Runoff losses of Nitrogen and Phosphorus from a No-till Cotton Field Fertilized with Broiler Litter

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Abstract

Broiler litter is rich in plant nutrients that increase cotton production, but surface application of broiler litter on no-till cotton allows nutrients to be transported from fields in surface runoff, while much of the ammonia-N volatilizes. Incorporation of broiler litter into the soil surface can reduce such problems, but has not been investigated for no-till cotton systems. A field experiment was conducted on an Atwood silt loam (fine-silty, mixed, thermic Typic Paleududalfs) soil at the Pontotoc Ridge-Flatwoods Branch Experiment Station in Pontotoc County, MS in 2004 to determine if surface incorporation of broiler litter applied to a no-till cotton influences the runoff loss of nutrients. The experimental design was a randomized complete block with 4 treatments replicated 3 times. Treatments included untreated control with and without surface incorporation and broiler litter applied at the rate of 8.2 Mg ha^{-1} with and without surface incorporation. Runoff volume increased by 30 % when litter was incorporated. Incorporation of broiler litter into soil surface decreased dissolved P and NH_4-N and increased NO_3-N concentrations of runoff water samples. Total suspended solids, total P and particulate P were greater for surface incorporation than non-incorporated treatments, indicating that greater soil loss resulted in greater amounts of particulate and total P being transported in runoff. Therefore, preliminary results suggest that incorporation of broiler litter into the soil surface of a no-till cotton field could be advantageous if erosion is controlled.

Introduction

Commercial broiler production in Mississippi generates 450, tons y^{-1} of broiler litter (manure and bedding material) which is applied to nearby pastures or cropland (Mississippi State University, 1998). Continuous applications of broiler litter to same land will increases the potential for enrichment of NO_3-N in groundwater and P in surface water (Edwards et al., 1992; Sharpley et al., 1996). To minimize these risks, producers must obtain additional land area to dilute the litter using N demanding crops and/or using alternative crops to receive broiler litter. The use of animal manure as fertilizer in row crop production have been encouraged. Substantial studies have been conducted to determine the effects of broiler litter on corn (*Zea mays* L.) (Brown et al., 1994; Wood et al., 1999) and cotton (*Gossypium hirsutum* L.) (Burmster et al., 1991; Glover and Vories, 1998; Malik and Reddy, 1999). Adoption of conservation tillage and use of poultry litter as an alternative source of fertilizer in cotton is increasing in the Southeastern USA. Manure application to no-till without surface incorporation may reduce its effectiveness as a nutrient source because of potential N loss (Eghball and Gilley, 1999). Surface application of broiler litter for no-till cotton productions may allow nutrients to be transported off the fields in runoff water, while much of the ammonia-N volatilizes. Elevated concentrations of nitrogen (N) and phosphorus (P) in surface runoff may degrade surface water quality. Phosphorus transported by surface runoff to streams and lakes often accelerates eutrophication, thus affecting the usage of water resources for many purposes such as drinking, fishing, and recreation (Foy and Withers, 1995). Water quality becomes a concern when using broiler litter as a nutrient source. Researchers have shown that broiler litter has increased nutrient levels and metals in surface runoff (Westerman et al., 1983; Edwards and Daniel, 1993; Woods et al., 1999), and may cause concern for surface water quality degradation. Muller et al. (1984) found that application of 8 Mg ha^{-1} (dry wt) dairy manure resulted in significantly greater dissolved and bioavailable P loss in no-till as compared to conventional till. Ammonium loss into surface waters can result in poisoning of aquatic organisms if the concentration is >2.5 mg L^{-1} (USEPA, 1986). Nitrate in runoff from fields receiving manure or fertilizer may be carried to rivers and lakes which may contribute to the hypoxia condition that is a zone depleted of oxygen and marine life. The water quality impact of these alternative cropping methods needs investigation. Findings by Vories et al. (1999) suggest nutrients from litter applied to cotton could be lost in runoff water particularly shortly after application when the incorporation is not effective. Incorporation of animal manure generally reduces the potential for P in runoff (Eghball and Gilley, 1999: Tabara, 2003). With no-till management of corn, dissolved P increased in the surface runoff (Bundy et al., 2001; Zhao et al., 2001). The magnitude of nutrient losses due to runoff under no-till or reduced-till cotton production system is not well documented. Incorporation of broiler litter into surface soil can reduce nutrient losses, but has not been used for row crops under a no-till cropping systems. The need exists for broiler litter management strategies that include surface incorporation techniques to minimize movement of nutrients off the field in runoff water. This study was conducted to determine the effects of surface incorporation of applied broiler litter to a no-till cotton field on nutrient losses in runoff.

Materials and Methods

Research was conducted on an Atwood silt loam (fine-silty, mixed, thermic Typic Paleududalfs) soil at the Pontotoc Ridge-Flatwoods Branch Experiment Station in Pontotoc County, MS in 2003 and continue until 2006. The experiment design for the study was a randomized complete block with a 2x2 factorial arrangement of treatments replicated three times. Treatments were broiler litter rate (0 and 8.2 Mg ha^{-1}) and application method (incorporation and non-incorporation). Before broiler litter application, soil samples were taken at the depth of 0-15 cm and analyzed for NH4-N and NO3-N (Keeney and Nelson, 1982), Mehlich 3P (Mehlich,1984), water soluble P, soil texture (Day, 1965), and soil pH. Broiler litter was also analyzed for nutrient concentrations. The results of chemical analyses of soil and broiler litter are shown in Table 1. Cotton was planted with 100 cm in row spacing on May 6, 2004 using a six-row 7340 MaxEmerge no-tillage vacuum planter. After cotton emergence, runoff micro plots were established. Individual runoff micro plot size was 120 by 130 cm with 10 cm hieght. Plots were established in 2004 using stain less steel. Runoff samples were collected in 5 gallon plastic container via a gutter equipped with a canopy to exclude direct input of rainfall. Runoff water samples were collected after each runoff producing rainfall event. The amount of rainfall and runoff volume was measured and recorded after each rain event. A 0.25-L aliquot of runoff water was collected from each plot in a plastic bottle, and frozen until analyzed.
Prior to chemical analyses, runoff water samples were filtered through a 0.45 μm filter. Nitrate-N and NH4-N concentrations were determined using aLachat (Zellwegger Analytics, Milwaukee, WI) system. Sediment from 50 mL of runoff water was collected on a 0.45 μm filter. The filter and sediment were dried to a constant weight and then weighed to determine suspended solids. To determine P on the sediment, the filter and sediment were then ashed in a muffle furnace at 450oC for 12 h followed by addition of 10 mL 1N HNO3 and heating at 200oC until dryness, and addition of 10 mL of 1.0 N HCl prior to ICP analysis for P (particulate P). Dissolved P concentration was determined using ICP. Non-filtered runoff samples were analyzed for total P (Johnson and Ulrich, 1959) , total N (Bremner, 1965) , K, Ca, Mg, Mn, Cu, and Zn

concentrations. Runoff water samples were used for measurement of pH and electrical conductivity. The General Linear Model (GLM) procedure in SAS (SAS Inst., 1987) was used to perform analysis of variance. All statistical tests were performed at a 0.05 level of significance.

Results and Discussions

Rainfall patterns were typical of the Southeast with most rain occurring early spring. Surface runoff water losses followed rainfall patterns in both incorporated and non-incorporated litter. Averaged across runoff events, runoff volume from incorporated plot was 38 % greater compared to not-incorporated treatment (Fig. 1).

Runoff concentrations of total N and NH_4-N were greater for non-incorporation of broiler litter versus incorporated broiler litter. The results of this study are in agreement with the findings of Eghball and Gilley (1999) who reported that surface application of manure without incorporation is further susceptible to runoff losses of NH_4 and P, especially when rainfall events occur soon after application. With non- incorporation of broiler litter, NH_4-N concentration in runoff water samples was greater than the critical 2.5 mg L^{-1}. Ammonium-N concentration >2.5 mg L^{-1} may be harmful to fish (USEPA, 1973). Ammonium is relatively immobile and generally followed the same trend as dissolved P. This can be attributed to the NH_4 content of broiler litter at the time of application (Table 1). However, NO_3-N concentration was significantly increased with incorporation of broiler litter into the soil surface. This could be due to an inherently high NO_3-N concentration in the untreated surface soil (Table 1) and incorporation of surface soil disturbed the soil and increased runoff loss of NO_3-N. Sharpley et al. (1985) found that the NO_3-N concentration of the top 0 to 5 cm soil did not have a significant effect on runoff NO_3 concentration but the 0 to 5 cm soil concentrations of dissolved P, particulate P and total N had significant effect on losses of these parameters. Nitrate concentration exceeded the 10 mg L^{-1} criterion recommended by the U.S. Environmental Protection Agency for primary drinking water supplies (U.S. Environmental Protection Agency, 1986).
Runoff concentration of dissolved P was greater for non-incorporated than the incorporated treatment (Tables 2 and 3). The concentration of dissolved P in runoff samples was <1mg L^{-1} for all treatments in the incorporated condition. However, the concentrations of total P and particulate P (sediment P) were greater for incorporated than not-incorporated treatments (Table 2 and 3) indicating that greater erosion from the incorporation of broiler litter into the soil surface resulted in more particulate and total P being carried by runoff. These results are in agreement with the work of Gilley and Eghball (1998) who found that total P and particulate P concentrations in runoff water was less for no-till than disked conditions. Regardless of surface soil management, the concentration of N and P for all runoff components were greater than untreated check plots. The trends for the load of nutrients in runoff were similar to those of concentration for all parameters. Dissolved P accounted for about 55% of the total P in runoff indicating the importance of dissolved P in water pollution. Runoff concentration of K, Ca, Mg, Mn, Cu and Zn decreased by approximately 28% when broiler litter was incorporated into the soil surface (Table 3).

Conclusion

Preliminary results from the first year of this study indicated that incorporation of broiler litter into the soil surface in a no-till cotton field increased runoff volume, total suspended solids, particulate P and total P concentrations reflecting greater soil loss. In contrast to P, runoff N

(NH4-N and total-N) concentration decreased with incorporation practice and NH4-N concentration was less than 2.5 mg L^{-1}, the critical runoff NH_4-N concentration for growth and reproduction of algae. Incorporation of broiler litter into the soil surface in a no-till cotton field could be agronomically and environmentally advantageous if erosion is controlled.

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Table 1. Selected properties of the soil and broiler litter used in the study at 0-15cm.

Parameter	Soil	Broiler litter
Dry matter, %	-----	87.6
pH	6.5	7.4
Mehlich 3 P, mg kg^{-1}	13.2	-----
Total N, g kg^{-1}	1.9	33.5
NH4-N, mg kg^{-1}	27.6	3552
NO3-N, mg kg^{-1}	52.4	1991
Carbon, g kg^{-1}	-----	308
Organic matter, g kg^{-1}	7.3	---
Texture	Silt loam	------
C to N ratio	-----	8

Table 2. Effect of surface incorporation on runoff N and P in a no-till cotton field fertilized with broiler litter averaged across runoff events.

Treatment	DP	PP	TP	NH4	NO3	TN	TSS
Control	------------------------------ mg L^{-1} -------------------- -------						g L^{-1}
Incorporated	0.43 b	0.66 b	1.14 c	0.52 c	4.8 c	4.5 c	1.31 a
Non-incorporated	0.48 b	0.25 c	0.66 d	0.85 c	3.0 d	5.5 c	1.00 b
Broiler litter							
Incorporated	0.56 b	1.86 a	3.96 a	2.2 b	10.0 b	12.1 a	0.66 c
Non-incorporated	1.48 a	1.00 b	2.24 b	4.1 a	6.0 a	15.0 b	0.25 d

DP = Dissolved Phosphorus
PP = Particulate Phosphorus
TP = Total Phosphorus
TN = Total Nitrogen
TSS = Total suspended solids

Table 3. Effect of surface incorporation on runoff K, Ca, Mg, Mn, Cu and Zn in a no-till cotton field fertilized with broiler litter

Treatment	K	Ca	Mg	Mn	Cu	Zn
Control	------------------------------		mg L^{-1} -------------------- -------			
Incorporated	2.9 b	3.2 c	3.7 c	0.49 b	0.20 a	0.33 b
Non-incorporated	2.3 b	2.5 c	3.2 c	0.63 b	0.20 a	0.35 b
Broiler litter						
Incorporated	2.2 b	6.6 b	6.6 b	0.38 b	0.25 a	0.34 b
Non-incorporated	5.4 a	10.0 a	8.0 a	1.24 a	0.34 a	1.23 a

DP = Dissolved Phosphorus
PP = Particulate Phosphorus
TP = Total Phosphorus
TN = Total Nitrogen

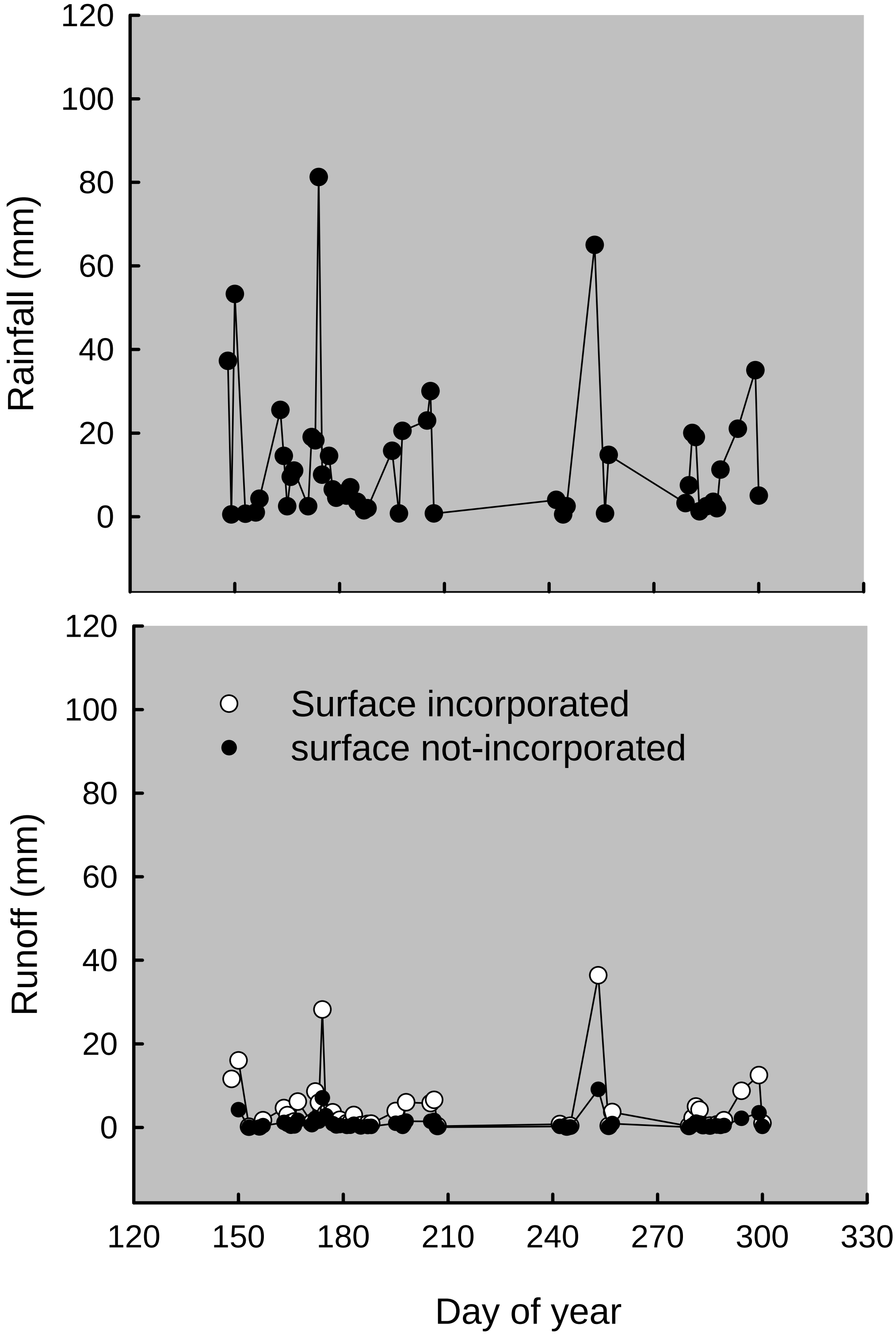

Fig. 1. Amount of rainfall and runoff volumes during the cotton growing season in 2004