Assessing the risks to water bodies from nitrogen vs. phosphorus-based broiler litter strategy

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The large amounts of poultry manure in localized areas and the high cost of implementing effective Best Management Practices (BMP's) often favor disposal rather than utilization of manure. Continual application of poultry manure at rates providing more N and P than removed by crops can increase soil N and P to levels that are of environmental rather than agronomic concern. Over application can enhance potential movement of N as NO3 to ground water and P in surface runoff. This study was conducted in 2007 at R.R. Foil Plant Science Research Center, Mississippi State University on a Mariate silt loam soil to investigate how N- vs. P-based poultry manure to perennial forage crops affects nitrate and P leaching from the crop root zones, N and P in surface runoff, crop removal and soil accumulation of the nutrients. An experimental field with bermudagrass has been established. Poultry manure was applied meeting the N or P requirement of Bermuda grass; fertilizer and control treatments serve as comparison purposes. Treatments replicated three times. Pen lysimeters were used to collect leachate for determining nitrate and P leaching losses. Runoff collection devices were installed for estimating runoff losses of N, soluble P and suspended solids. A rainfall simulator was used to simulate precipitation events and following each rain event, runoff and leachate samples were collected for nutrient analysis. Seasonal nitrate and P distributions in the soil profile will be monitored. Yield and nutrient utilization efficiency will be determined. This project will generate comprehensive and quantitative N and P data in both leachate and runoff when manure is applied at two contrasting rates to forage based system. Such data will provide much needed information for devising and effective decisions on how best to manage the vast amount of poultry manure nutrients for protecting waters while sustaining animal agriculture.

Keywords: Poultry manure, BMP's, Leachate, Runoff, Nitrate, Phosphorus

Introduction

Commercial broiler production in Mississippi generates approximately 500, 000 Mg broiler litter ha-1 which is mainly applied to nearby pastures or croplands as the most common method of disposal. Broiler litter contains significant concentration of N, P and K and is considered as an alternative source of fertilizer. Typically, broiler litter is about1.3 to 1.7% P on a dry weight basis with N:P ratios reported 2.3:1 by Baker et al. (1994). Since the N/P ratio in plant uptake is much greater than N/P ratio in broiler litter, repeated application of broiler litter based on N needs of the crop leads to the over-application of P to the soil and may result in accumulation of P(Adeli et al., 2007; Torbert et al., 2005). Accumulation of P in soils from broiler litter applications has been reported for soils used for forage (Sharpley et al., 1993; Kingery et al., 1994; Franzluebbers et al., 2004). Accumulation of P in surface soils raises concerns about losses in runoff and eutrophication of streams and water bodies contributing to water quality decline (Moore et al., 1995; Sharpley et al., 1994). Eutrophication can impair water use for drinking, recreation, habitat, and industrial use by producing algal blooms and reducing dissolved oxygen content of the water (Dougherty et al., 2004). With proper management practices, broiler litter can be a valuable source of nutrients for crop production with minimal or no adverse environmental impacts. Application of broiler litter based on P needs of the crop is being practiced recently. Therefore, our objective was to determine if broiler litter management would reduce the potential for excessive accumulation of soil P and runoff N and P concentrations.

Materials and Methods

This study was conducted at Plant Science Center (South farm), Mississippi State University, on Mariatta silt loan (fine-loamy, siliceous, active, thermic Fluvaquentic Eutrudepts) soil in which bermudagrass already established. Soil was slightly acidic having a pH of 5.4. Soil test P level at the 0-15 cm depth using Mississippi Soil Testing Laboratory before initiation of the experiment was 55 mg P kg-1 which is greater than agronomic minimum response level of 50 mg P kg-1. Therefore, no P was applied to the control or inorganic fertilizer treatments during the experiment. The experimental design was a randomized complete block with four treatments replicated 3 times. Treatments included: (i) Control, receiving no N or P input; (ii) inorganic fertilizer N and P supplied by chemical fertilizer at the recommended rate for bermudagrss; (iii)N-based broiler litter, broiler litter applied to meet crop N uptake requirements; (iv)P-based broiler liter, broiler litter applied to supply crop P uptake requirements with the shortfall in N met using ammonium nitrate. Plot size was 14 ft by 7 ft. Runoff collectors were installed at the bottom of each plot. Runoff collector was build to collect 1/10 or 1/100 of total runoff volume in each plot.

Broiler litter was broadcast to individual plot at the rate of 9 Mg ha-1 for the N-based and 2.2 Mg ha-1 for the P-based treatments. Five days after broiler litter application, rainfall was generated by applying artificial rainfall using TeeJet1/2HHSS 50 WSQ nozzle (Spraying System Co., Wheaton, IL) placed approximately 10 ft above the soil surface. Rainfall was delivered at an average intensity of 27 mm h-1 and continued for approximately 5 min after initiation of runoff. Rainfall-runoff simulations were performed at 0, 7, 21, 42, 72 and 132 days after broiler litter application. Runoff was collected for each rain event and the volume was recorded. Unfiltered runoff samples were acid digested and analyzed for total N and P (Bremner, 1996). A 25-ml aliquot was centrifuged and filtered for NO3-N, NH4-N and dissoled P. Bermudagrass was harvested after each rain and dry weight yield was recorded. Forage samples were ground to pass 2 mm sieve. Total N and C contents were determined using C/N analyzer. Bermudagrass samples were also dry-ashed and total P in the plant samples was determined using ICP. Soil samples were taken at the end of growing season. Soil samples were extracted using both Mehlich 3 and KCL. Soil P and N concentrations were determined using ICP and Lachat systems.

Data were were subjected to analysis of variance for a randomized block design. Analysis of variance conducted using SAS (1998). All statistical tests performed at the 0.05 level of significance.

Results and Discussion

Dry matter yield and N and P uptake

Dry matter yields for all treatments were greater than the control. Dry matter yield for the N-based was similar to that for P based treatment. However, N-based treatment resulted in greater dry matter yield than the fertilizer treatment but no significant difference in dry matter production was obtained between P-based and fertilizer treatments. This indicates that broiler litter applied to supply the crop P requirements with additional N fertilizer can provide added nutrients to bermudagrass, similar to fertilizer application, with added the benefits of organic matter and micronutrients addition to the soil.

For broiler litter applications, N uptake by bermudagrss paralleled dry matter yield and no significant differences in N uptake was obtained between N-based and P-based treatments. However, fertilizer N application resulted in greater total N uptake than did the broiler litter treatments (Table 1). This reflects the inadequate amount of available N applied from broiler litter treatment as compared to inorganic fertilizer. Apparent N recovery was 88% for inorganic fertilizer, 55% for N-based treatment and 74% for P-based treatment. Although there was no significant differences in N uptake between N-based and P based treatments but N use efficiency was 26% greater for P-based treatment than N-based treatments. Phosphorus-based broiler litter application resulted in greater P uptake and P use efficiency than N-based treatment (Table 1). This is because smaller amounts of P were applied with P-based than with N-based application, indicating greater P use efficiency for lower P application rate (Eghball and Sander, 1989).

Nitrate and P losses in runoff

Application of broiler litter and inorganic fertilizer resulted in greater N and P losses in runoff the control (Table 2). Nitrogen-based litter application had greater total P, dissolved P and total N in runoff than the P-based broiler litter application (Table 2). However, no significant different in both P and N in runoff were observed between P-based broiler litter application and inorganic fertilizer treatments. Nitrate-N concentrations were 2.7, 10.1, 8.2 and 10.7 mg L-1 for the control, inorganic fertilizer, N-based and P-based broiler litter application respectively. The reason for the higher runoff NO3-N concentration in the P-based broiler litter application than N-based treatment can be explained that more N became available in the P-based broiler litter treatment, in which half of the N inputs broiler litter treatment was as inorganic N fertilizer, 100 of 191kg N ha-1) than in the N-based treatment which had much of the N in slowly mineralized organic forms.

Soil Phosphorus

Soil P concentration at the top 15 cm for all treatments were greater than those for the control plots (Fig. 1). This is because of removal of soil P by bermudagrass from the control plots, which did not receive P. Soil P concentrations at the top 15 cm were 20, 22, 34, and 69 mg kg-1 for the control, inorganic fertilizer, P-based and N-based treatments, respectively, indicating P accumulated at the soil surface when broiler litter applied to the bernudagrass based on N needs of the crop. Broiler litter application to provide for plant P requirements, with additional N as fertilizer, resulted in significantly lower soil P levels than the N-based broiler litter application

Conclusion

Phosphorus-based broiler litter application, was agronomically and environmentally advantageous as evidenced by similar bermudagrass dry matter production and resulted in greater P uptake or P use efficiency which avoided soil P accumulation. The concentration of P in runoff for P-based broiler litter treatment was lower than N-based treatment. Phosphorus based broiler litter application reduces the P transport to the surface water bodies.

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Table 1. Effects of broiler litter fertility regimes on bermudagrass dry matter yield, N uptake and P uptake.

Treatments	DMY	N input	N uptake	P input	P uptake
	$Mg\ ha^{-1}$	---------------------- $kg\ ha^{-1}$ ----------------------			
Control	3.2 c	0	60 c	0	10 d
Recommended fertilizer	7.8 b	220	254 a	0	22 c
N-based	10.5 a	280	215 b	171	33 b
P-based + N fertilizer	9.1 ab	191	203 b	47	41 a
$LSD_{(0.05)}$	1.5	----	23.1	----	3.6

Table 2. Effects of broiler litter fertility regimes on runoff nutrient concentrations.

Treatments	Total P	Dissolved P	Total N	NO3-N
- mg L^{-1} -				
Control	1.3d	1.1c	3.1c	2.7 d
Recommended fertilizer	2.4 c	2.2 b	9.8 b	10.1 a
N-based	7.0 a	5.4 a	12.1 a	8.2 b
P-based + N fertilizer	3.2 b	2.3 b	7.5 b	10.3 a
$LSD_{(0.05)}$	0.36	0.29	2.4	0.67

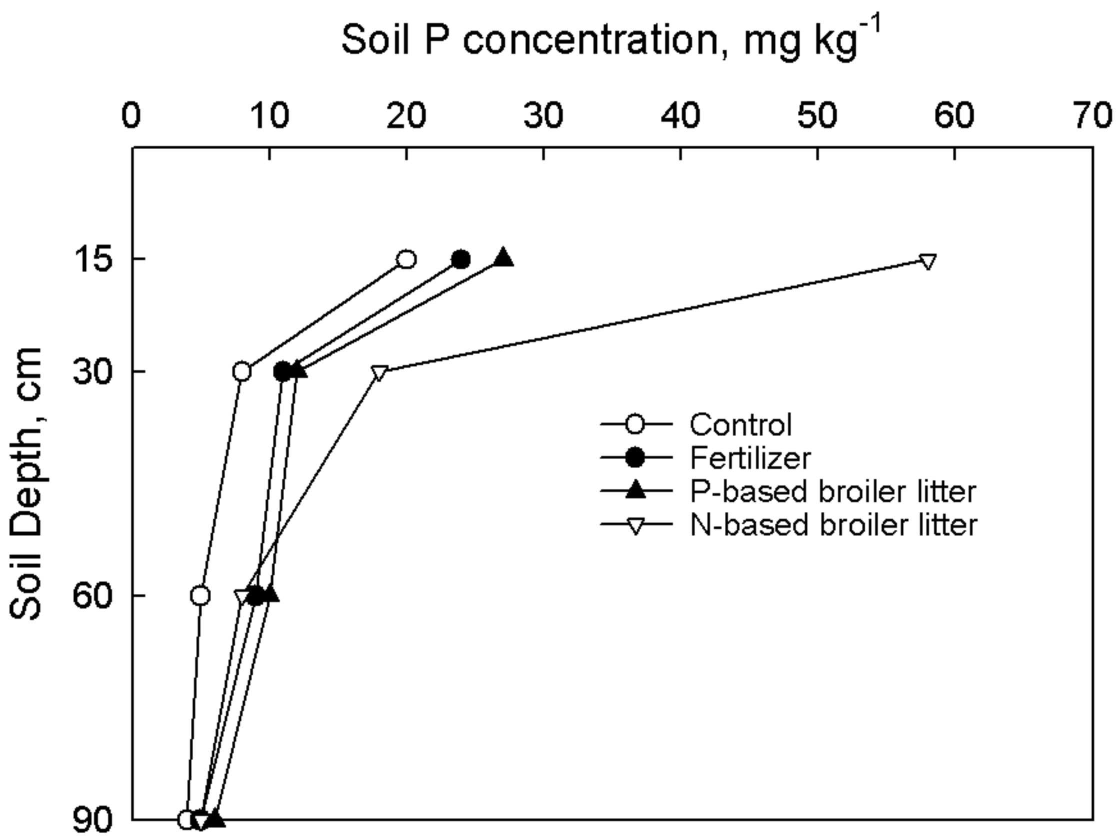

Fig. 1. Effects of broiler litter management on soil P concentration.