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SOIL CARBON AND NITROGEN IN COTTON PLOTS UNDER CONSERVATION TILLAGE AND POULTRY LITTER

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Abstract

Conservation tillage and waste management are manipulative strategies for sequestering carbon in the soil in the cotton belt, where a large amount of poultry litter and mulch-till (MT) systems, surface application of poultry litter (PL), and winter rye (*Secale cereale L.)* cover crop on soil pH, soil organic matter (SOM), soil C and N concentration s and growth and yield of cotton *(Gossypium hirsutum L.)* was initiated in 1996 at Alabama Agriculture Experiment Station, Belle, Mina, AL. Five years of using the above treatments did not significantly affect soil pH. In 2001 and 2002, the effects of tillage, cover cropping and PL treatments on total soil C and total soil N were significant in the top 0-5 cm soil profile, due to the accumulation of organic residues from the crops and PL at the soil surface. In 2001, MT had 31% and 17% greater (P< 0.05) SOM compared to bare fallow and no-till respectively. Mulch-till had 47% and 51% greater (P<0.05) soil C than BF system in 2001 and 2002, respectively in the 0-5 cm soil profile. Cover cropping significantly increased soil C compared to BF and cotton winter-fallow (CF) systems by 42% and 25% respectively in the top 0-5 cm soil profile in 2001. Similar figures for 2002 were 48% and 21% respectively. Plots which received 200 kg N ha^{-1} in the forming the form PL had 35% greater (P< 0.05) soil C in the 0-5 cm compared to the 0 kg N ha^{-1} treatment in 2001. In 2002 the 100 kg N ha^{-1} AN, 100 kg N ha^{-1} PL and 200 kg N ha^{-1} PL had 27%, 31%, and 54% greater (P< 0.05) soil C in the 0-5cm profile compared to the 0 kg N ha-1 treatment, respectively. Compared to 2001, soil C for each treatment at each depth was greater in 2002. In 2001, total soil N in the 0-5 cm profile under NT and BF was 30% and 42% significantly lower than that under MT respectively. In 2002, total soil N under BF was 40% lower than that under CT and MT and 30% lower than that under NT. Total soil N in the 0-5cm profile under CR was 17% and 42% greater than that in CF and BF plots respectively, in 2002. In 2002, total soil N in the 0-5cm soil profile in plots which received 200 kg N ha^{-1} PL was 54%, 29%, 20% greater than in plots which received 0 kg N ha^{-1}, 100kg N ha^{-1} AN, 100 kg N ha^{-1} PL treatments, respectively. There was no significant accumulation on N in the deeper soil profile due to PL at 200 kg N ha-1treatments would be ideal for increasing total SOM and soil C in cotton plots.

Introduction

Implementation of conservation tillage systems such as no-till and mulch-till with winter rye cover cropping and the application of poultry litter in cotton production may lead to significant changes in soil physical, chemical, and biological properties in the plow layer. These changes can have a significant impact on the environment and hence the sustainability of cotton production systems (Nyakatawa et al., 2001a). Despite being one of the most profitable crops available to growers in the southern and mid-southeastern region, cotton is considered to create a greater soil erosion hazard than other annual crops such as corn and soybean (Nyakatawa, et al., 2001b). The adoption of mulch-till and no-till practices and leaving crop residue on the soil surface can increase the amount of carbon in agricultural systems. In addition, no-till can reduce soil erosion while maintaining or increasing soil productivity (Steven et al., 1992). The main reason for this is that the soil is less exposed to air, thus less soil carbon is oxidized and released into the atmosphere as CO_2. Agricultural soils play an integral part in C sequestration and storage that can help mitigate global warming (Lal et al., 1998). Poultry litter is a by-product that needs to be disposed of safely to avoid environmental issues, primarily due to soil NO_3 and phosphorous enrichment from the litter. Plant residue management that combines no-till with cover crops offers soil coverage with protective residue and therefore, maximal benefit for reduced erosion and preserved soil quality (Gatson et al., 2001). The objectives of this study were to evaluate the effects of no-till and mulch-till with winter cover cropping and poultry litter on soil pH, SOM, and soil C and N in cotton plots on a Decatur silt loam soil in north Alabama.

Materials and Methods

The study has been conducted since 1996 at the Alabama Agricultural Experiment Station, Belle Mina, AL ($34^0$41`N,$86^0$52`W) on a Decatur silt loam soil (clayey, kaolinitic thermic, Typic Paleudults) and the results reported here in comes from 2001 cropping season. The cropping history of the plots is presented in (Table1). The treatments included three tillage systems: conventional till, mulch-till, and no-till; two cropping systems: cotton-winter fallow, (cotton in summer and fallow in winter) and cotton-rye sequential cropping (cotton in summer and rye (*Secale cereale* L.) in winter; three N rates: 0, 100 and 200kg N ha^{-1} and two N sources: ammonium nitrateand fresh poultry litter. In addition a continuous bare fallow treatment was included. The experimental design was a randomized complete block design with four replications. Plots were 8 m wide and 9 m long, which resulted in eight rows of cotton, 1 m apart. Conventional tillage included moldboard plowing in November and disking in April before cotton seeding. Mulch-till included tillage with a field cultivator to partially incorporate crop residues before cotton seeding. No-till involved seeding without any tillage operation. The crop residues were left lying on the surface. Weeds were controlled by spot applications of herbicides in the no-till and mulch till systems.

The poultry litter was broadcasted by hand and incorporated to a depth of 5 to 8 cm by pre-plant cultivation in the conventional and mulch-till systems. In no-till system, the poultry litter was surface applied. The N content for the poultry litter was determined by digesting 0.5g samples using the Kjeldhal wet digestion method (Bremner and Mulvaney, 1982), followed by N analysis using the Kjeltec 1026 N analyzer (Kjeltec, Sweden). The winter rye cover crop variety Oklon, was planted in fall and killed by Roundup herbicide (glyphosate) about 7 days after flowering in spring. Cotton variety Deltapine NuCotton 33B was planted in all plots at 16 kg ha^{-1}, using a no-till planter.

Four soil cores, each 5 cm in diameter, were randomly collected from the central four rows of each plot in April 2001 using a tractor powered hydraulic probe. The soils were composited within each plot at depths of 0-5, 5-15, 15-30, 30-60, and 60-90cm. The soil was air-dried and ground to pass through a 2mm sieve before analysis. Soil pH was measured using a glass electrode connected to the Orion A290 pH meter (Orion Research Inc., Boston, MA) in 1:1 soil: water suspension at Alabama A&M University. Total soil N and C were measured using the LECO Carbon analyzer at the USDA/ARS soil Dynamics Research Laboratory, Auburn, AL.

Results and Discussion

Soil pH

There were no significant differences in soil pH among the treatments prior to cotton planting in 2001 and 2002, after five years of study (data not shown). Average soil pH in the top 15 cm was about 6.0 which is within the optimum range for cotton (5.8 to 6.5).

Soil Organic Matter

In 2001, soil organic matter (SOM) in the 0-5cm soil profile under NT and BF was 17% and 31% significantly lower than that under MT, respectively (Table 2). In the 60-90cm soil depth, SOM under NT, BF, and CT was 17%, 12% and 7% lower than that under MT, respectively. Mulch tillage resulted in the highest level of organic matter content in the 0-5cm depth because of partial incorporation of crop residues, unlike in NT where the crop residues are left on the surface. Higher rate of decomposition of crop residues under MT results in higher SOM in the short term, where as in NT, the residues remain intact longer. There were no significant effects of cropping systems and N treatments on SOM (Table 2).

Soil Carbon

Soil carbon averaged over all treatments the top 0-5 cm was about three times that in the bottom 30-90 cm soil profile (Table 3). This can be explained by the accumulation of organic residues from crops and poultry litter on the soil surface and the top soil layer. Soil C in the 0-5cm profile under MT system was 47% and 51% greater ($P < 0.05$) than that under bare fallow (BF) system in 2001 and 2002, respectively. This can be attributed to the higher rate of mineralization of organic residues from the cover crop and PL under MT system. Soil C under cotton-winter rye cropping (CR) system was significantly greater ($P < 0.05$) than that under BF and cotton winter- fallow (CF) systems by 42% and 25% respectively in the top 0-5cm soil profile in 2001. Similar figures for 2002 were 48% and 21% respectively. These results show the advantage of additional C from the cover crop (Nyakatawa et al., 2001b). Plots which received 200kg N ha^{-1} in the form PL had 35% greater ($P < 0.05$) soil C in the 0-5 cm soil profile compared to the 0 kg N ha^{-1} treatment in 2001. In 2002, the 100kg N ha^{-1} AN, 100kg N ha^{-1} PL, and 200kg N ha^{-1} PL treatments had 27%, 31%, and 54% greater ($P < 0.05$) soil C in the 0-5cm profile compared to the 0kg N ha^{-1} treatment, respectively. These differences can be attributed to C supplied by higher biomass associated with fertilizer application and also to the fact that PL directly supplies additional C to the soil.

Soil Nitrogen

In 2001, total soil N in the 0-5cm soil profile under NT and BF was 30% and 42% significantly lower than that under MT, respectively (Table 4). In 2002, total soil N under BF was 40% significantly lower than that under CT and MT and 30% lower ($P < 0.05$) than that under NT. As with soil C, these results reflect the higher mineralization of crop residues and PL under MT system (Nyakatawa et al., 2001a). As was expected, bare fallow plots contained the least amount of residual total soil N. Total soil N in the 0-5cm profile under CR was 17% and 42% greater than that in CF and BF plots, respectively, in 2002. This can be attributed to additions of N released from mineralization of the cover crop residues and PL in CR system. In 2002, total soil N in the 0-5cm soil profile in plots which received 200kg N ha^{-1} PL was 54%, 29%, 20% greater than in plots which received 0 kg N ha^{-1}, 100kg N ha^{-1} AN, and 100kg N ha^{-1} PL treatments, respectively. However, there was no detectable accumulation of total soil N under the 200 kg N ha^{-1} PL treatment in the deeper soil profile. In the top 5cm of the soil, the residual soil N is easily accessible and available for use by the following summer crop, thereby reducing the risk of nitrate leaching.

Conclusion

Results from this study show that conservation tillage and poultry litter treatments did not significantly effect soil pH in cotton plots on the Decatur silty loam soil after five years of study. This is a good result for the sustainability of the soil. Among the tillage systems, MT was the best for increasing total soil C in the 0-5cm soil profile. The additional C from the cover crop under CR significantly increased soil C in 0-5 soil profile. The use of PL increased soil C in the 0-5cm soil profile due to direct additions of C to the soil. Our treatments so far do not suggest accumulation of residual total soil N in the deeper soil profile, which could otherwise pose a leaching problem.

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Table 1. Cropping history of plots used in the study, Belle Mina, AL 1996 – 2002.

Season	**Year**	**Cropping System**
Summer	1996	Cotton
Winter/Spring	1996/1997	Rye
Summer	1997	Cotton
Winter/Spring	1997/1998	Rye
Summer	1998	Cotton
Winter/Spring	1998/1999	Fallow
Summer	1999	Corn
Winter/Spring	1999/2000	Rye
Summer	2000	Cotton
Winter/Spring	2000/2001	Rye
Summer	2001	Cotton
Winter/Spring	2001/2002	Fallow

Table 2. Soil Organic Matter in cotton plots as influenced by tillage systems and N treatments, Belle Mina AL, 2001-2002.

	Tillage System g kg^{-1} Spring 2001			
Soil Depths	**CT**	**MT**	**NT**	**BF**
0-5	22.44ab	25.59b	21.15ab	17.49a
5-15	19.33a	18.97a	16.30a	16.91a
15-30	14.92a	15.17a	14.92a	13.90a
30-60	16.04a	7.95a	6.31a	6.31a
60-90	5.65a	6.14b	5.09a	5.38ab

	Cropping System g kg^{-1} Spring 2001		
Soil Depths	**CF**	**CR**	**BF**
0-5	19.89a	23.32a	17.49a
5-15	17.31a	18.20a	16.91a
15-30	14.30a	15.21a	13.90a
30-60	6.07a	6.67a	6.31a
60-90	5.14a	5.63a	5.38a

	N Treatments g kg^{-1} Spring 2001			
Soil Depths	**0N**	**100AN**	**100PL**	**200PL**
0-5	20.40a	21.68a	24.50a	20.61a
5-15	17.14a	18.91a	17.05a	17.35a
15-30	14.43a	15.26a	14.34a	15.85a
30-60	6.93a	6.10a	7.03a	5.51a
60-90	5.34a	5.46a	5.60a	5.70a

[†]Means within a row followed by the same letter are not significantly different at P = 0.05.

Table 3. Soil carbon in cotton plots (%) as influenced by tillage systems, cropping systems, and N treatments, Belle, Mina, AL 2001-2002.

Tillage System g kg $^{-1}$

Soil	Spring 2001				Spring 2002			
Depths	**CT**	**MT**	**NT**	**BF**	**CT**	**MT**	**NT**	**BF**
0-5	13.67a	14.88a	12.98a	10.16b	16.0a	17.09a	15.29a	11.3b
5-15	11.20a	11.0ab	10.0ab	9.83b	11.16ab	10.59a	10.65ab	10.45b
15-30	9.21a	8.82a	8.67a	8.08a	9.30a	10.59b	9.06a	9.64a
30-60	3.98a	4.62a	4.10ab	3.67b	4.56a	5.41a	4.42a	4.56a
60-90	3.28a	3.57a	2.96b	3.13ab	3.64a	3.61a	3.37a	3.16a

Cropping System g kg $^{-1}$

Soil	Spring 2001			Spring 2002		
Depths	**CF**	**CR**	**BF**	**CF**	**CR**	**BF**
0-5	11.54b	14.46a	10.16b	13.81b	16.67a	11.30b
5-15	10.06a	10.92a	9.83a	10.83a	11.09a	10.45a
15-30	8.31a	9.13a	8.08a	8.71a	9.70a	9.64a
30-60	3.85a	4.28a	3.67a	4.57a	4.69a	4.56a
60-90	2.99a	3.27a	3.13a	3.67a	3.45a	3.16a

N Treatments g kg $^{-1}$

Soil	Spring 2001				Spring 2002			
Depths	**0N**	**100AN**	**100PL**	**200PL**	**0N**	**100AN**	**100PL**	**200PL**
0-5	11.86b	13.3ab	14.24ab	15.98a	12.55c	15.98b	16.41b	19.27a
5-15	9.96a	10.99a	10.81a	10.09a	10.41a	11.09a	1142a	10.80a
15-30	8.39a	8.87a	9.90a	9.21a	8.96a	9.28a	10.11a	9.83a
30-60	4.03a	4.17a	4.09a	4.27a	4.43a	4.59a	4.94a	4.70a
60-90	3.10a	3.17a	7.34a	3.31a	3.34a	3.52a	3.47a	3.58a

†Means within a row followed by the same letter are not significantly different at P = 0.05.

Table 4. Soil N in cotton plots (%) as influenced by tillage systems and N treatments, Belle, Mina, AL, 2001-2002.

	Tillage System $g\ kg^{-1}$							
Soil	Spring 2001				Spring 2002			
Depths	CT	MT	NT	BF	CT	MT	NT	BF
0-5	0.93ab	1.04a	0.80b	0.73b	1.30a	1.30a	1.21a	0.93b
5-15	0.82a	0.81a	0.65a	0.70a	0.99a	1.01a	1.46a	0.91a
15-30	0.70a	0.71a	0.60a	0.61a	0.90a	0.97a	0.88a	0.89a
30-60	0.49ab	0.57a	0.42b	0.43ab	0.69a	0.79a	0.99a	0.63a
60-90	0.54a	0.59a	0.45a	0.48a	0.69a	0.70a	0.68a	0.64a

	Cropping System $g\ kg^{-1}$					
Soil	Spring 2001			Spring 2002		
Depths	CF	CR	BF	CF	CR	BF
0-5	0.77a	0.93a	0.73a	1.12b	1.32a	0.93c
5-15	0.69a	0.77a	0.70a	1.80a	0.98a	0.91a
15-30	0.62a	0.67a	0.61a	0.85a	0.93a	0.89a
30-60	0.43a	0.50b	0.43a	0.73a	0.87a	0.63a
60-90	0.47a	0.52a	0.48a	0.69a	0.69.a	0.64a

	N Treatments $g\ kg^{-1}$							
Soil	Spring 2001				Spring 2002			
Depths	0N	100AN	100PL	200PL	0N	100AN	100PL	200PL
0-5	0.84a	0.87a	0.87a	0.98a	1.03c	1.23b	1.32b	1.59a
5-15	0.74a	0.80a	0.68a	0.63a	0.95a	1.48a	1.00a	0.98a
15-30	0.67a	0.68a	0.61a	0.58a	0.88a	0.89a	0.94a	0.94a
30-60	0.51a	0.48ab	0.45ab	0.35b	0.67a	0.70a	1.18a	0.71a
60-90	0.52a	0.53a	0.51a	0.45a	0.66a	0.69a	0.73a	0.72a

†Means within a row followed by the same letter are not significantly different at P = 0.05.