TILLAGE, ROTATION, AND N SOURCE INTERACTIONS ON CHEMICAL PROPERTIES OF AN APPALACHIAN PLATEAU SOIL

A. C. V. Motta[1], D. W. Reeves[2], and J. H. Edwards[2]

AUTHORS: [1]Agronomy and Soils Department, Auburn University; [2]USDA-ARS National Soil Dynamics Laboratory, 411 S. Donahue Dr., Auburn, Al 36832. Corresponding author A. Motta, Email: amotta@acesag.auburn.edu.
REFERENCE: J.E. Hook (ed.) *Proceedings of the 22nd Annual Southern Conservation Tillage Conference for Sustainable Agriculture,* Tifton, GA. 6-8 July 1999. Georgia Agriculture Experiment Station Special Publication 95. Athens, GA.

INTERPRETATIVE SUMMARY

Problem

Soil quality can be strongly affected by soil management. Adoption of conservation tillage, crop rotation, and use of animal manures have all been shown to improve soil quality in certain situations. However, studies including all three management practices are scarce and such knowledge is needed to better integrate crop and animal production systems. This study evaluated effects of these management practices on some chemical indicators of soil quality in the poultry-intensive Appalachian Plateau of northern Alabama.

Study Description

The study was established in 1982 on a Hartsells fine sandy loam in northeastern Alabama (fine-loamy, siliceous , thermic Typic Hapludult) and has as treatments rotations of corn (*Zea mays* L.) or soybean [*Glycine max* (L.) Merr.] following a wheat (*Triticum aestivum* L.) cover crop under conventional tillage and conservation tillage. The conservation tillage treatment consisted of planting directly into residue from the wheat cover crop that had been desiccated with paraquat each year. In some years the conservation tillage treatment was lightly disked (2 to 4 inches deep) in fall before drilling wheat. Conventional tillage consisted of a shallow disking prior to planting the wheat cover crop in the fall; followed by disking, chisel plowing (6 to 8 inch depth), and leveling with a disk in spring. Two N sources for the wheat cover crop; poultry litter and NH_4NO_3, were introduced as treatments in 1992. We assumed that the fall-applied litter supplied about 60 lb N/acre (67 kg N/ha) to the soil/plant system each year, based on extension recommendations that about 50% of the total N in poultry litter becomes available (is mineralized) the first year of application. Each year corn received 50 lb N/acre (56 kg N/ha) at planting and an additional 150 lb N/acre (168 kg/ha) as NH_4NO_3 2 to 3 weeks after emergence. Soil samples were collected in 1997 from the 0-1.2, 1.2-2.4, 2.4-4.8, and 4.8-9.6 inch depths (0-3, 3-6, 6-12, and 12-24 cm depths). The experimental field design was a split-split-plot design with four replications. Tillage, rotations, and source of wheat N fertilizer were main, sub, and sub-subplots, respectively. Sampling depths were analyzed as an additional split in the design. Analyses of variance was conducted on all response variables and mean separation was done with Fisher's protected least significant difference (LSD) values at the 95% level of confidence. Correlation, simple, and step wise regression were also used to analyze relationships among chemical soil quality variables.

Applied Question

How did tillage and rotation interact with poultry litter applications to change soil chemical properties?

Results presented in Table 1 indicate that soil organic carbon (SOC) was affected by the interaction of tillage, N source, and depth ($P \leq 0.05$). Poultry litter application increased SOC within the first 2.4 inches of soil only under conservation tillage. Under conventional tillage, litter increased SOC only between 1.2 and 2.4 inches, as a result of litter incorporation by shallow disking. Calculated SOC mass (using SOC concentration and bulk density) to the 9.6-inch depth with poultry litter application under conservation tillage was 3486 lb/acre, compared to 1664 lb/acre under conventional tillage. This increase can be attributed to increased residues under conservation tillage and/or C from the litter being retained with conservation tillage compared to conventional tillage. Soil organic carbon was also affected by a rotation x poultry litter interaction ($P \leq 0.01$)(data not shown). The concentration of SOC increased with the corn rotation (12.6 g/kg) compared to soybean (10.5 g/kg) when poultry litter was used. This was probably associated with greater residue production under corn as well as the wider C:N ratio of corn residue compared to soybean.

Like SOC, pH was also affected by tillage, N source, and depth. A higher soil pH between 1.2 and 4.8 inches was maintained under conservation tillage with poultry litter compared to conservation tillage with NH_4NO_3 ($P \leq 0.05$). The same trend was observed between 4.8 and 9.6 inches. However, poultry litter had no effect on pH under conventional tillage where lime and poultry litter were incorporated together. Rotation had a large impact on soil pH due to fertilization of corn with 200 N lb/acre. Nitrification decreased pH an average of 0.6 units within 1.2 and 4.8 inches under conservation tillage with the corn system (data not shown).

Under conservation tillage, Ca concentrations were stratified, especially when litter was applied. Litter applications increased Ca concentration to the 4.8 inch depth under conservation tillage while under conventional tillage litter increased Ca concentrations only to the 2.4 inch depth. Calcium and K are the second most abundant plant nutrients in poultry litter. This, coupled with organic acid formation from decomposition of organic matter in crop residues and litter, offers an explanation for the increase in Ca deeper in the soil profile under conservation tillage compared to conventional tillage. Organic acids have been shown to complex bases and facilitate leaching of these elements.

Because SOC and pH exert a strong effect on other soil chemical properties, they can be used to estimate these properties using simple mathematical functions. These estimating functions are called continuous pedotransfer functions. In our study many soil properties were strongly related to SOC and/or pH. As expected, variation in SOC explained 98% of the total variation in total soil N (Table 2). Together with pH, SOC explained 82, 84, and 86 % of the variation in CEC, extractable Ca, and Mg, respectively. These results confirmed that the majority of negative charge for this soil came from organic matter and is pH dependent. Therefore, the increase in SOC and pH, as well as Ca and Mg present in the litter, provided an increase in Ca and Mg availability.

A great influence of SOC and pH on extractable micronutrients was also observed. Like Ca and Mg, B was strongly associated with SOC and pH, as was Mn (Table 2). In accord with other research, appreciable P accumulation (Mehlich I extractable) was observed with continued application of poultry litter, especially under conservation tillage. Stratification of extractable P in surface soil can increase the possibility of surface water contamination from runoff and erosion losses. However, increasing infiltration and soil coverage under conservation tillage might also diminish erosion and runoff and consequently decrease P contamination in surface water. This P increase as a result of litter application might also generate plant nutritional imbalances with micronutrients. However, our study showed that variations in extractable P were closely associated with extractable Zn and Cu. This should avoid possible imbalances among P and these nutrients. Likewise, a nutritional imbalance between Ca and B is unlikely as a linear relationship was observed between extractable Ca and B.

Our results confirm the importance of tillage, rotation, and source of N fertilizer as factors for changing soil properties. The majority of soil properties analyzed were affected by interaction effects of tillage and N source and some were also influenced by interactions with crop rotation. Phosphorus accumulation in the soil surface with litter under conservation tillage could increase risks of surface water contamination. Therefore, this needs more attention in future studies. Overall, the change in soil chemical properties provided by tillage, crop rotation, and litter were strongly related to SOC and pH. Thus, SOC and pH have an important role as basic soil quality indicators and are useful as continuous pedotransfer functions.

This paper was peer-reviewed and accepted. Since it was presented in the form of an interpretative summary, it was included here with other interpretative summaries.

Table 1. Soil organic C, pH, extractable Ca, and P from a long-term experiment with application of poultry litter under different tillage systems, averaged over rotations.

Depth	Conservation Tillage		Conservation Tillage		Conservation Tillage		Conservation Tillage	
	poultry litter	NH_4NO_3	poultry litter	NH_4NO_3	poultry litter	NH_4NO_3	poultry litter	NH_4NO_3
in.		C(%)				pH		
0 - 1.2	2.39 a†	2.07 b	11.6 a	11.1a	6.29 a	6.30 a	5.57 a	5.41 a
1.2 - 2.4	1.48 a	1.14 b	11.0 a	9.1b	5.91 a	5.57 b	5.99 a	6.00 a
2.4 - 4.8	0.95 a	0.95 a	9.2 a	7.5a	5.73 a	5.47 b	6.06 a	6.00 a
4.8 - 9.6	0.64 a	0.57 a	5.9 a	6.2a	5.82 a	5.58 a	6.00 a	5.90

Depth	Conservation Tillage		Conservation Tillage		Conservation Tillage		Conservation Tillage	
	poultry litter	NH_4NO_3	poultry litter	NH_4NO_3	poultry litter	NH_4NO_3	poultry litter	NH_4NO_3
in.		P(ppm)				Ca(ppm)		
0 - 1.2	154 a	51 b	61 a	31 b	1153 a	828 b	499 a	400 b
1.2 - 2.4	99 a	36 b	61 a	28 b	612 a	379 b	520 a	399 b
2.4 - 4.8	63 a	30 b	50 a	24 a	439 a	314 b	458 a	372 a
4.8 - 9.6	32 a	25 a	24 a	19 a	355 a	298 a	387 a	363 a

† Within a tillage and depth, N source means followed by the same letter in the row are not significantly different at the 0.05 level by LSD.

Table 2. Relationships among soil chemical properties from a long-term experiment with application of poultry litter under different tillage systems and rotations.

Dependent variable	Independent variable(s)	R^2
N	0.0019 + 0.036 C	0.97
CEC	- 7.78 + 2.02 C + 1.53 pH	0.82
Ca	- 1321.22 + 314.62 C + 251.09 pH	0.84
Mg	- 33.6 + 88.3 C + 61.4 pH	0.86
Mn	28.18 + 2.48 C - 4.64 pH + 3.17 CEC	0.72
Zn	- 1.43 + 3.44 C	0.55
B	-0.62 + 0.18 C + 0.12 pH	0.85
Zn	-0.73 + 0.061 P	0.80
Cu	0.004 + 0.019 P	0.69
B	0.045 + 0.00052 Ca	0.93