Soil Carbon and Nitrogen as Influenced by Tillage and Poultry Litter in North Alabama

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ABSTRACT

Conservation tillage and waste management are manipulative strategies for sequestering carbon (C) in the soil in the Cotton Belt, where a large amount of poultry waste is being produced every year. A study was initiated in 1996 at the Tennessee Valley Research and Extension Center, Belle, Mina, AL, to study the effects of no-till and mulch-till systems, surface application of poultry litter, and winter rye (*Secale cereale* L.) cover cropping on soil pH, C and N concentrations and growth and yield of cotton (*Gossypium hirsutum* L.). There were no significant differences in soil pH among the treatments prior to cotton planting in 2001. In April 2001, soil C in the upper 5 cm under mulch-till was 12% greater than that under conventional till, and 46% higher than that in bare fallow (BF) plots. In a cotton-winter rye cropping system, soil C in the upper 5 cm was 25% and 42%, greater than under cotton-winter fallow and BF plots, respectively, while in plots which received 100 kg N ha^{-1} and 200 kg N ha^{-1} in the form of poultry litter (PL), it was 7% and 20%, greater than in plots which received 100 kg N ha^{-1} in the form of ammonium nitrate (AN), respectively. Total soil N in the 0-5 cm soil depth at the start of the season in April 2001 under no-till was not significantly different from that in the conventional till. However, mulch-till plots contained 10% and 25% greater total soil N, compared to conventional till and no-till, respectively. The results from this study show that four years of conservation tillage system with winter rye cover cropping and poultry litter as a source of N did not have adverse effects on soil pH and that winter-rye cover cropping and PL use in conservation tillage increased total soil C in the top 5 cm of soil.

KEYWORDS

Conservation tillage, cover crop, cotton, rye, soil pH.

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 (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] (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; Triplett *et al.*, 1996). 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). The moldboard plow has been the symbol of U.S. agriculture over the last 150 years and through its intensive usage, agricultural soils have been mineralized or oxidized of its soil C and soil organic matter (Reicosky, 2001). Until recently, cotton in north Alabama was mainly grown under conventional tillage systems. This includes the moldboard plow or chisel plow primarily in the fall, spring disking or harrowing, and inter-row cultivation for weed control during the cotton-growing season. These tillage operations make the soil more susceptible to erosion that leads to the depletion of soil C and nitrate leaching.

Poultry litter accumulation in several southeastern states is becoming an increasing problem to farmers. 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. The application of

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poultry litter to crop lands serves both as an important means of waste disposal and a valuable source of plant nutrients, such as N and P. When applied in no-till conservation tillage systems, this waste acts as a mulch which reduces soil erosion while at the same time improving soil organic matter, conserving soil moisture, and providing nutrients for crops (Reddy *et al.*, 2000; Nyakatawa *et al.*, 2001a; 2001b; 2001c;). In north Alabama, the poultry industry produces an abundant supply of poultry litter whose application to croplands as a fertilizer provides an environmental friendly way of disposing large quantities of poultry 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 (Reeves, 1997). The attributes that make winter rye a superior cover crop over legumes include vigorous growth, winter hardiness, early spring growth, herbicide sensitivity, and mulch persistence (Brown *et al.*, 1985; Bauer and Reeves, 1999). Winter rye cover crops may also reduce leaching losses of residual N fertilizer (Kelley *et al.*, 1992). 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, 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 Tennessee Valley Research and Extension Center,, Belle Mina, AL (34°41‘N, 86°52‘W) on a Decatur silt loam soil (clayey, kaolinitic thermic, Typic Paleudults) and the results reported here are from the 2001 cropping season. The cropping history of the plots is presented in Table1. Treatments included three tillage systems (conventional till, mulch-till, and no-till), two cropping systems (cotton plus winter fallow and cotton plus winter rye (*Secale cereale* L.) sequential cropping), three N rates (0, 100 and 200 kg N ha^{-1}), and two N sources (ammonium nitrate and fresh poultry litter). Ammonium nitrate was used at one N rate (100 kg N ha^{-1}) only. 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. A field cultivator was used to prepare a smooth seedbed after disking. A field cultivator and spot applications of herbicides were used for controlling weeds during the season. 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.

Ammonium nitrate and poultry litter were applied immediately before cotton seeding. 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 amounts of poultry litter to supply 100 and 200 kg N ha^{-1} were calculated each year based on the N content of the poultry litter. A 60% adjustment factor was used to compensate for the N availability from poultry litter during the first year of application. At the beginning of the experiment in 1996, all plots received a blanket application of 336 kg ha^{-1} of 0-20-20 fertilizer to nullify the effects of P and K applied through poultry litter.

The winter rye cover crop cv. Oklon, was planted in fall and killed by Roundup herbicide (glyphosate) about 7 days after flowering in spring. A no-till planter was used to seed the rye cover crop at a rate of at 60 kg ha^{-1} into the previous cotton stubble immediately after cotton harvest. Cotton cv. Deltapine NuCotton 33B was planted in all plots at 16 kg ha^{-1}, using a no-till planter. A herbicide mixture of Prowl (pendimethalin) at 2.3 L ha^{-1}, Cotoran (fluometuron) at 3.5 L ha^{-1}, Gramoxone Extra (paraquat) at 1.7 L ha^{-1} was applied to all plots before planting in May for weed control. In addition, all plots received 5.6 kg ha^{-1} of Temik (aldicarb)

Table1. Cropping history of plots used in the study, Belle Mina, AL 1996 to 2002.

Season	Year	Crop
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

for the control of thrips. During the season, a cultivator was used for controlling weed in conventional till system while spot applications of Roundup using a knapsack sprayer were used to control weeds in the no-till and mulch-till systems. Aphids were controlled with Karate (cypermethrine). The growth regulator, Pix at 0.8 kg ha^{-1} was applied to cotton to reduce vegetative growth at 2.5 months after planting. The cotton was defoliated with a mixture of Finish at 2.3 L ha^{-1} and Def at 0.6 kg ha^{-1} two weeks before the first harvest. Seed cotton yield was determined by mechanically harvesting open cotton bolls in the central four rows of each plot.

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 60-90 cm. The soil was air-dried and ground to pass through a 2 mm 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

There were no significant differences among treatments for soil pH (Table 2). 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) (Burmester, 1993). Soil carbon in 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 manure in the upper soil layer.

Table 2. Soil pH in cotton plots under conventional till (CT), mulch-till (MT), and no-till (NT) tillage systems; cotton-winter fallow (CF), cotton-rye sequential (CR), and bare fallow (BF) cropping systems, and ammonium nitrate (AN) and poultry (PL) sources of N prior to cotton planting in April 2001 at the Tennessee Valley Research and Extension Center, Belle Mina, AL.

Depths	**Tillage system**			
-- cm --	CT	MT	NT	BF
0 - 5	5.84a†	5.73a	5.78a	5.37a
5 - 15	5.91a	5.98a	5.96a	5.72a
15 - 30	5.82a	5.79a	5.91a	5.68a
30 - 60	5.50a	5.46a	5.51a	5.32a
60 - 90	5.12a	5.01a	5.05a	4.97a
	Cropping system			
	CF	CR	BF	
0 - 5	5.74a	5.82b	5.37a	
5 - 15	5.93a	5.95a	5.72a	
15 - 30	5.86a	5.86a	5.68a	
30 - 60	5.46a	5.51a	5.32a	
60 - 90	5.01a	5.09a	4.97a	
	N-treatment, lbs N $acre^{-1}$			
	0N	100AN	100PL	200PL
0 - 5	5.80b	5.63a	5.97b	5.68a
5 - 15	5.93a	5.92a	5.95a	5.94a
15 - 30	5.85a	5.82a	5.88a	5.86a
30 - 60	5.47ab	5.56b	5.45ab	5.24a
60 - 90	5.08a	5.12a	4.99a	4.89a

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

Table 3. Soil carbon [%] in cotton plots under conventional till (CT), mulch-till (MT), and no-till (NT) tillage systems; cotton-winter fallow (CF), cotton-rye sequential (CR), and bare fallow (BF) cropping systems, and ammonium nitrate (AN) and poultry (PL) sources of N prior to cotton planting in April 2001 at the Tennessee Valley Research and Extension Center, Belle Mina, AL.

Depths	**Tillage system**			
-- cm --	CT	MT	NT	BF
0 - 5	1.37bc†	1.49c	1.30b	1.02a
5 - 15	1.12b	1.10b	1.00b	0.98a
15 - 30	0.92a	0.88a	0.87a	0.81a
30 - 60	0.40a	0.46b	0.41ab	0.37a
60 - 90	0.32ab	0.36b	0.30a	0.31a
	Cropping system			
	CF	CR	BF	
0 - 5	1.01a	1.09b	0.98a	
5 - 15	0.83a	0.91b	0.81a	
15 - 30	0.39a	0.43a	0.37a	
30 - 60	0.30a	0.33a	0.31a	
60 - 90	1.16a	1.45b	1.02a	
	N-treatment, lbs N $acre^{-1}$			
	0N	100AN	100PL	200PL
0 - 5	1.18a	1.32a	1.42ab	1.59b
5 - 15	0.99a	1.09a	1.08a	1.00a
15 - 30	0.84a	0.88a	0.90a	0.92a
30 - 60	0.40a	0.41a	0.40a	0.42a
60 - 90	0.31a	0.31a	0.32a	0.33a

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

Differences in soil C among the tillage treatments were significant in the top 0-5 and 5-15 cm soil profile. In the top 0-5 cm, soil C under mulch till was 12% greater than that under conventional till and no-till and 46% higher than that in BF plots (Table 3). There was no significant difference in soil C between no-till and conventional till systems.

Soil C in the 0-5 cm soil profile under cotton-winter rye cropping system was 25% and 42% greater than that under cotton-winter fallow and bare fallow plots respectively (Table 3). Soil C in the 0-5 cm soil profile in plots, which received 100AN, 100PL, and 200PL, were 13%, 20% and 36%, greater than in the 0N plots respectively (Table 3). Plots receiving 100PL and 200PL had 7% and 20% greater soil C than 100AN plots, respectively. This shows the advantage of using PL as a N source in increasing soil C.

Differences in total soil N among the treatments were significant in the top 0-5 and 5-15 cm soil profile. Total soil N under no-till in the 0-5 cm soil depth was not significantly different from that in conventional till (Table 4). However mulch-till plots contained 10% and 25% greater total soil N, compared to conventional till and no-till respectively. The difference between mulch till and no-till can be attributed to the higher mineralization of crop residues in mulch till compared to no-till, while that between mulch till and conventional till may be attributed to greater amount of crop residues in mulch till (Nyakatawa *et al.*, 2001a). As was expected, bare fallow plots contained the least amount of residual total soil N, since these plots did not receive any N fertilizer and also, had no residues which supply N after mineralization. Similar results were found in the 5-15 soil depth.

Table 4. Soil nitrogen [%] in cotton plots under conventional till (CT), mulch-till (MT), and no-till (NT) tillage systems; cotton-winter fallow (CF), cotton-rye sequential (CR), and bare fallow (BF) cropping systems, and ammonium nitrate (AN) and poultry (PL) sources of N prior to cotton planting in April 2001 at the Tennessee Valley Research and Extension Center, Belle Mina, AL.

Depths	**Tillage system**			
-- cm --	CT	MT	NT	BF
0 - 5	0.09a[†]	0.10a	0.08a	0.07a
5 - 15	0.08b	0.08b	0.07a	0.07a
15 - 30	0.07a	0.07a	0.06a	0.06a
30 - 60	0.05ab	0.06b	0.04a	0.04a
60 - 90	0.05a	0.06a	0.05a	0.05a
	Cropping system			
	CF	CR	BF	
0 - 5	0.07a	0.08a	0.07a	
5 - 15	0.06a	0.07a	0.06a	
15 - 30	0.04a	0.05b	0.04a	
30 - 60	0.05a	0.05a	0.05a	
60 - 90	0.08a	0.09b	0.07a	
	N-treatment, lbs N acre^{-1}			
	0N	100AN	100PL	200PL
0 - 5	0.08a	0.09a	0.09a	0.09a
5 - 15	0.07a	0.08a	0.07a	0.06a
15 - 30	0.07a	0.07a	0.06a	0.06a
30 - 60	0.05a	0.05a	0.05a	0.04a
60 - 90	0.05a	0.05a	0.05a	0.05a

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

Total soil N in the 0-5 cm soil profile under cotton-winter rye cropping system was 13% and 29%, greater than that under cotton-winter fallow and bare fallow plots respectively (Table 4). The great amount of residual soil N in cotton-winter rye cropping system was from the residues from the winter rye cover crop. Total soil N in the 0-5 cm soil profile in plots which received poultry litter at 200 kg N ha^{-1} PL (200PL) was 10% greater than that in plots which received 100AN and 100PL N treatments (Table 4). Plots receiving 100AN and 100PL N treatments had the same amount of total soil N.

CONCLUSION

Results from this study show that the use of no-till and mulch till conservation tillage systems with winter cover cropping and poultry litter as a source of N generally have had no significant effect on soil pH in cotton plots on the Decatur silt loam soil at Belle Mina Alabama over the five year duration of the experiment. This is a good result in the sustainability of the soil. The other positive result from this study is that there is no significant accumulation of residual total soil N among the treatments, especially in the deeper soil profile, which could otherwise pose a leaching problem. In the top 5 cm of the soil, the residual soil N is easily accessible and available for use by the following summer crop. Finally, this study demonstrates that winter rye cover cropping and poultry litter use in conservation tillage can increase total soil C in the top soil which improves soil moisture conservation, soil structure, and nutrient holding capacity of the soil.

LITERATURE CITED

Bauer, P.J. and D.W. Reeves. 1999. A comparison of winter cereal species and planting dates as residue cover for cotton grown with conservation tillage. Crop Sci. 39:1824-1830.

Bremner, J.M. and Mulvaney, C.S. 1982. Nitrogen-Total. pp. 595-625. *IN* A.L. Page *et al.*, (eds). Methods of Soil Analysis. Part 2. 2nd ed. Agronomy Monographs.

Brown, S.M., T. Whitewell, J.T. Touchton, and C.H. Burmester. 1985. Conservation tillage for cotton production. Soil Sci. Soc. Am. J. 9:1256-1260.

Burmester, C.H. 1993. Cotton Production Guide. Alabama Cotton Notes. Alabama Cooperative Extension Service/Auburn University, Alabama. February 1993. 2-10.

Delaney, D. 1991. Strip-till and no-till demonstrations in north Alabama. pp. 1-4. *IN* FarmDemonstrations Rep. Alabama Coop. Ext. Service, Auburn Univ., Auburn, AL.

Kelley. K.R., J.J. Mortvedt, J.M. Soileau, and K.E. Simmons. 1992. Effect of winter cover crops on nitrate leaching. P. 282. In Agronomy abstracts. ASA, Madison, WI.

Lal, R., Kimball, J., Follet, R. F. and Cole, C.V. 1998. The potential of U.S. cropland to sequester carbon and mitigate the green house effect, Sleeping Bear Press: Ann Arbor, MI, 128 pp.

Nyakatawa, E.Z., K.C. Reddy, and J.L. Leymunyon. 2001a. Predicting soil erosion in conservation tillage cotton production systems using the Revised Universal Soil Loss Equation (RUSLE). Soil Tillage Res., 57:213-224.

Nyakatawa, E.Z., K.C. Reddy, and K. R. Sistani. 2001b. Tillage, cover cropping, and poultry litter effects on selected soil chemical properties. Soil Tillage Res., 58:69-79.

Nyakatawa, E.Z., K.C. Reddy, and G.F. Brown. 2001c. Residual effect of poultry litter on yield and N uptake of corn and rye in conservation tillage systems. Filed Crops Res., 71:159-171.

Reddy, K.C., E.Z. Nyakatawa, and R. Malik. 2000. Sustainable cotton production systems for SE USA. Extended Summaries-Invited Papers of the International Conference on Managing Natural Resources for Sustainable Agricultural Production in the 21st Century At New Delhi, India during Feb. 14-18, 2000. pp. 129-130.

Reeves, D.W. 1997. The role of soil organic matter in maintaining soil quality in continuous cropping systems. Soil and Tillage Res. 43:131-167.

Reicosky, D.C. 2001. Tillage-induced CO_2 Emissions and Carbon Sequestration: Effect of secondary tillage and compaction I World Congress on Conservation Agriculture Madrid, Oct. 1-5, 2001. pp. 266-274.

Stevens, W.E., J.R. Johnson, J.J. Vacro, and J. Parkman. 1992. Tillage and winter cover management effects on fruiting and yield of cotton. J. Prod. Agric. 5:570-575.

Triplett, G.T., S.M. Dabney and J.H. Siefker. 1996. Tillage systems for cotton on silty upland soils. Agron.J.88:507-51.