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Effects of tillage and broiler litter on crop productions in an eroded soil☆

Ardeshir Adeli[a,*], Seth M. Dabney[b], Haile Tewolde[a], Johnie N. Jenkins[a]

[a] United States Department of Agriculture, Agricultural Research Service, Genetics and Precision Agriculture Research Unit, Post Office Box 5367, Mississippi State, MS 39762 USA

[b] United States Department of Agriculture, Agricultural Research Service, National Sedimentation Laboratory, 598 McElroy Dr, Oxford, MS 38655, USA

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ABSTRACT

This study was initiated in 2005 at the Plant Material Center, NRCS, in Coffeeville MS, on an eroded Loring silt loam soil with 1–3% slope to determine the effects of broiler litter with tillage and cropping systems on improving soil quality and crop production. A randomized complete block design with three replications and split-plot arrangement of treatments was used. The main plots were tillage and no-till and the sub-plots were an unfertilized control, broiler litter at low (9 Mg ha^{-1}) and high (18 Mg ha^{-1}) rates. The cropping system was corn-wheat rotation. Broiler litter was applied as N source to corn (*Zea mays*) grown under no-tillage (NT) and conventional tillage (CT) in 2005 and 2007. Winter wheat (*Triticum* spp) was planted after harvesting corn and harvested for grain in June 2006 and 2008 in the same plots that previously received litter. Corn grain yield, grain N and P uptake were significantly increased with increasing broiler litter applications. Averaged across years, corn grain yield and N uptake were greater with conventional tillage (4014 and 63 kg ha^{-1}) than no-till corn (2608 and 42 kg ha^{-1}), respectively. Residual effect of broiler litter at the high rate significantly increased wheat grain yield and grain N uptake (1778 and 26 kg ha^{-1}) as compared to the control (901 and 14 kg ha^{-1}), respectively. Biennial application of broiler litter to an eroded soil enhanced corn- wheat productions, and improved soil quality by increasing soil C, water stable aggregate and infiltration and reducing soil penetration resistance.

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1. Introduction

Soils in the southeastern United States, where the climate is subtropical, are eroded from intense row crop agriculture and rainstorms during dormant season where crops are not present. many years ago. In this region, row crops have historically been conventionally tilled and supplemented with inorganic fertilizers. These agronomic practices have left the soil relatively compacted and infertile, low in pH and organic matter. Although these fields continue to be in production, the eroded conditions often have resulted in decreased agronomic productivity. Researchers have shown that crop yields are generally reduced by erosion (Frye et al., 1982). Soil erosion not only reduces corn grain but total biomass (stover) yields are also reduced, and it has been found that soil erosion delays crop emergence, reduces plant height, and decreases an uneven plant population (Olson et al., 1990; Schumacher et al., 1994). Application of organic amendment has been reported to improve soil aggregation, reduce bulk density, and increase soil water retention, mainly by an increase in organic matter content (Chaney et al., 1986a,b) and as a nutrient source has been found to alleviate the influence of topsoil and soil organic matter (SOM) loses due to erosion (Izaurralde et al., 2006; Larney et al., 2011; Larney and Angers, 2012).

Poultry litter (PL) is one of the most promising organic amendment sources due to its relative availability in the region and has been shown to increase soil organic matter, supply needed crop nutrients, and help offset losses in soil fertility (Edwards and Daniel, 1992). Georgia, Arkansas, Alabama and Mississippi are the top four states with the highest broiler production and associated manure generation. An estimated 25 million metric tons of poultry litter, which accounted for 48% of total litter in the U.S. was

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* Corresponding author.
E-mail address: ardeshir.adeli@ars.usda.gov (A. Adeli).

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Table 1
Initial chemical and physical properties of soil at 0–15 cm depth for eroded and uneroded soil having the same soil type at Plant Material Center in Coffeeville, NRCS, MS.

Eroded								Uneroded							
ρ_b (g cm^{-3})	pH	WSA (%)	PR (MPa)	TC	TN	P (mg kg^{-1})	C:N	ρ_b (g cm^{-3})	pH	WSA (%)	PR (MPa)	TC	TN	P (mg kg^{-1})	C:N
				gkg^{-1}								gkg^{-1}			
1.39	4.3	52	6.1	5.3	0.46	4.6	12	1.29	5.7	68	4.4	12.3	0.76	12.4	16
Texture (%) at 0–15 cm depth															
Sand		Silt			Clay			sand		Silt			Clay		
18.5		57.4			24.1			15.4		59.3			25.3		

ρ_b = bulkdensity WSA = waterstableaggregate TC = totalC TN = totalN PR=penetrationresistance.

generated in those four states (USDA, 2009). Over 10% of the nation's poultry supply was from Mississippi, which generated approximately five million metric tons of broiler litter annually. Broiler litter has been used as an effective alternate source of plant nutrient for agricultural production. The effect of broiler litter relative to inorganic fertilizer on cotton (*Gossypium hirsutum*) (Adeli et al., 2011; Tewolde et al., 2010; Tewolde et al., 2011), corn (Adeli et al., 2012; Tewolde et al., 2013), soybean (Glycine max L. Merr.) (Adeli et al., 2005; Adeli et al., 2015) hay field (Sistani et al., 2004) and pastures (Kingery et al., 1994) has been documented. Although the benefits of PL applications for agricultural production systems are apparent, little work has been conducted to determine the direct benefit of PL on crop production in eroded/degraded soils. Diacono and Montemurro (2010) reported application of poultry litter to a highly degraded soil increased crop yield by 250% when compared with inorganic fertilizer. The beneficial effects of poultry litter on crop yield in degraded soil could be related to soil quality characteristics. Poultry litter contains approximately 39% C, which has the potential to remediate eroded soils by increasing soil organic C and has been attributed to improved soil physical properties (Larney and Janzen, 1996). Kingery et al. (1994) reported long-term application of broiler litter to tall fescue resulted in greater soil organic C concentration at a depth of 0–15 cm. Sistani et al. (2004) reported application of 16 Mg ha^{-1} yr^{-1} broiler litter to bermudagrass (*Cynodon dactylon*) increased soil total C (TC) from 11.7 to 17.4 g kg^{-1}. Adeli et al. (2007) reported application of broiler litter to cotton grown under both no-till and conventional till systems increased microbial biomass C and soil aggregate stability as compared to inorganic N fertilizer. Whalen and Chang (2002) reported long-term manure applications increase soil organic C through the addition of plant residue as a result of an increase in crop biomass production. Gao and Chang (1996) reported long-term (18-yr) application of cattle feedlot manure increased surface soil (0–15 cm) cation exchange capacity, total organic C, and total N (TN). The beneficial effects of crop rotations and no-till system on soil physical (e.g. bulk density, water stable aggregate), chemical (e.g. organic C and total N), and biological (e.g. microbial biomass C and N) properties have been reported (Karlen et al., 1994; Karlen and Colvin, 1992). Reddy et al. (2006) reported organic matter content in soil surface (0–5 cm) was greater for cotton −corn rotation than continuous cotton. Adeli et al. (2007) reported changes in soil chemical and physical characteristics were less responsive to litter treatments applied to cotton grown under conventional tillage than no-till system. The effects of soil management and organic amendments on restoration of eroded soil have not been extensively studied in the southeastern region of the United States. A range of management practices (e.g. soil, crop and manure) should be considered in order to mitigate and reduce negative impact of eroded soil on crop production in such agroecosystems. We hypothesized that physical characteristics and related quality indicators of eroded soil are improved by integration of poultry manure with cropping system and conservation practices. The objectives of this study were to determine the effect of broiler litter with cropping system and soil management on crop production and soil chemical and physical properties in an eroded soil.

2. Materials and methods

Experiment was initiated in 2005 at Plant Material Center (33°58′240″N 89°40′38″W), NRCS, approximately 8 km Northwest of Coffeeville, MS. The soil series in the studied field is Loring silt loam (fine-silty, mixed, thermic, Glossic Fragiudalf) soil with 1–3% slope, with a AP horizon of moderate medium granular and friable structure. The soil had been under continuous no-till farming about 20 years. The surface soil of uneroded site was well structured and dominated with mid-sized aggregates. In contrast, the eroded site had noticeable looser structure with the dominance of small aggregates. The erosion was identified based on the thin topsoil above a red clay residuum (Bt horizon) compared to uneroded soil. To characterize the eroded condition of the soil at the experimental site, background soil samples were taken from both eroded and uneroded sites at depth of 0–15 cm before conducting the experiment and analyzed for physical, chemical and biological properties. Soil texture including silt, sand and clay content were determined (Gee and Bauder, 1986). Samples were air-dried, ground to pass through a 2-mm sieve and analyzed for pH and Mehlich 3 extractable P, Ca, Mg, Cu and Zn (Mehlich, 1984). Initial soil properties are shown in Table 1. Rainfall data were collected from a weather station located at the study site (Table 3). A split-plot design was used with three replications and experimental plots were maintained over a four-yr period. The main plot treatment (each a 6 × 12 m area) were chisel tillage and no-till. Conventional tillage consisted of primary tillage with a chisel plow 20- to 25-cm deep in the fall after harvest, and secondary tillage with a field cultivator before planting in the spring. Stale seedbed plantings was place in the spring behind field preparation in the fall.The sub-plot treatment was fertilization consisting of an unfertilized control, 9 Mg broiler litter ha^{-1} and 18

Table 2
Nutrient concentration and applied nutrient from broiler litter used in the study.

Year	pH	Total N	Total C	K	Ca	Mg	P	Zn
	Broiler litter nutrient concentration							
		g kg^{-1}						mg kg^{-1}
2005	7.2	32.4	338	29.1	24.4	8.0	17.1	624
2007	7.4	33.2	354	20.8	27.9	8.9	18.3	621
2005	Nutrient applied from broiler litter							
kg ha^{-1}								
9, Mg ha^{-1}		291	3042	262	217	71	152	5.6
18 Mg ha^{-1}		582	6084	524	436	142	306	11.2
2007								
9, Mg ha^{-1}		299	3182	187	248	79	163	5.5
18 Mg ha^{-1}		596	6372	374	499	159	328	11.1