plots (CN and MN) four months after application (see Fig. 3, NT and ST Sorghum 2000) suggest that, as expected, ST

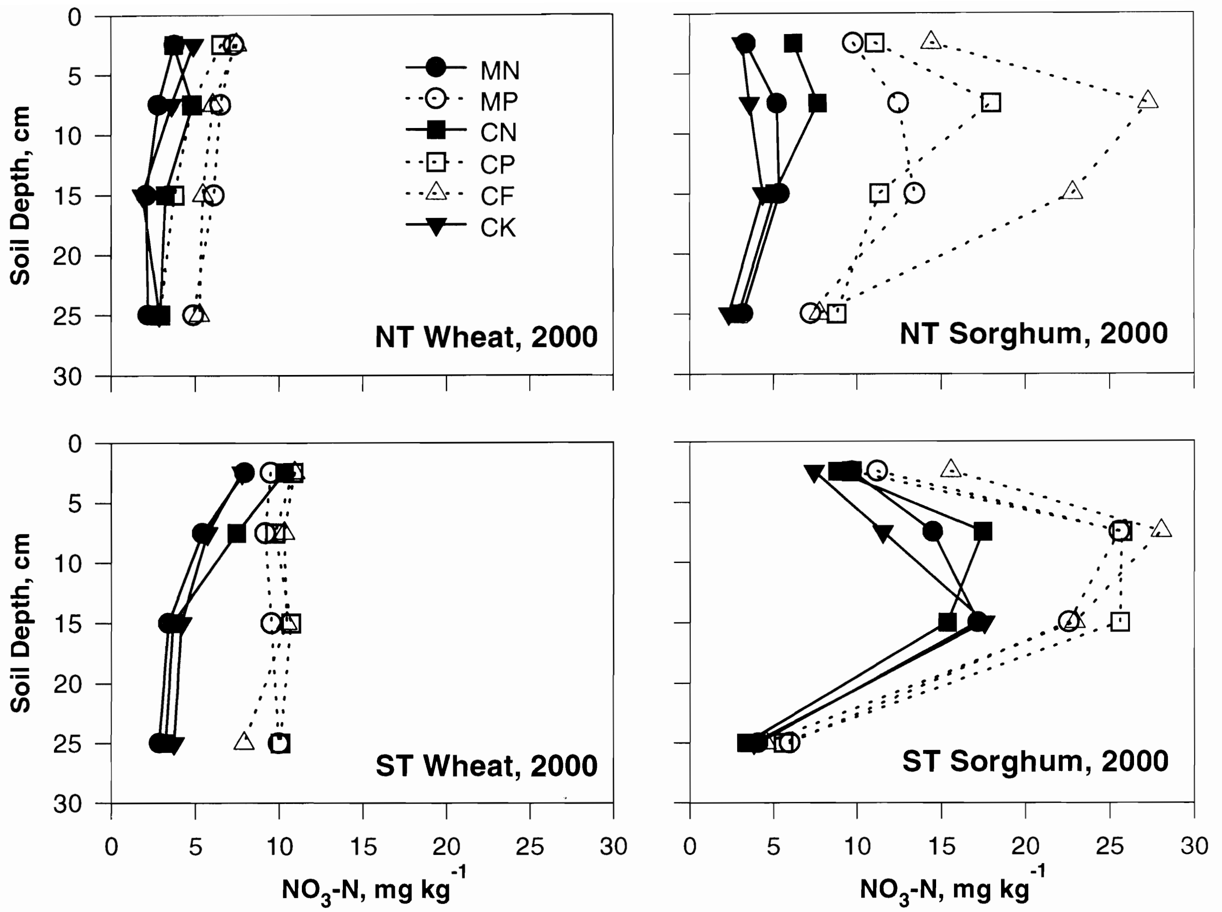

Fig. 3. Depth profiles of mean soil NO_3^--N in June 2000 after wheat harvest and in November 2000 after sorghum harvest. All contrasts of the effect of organic (MN, CN) versus commercial urea fertilizer (MP, CP, CF) were significant at the 0.05 level at all depths for these data sets.

promoted a greater N mineralization of both manures and native soil organic matter, especially near the soil surface. Low residual NO_3^--N after wheat (Fig. 3) coupled with twice as much NO_3^--N near the surface during the previous fallow (not shown) suggests that wheat behaved as a good scavenger of soil nitrates accumulated over the fallow phase.

The above relationships between sorghum yield, N-uptake, and residual nitrate concentrations suggests mineralization of N is slower under NT than ST. Hence, under NT, nitrogen may have limited sorghum grain yield in 1999 for the plots that only received manure or compost as the nitrogen source. Above average growing season precipitation in 1999 may have also caused greater losses of applied and native sources of nitrates in NT plots via runoff and leaching (Eck and Jones, 1992; Jones et al., 1995). However, accumulation of NO_3^--N near the soil surface in 2000 under ST (Fig. 3) suggests that mineralization was greater in these plots during this particularly dry growing season.

CONCLUSIONS

Greater uptake of N by wheat and sorghum in conjunction with higher levels of residual nitrates in ST plots as compared with NT indicate mineralization of soil organic matter proceeded at a more rapid rate under ST. Plots receiving urea had significantly greater sorghum yields and N-uptake than manure and compost amended plots. Sorghum grain yield response to fertilizer treatments was reduced under ST as compared to NT due to the higher levels of residual NO_3^--N near the surface and possibly at greater depths. Sweep-tillage may be required to maintain higher mineralization rates to permit a more efficient use of manure nitrogen. However, nitrogen requirements under ST are not as great as compared to NT due to greater water economy with NT.

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