COMPARISON OF ANNUAL AND MULTI-YEAR N-BASED AND P-BASED MANURE APPLICATIONS

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ABSTRACT

This 4-yr study (2000-2003) compares beef manure application strategies in their impact on soil and plant nutrient concentrations and nutrient runoff and leaching. The treatments were a fertilizer control, annual N-based manure application, N-based applied every other year, annual P-based, P-based applied every other year, and P-based applied once every four years. By the third year of the study, soil test P levels in the soil surface reflected the amount of P_2O_5 applied either as manure or fertilizer, but there was no significant treatment effect below 30 cm. Corn earleaf P concentration also followed the pattern of increasing with P application rate. However, soil NO_3-N did not reflect application rates in a similar manner, and soil NH_4-N was not significantly impacted by treatment at any depth. On the other hand, nutrient concentrations in runoff in year four were directly related to the amount of nutrient applied during the previous 4-yr period. The annual N-based manure application treatment had significantly higher soluble P in runoff than the annual P-based manure application rate; however, there was no difference in runoff P concentrations between the annual and 4-yr P-based manure application treatments.

INTRODUCTION

The U.S. Environmental Protection Agency released a new Concentrated Animal Feeding Operation regulation in 2003. The new regulation requires that each field that receives manure be evaluated using a risk assessment tool to determine the extent of risk of P loss from the field (Davis, 2003). If the P runoff risk is low, then manure can be applied at N-based agronomic rates. Nitrogen-based manure application rates have been shown to lead to soil P buildup. If the P runoff risk is high, then manure must either be applied at P-based agronomic rates or not be applied at all.

In addition, the new regulation allows for multi-year P applications on fields that do not have a high potential for P runoff to surface water. A multi-year approach allows a single manure application to meet several years of a P requirement as long as the manure application rate does not exceed the N-based agronomic rate during the year of application. The multi-year allowance came into place due to practical limitations of manure spreading equipment, but its impacts on water quality remain largely unknown.

MATERIALS AND METHODS

This 4-yr study (2000-2003) compares manure application strategies in their impact on soil and plant nutrient concentrations and nutrient runoff and leaching. The strategies are all based on soil testing either to meet N or P requirements of the crop. Treatments were annual N-based, N-based applied every other year to meet two years of crop N requirement, annual P-based, P-based applied every other year to meet two years of crop P requirement, and P-based applied every four years to meet four years of crop P requirement. The 2-yr P application rate was lower than the 1-yr N-based agronomic rate, but the 4-yr P application rate was higher than the 1-yr N-based rate. Beef manure from a local feedlot was used, and manure was fall applied with immediate incorporation. A control that received fertilizer only (based on soil testing) was included; fertilizer was applied pre-plant based on P needs and at sidedress to meet remaining crop N requirements. Fertilizer applications were also made to supplement manure applications in order to assure that nutrient requirements were met. The manure application strategies used resulted in a wide range of manure, N and P_2O_5 applications (Table 1).

Table 1. Total manure, N, and P_2O_5 applied to each treatment from 1999-2003.

Treatment	Manure Applied --tons/acre--	N Applied --lbs/acre--	P_2O_5 Applied --lbs/acre
Control	0	320	240
Annual N-based	48	1120	1164
2-yr N-based	60	1380	1440
Annual P-based	17	656	418
2-yr P-based	18	720	432
4-yr P-based	24	722	576

Each plot was 20 ft x 40 ft in size, and treatments were replicated four times in a randomized complete block design. Continuous corn was grown under a line-source irrigation system using conventional tillage. The research site was located in northern Colorado at the Colorado State University Agricultural Research Development and Education Center north of Fort Collins.

Every fall after harvest and before manure application, soil was sampled to 120 cm depth in 30 cm increments. Three probes were made per plot and composited for analysis at the deeper depths, and nine total cores were composited from the 0-30 cm depth increment. Samples were air-dried, ground to pass a 2 mm sieve, and analyzed for NO_3-N and NH_4-N concentration following KCl extraction and for available P following $NaHCO_3$ extraction (Olsen).

Plant samples were taken annually at two different growth stages. Whole plants were collected from 0.5 m length of row at V6 (6-leaf stage), and 30 ear leaves were collected and composited per plot at tasseling. Plant samples were washed with distilled water, oven dried, and ground prior to digestion for total N and P content.

Runoff, erosion, and nutrient losses were measured from the control, annual N-based, annual P-based, and 4-yr P-based treatments in 2000 and 2003. In 2000, duplicate 6 m^2 (2-m wide by 3-m long) plots were used, and in 2003 triplicate 3 m^2 plots (1.5-m wide by 2-m long) were used. Plots were exposed to 1 h of simulated rainfall (50 mm h^{-1} in 2000 and 70 mm h^{-1} in 2003). Each plot had similar slopes (~1%). Rainfall was applied with an oscillating nozzle (80100 Veejet nozzles) rainfall simulator in 2000 (Foster et al., 1982) and with a single nozzle (TeeJet^{TM} ½HH-SS50WSQ) rainfall simulator based on the design of Miller (1987) in 2003. Deep well water was used in all simulations. Runoff and erosion were measured continuously at 5-min intervals during each simulated rainfall event. Runoff and erosion were determined gravimetrically, and infiltration was calculated by difference (rainfall minus runoff). Total N and P were analyzed by digestion of unfiltered runoff samples (Pierzynski, 2000). Runoff samples were filtered through 45 micron filters and analyzed for NO_3-N, NH_4-N, and dissolved inorganic P (DIP) colorimetrically. Total dissolved P (TDP) was measured in filtered samples using an ICP.

RESULTS AND DISCUSSION

Soil test P levels had significant treatment effects in the 0-30 cm depth increment in every year of this study. In general, the fertilizer control had the lowest soil test P levels, and the 2-yr N-based rate and 4-yr P-based rates had the highest soil test P levels. However, the 4-yr P-based rate was only significantly higher than the P-based annual rate in soil test P in the first year of the study (immediately following the 4-yr dosage); there was no significant difference in subsequent years. On the other hand, the annual N-based and P-based rates didn't result in significantly different soil test P levels until the third year of the study. Soil test P in the third year reflected the same trend as the P_2O_5 application (Table 1). There were no significant differences in soil test P below the 30 cm depth.

Soil NO_3-N concentrations showed significant treatment effects in the 30-60 cm depth increment in year 1 and in the 0-30 cm depth increment in year 2. However, in the third year significant differences were evident from 0-90 cm. The fertilizer control had the lowest soil NO_3-N concentrations, and the annual P-based manure application treatment had the highest NO_3-N concentrations from 0-90 cm. Soil ammonium concentrations showed no significant treatment differences except for one depth in one year.

Manuring increased earleaf P concentrations as compared to the fertilizer control (Table 2). In general, the N-based application rates resulted in higher leaf P concentrations than the P-based rates. However, the same trends did not hold true for N or P in the whole plant samples taken at V6 or for N in earleaves.

Table 2. Corn earleaf P concentrations (%) as a function of treatment.

Treatment	2000	2001	2002
Control	0.21 D	0.23 C	0.27 B
Annual N-based	0.25 BC	0.27 A	0.32 A
2-yr N-based	0.27 A	0.26 A	0.32 A
Annual P-based	0.24 C	0.25 BC	0.30 A
2-yr P-based	0.24 BC	0.25 BC	0.30 A
4-yr P-based	0.26 AB	0.26 AB	0.31 A

A, B, C, D Treatments with a common letter are not significantly different by Least Significant Differences ($p<0.05$).

Nutrient concentrations in runoff in 2003 (yr 4) reflected differences in total nutrient applications over the 4-yr period (Table 3). The annual N-based treatment had significantly higher soluble P (TDP and DIP) concentrations in runoff than the other treatments, and it received over twice the P_2O_5 than the other treatments evaluated over the 4-yr period (Table 1). The control had significantly less Total N in runoff than the other treatments, and it received less than half the amount of N applied than the other treatments. The patterns in the runoff data from 2000 do not follow the application amounts as closely, probably due to the delay in N and P mineralization combined with the immediate release of fertilizer nutrients in the control treatment.

Table 3. Nutrient concentrations (mg/L) in runoff by treatment in 2003.

Treatment	NH_4-N	NO_3-N	TDP	DIP	Total P	Total N
Control	0.23	0.35	0.04 B	0.03 B	3.22	4.41 B
Annual N-based	0.13	0.25	0.16 A	0.12 A	3.55	6.21 A
Annual P-based	0.11	0.20	0.04 B	0.03 B	2.90	7.61 A
4-yr P-based	0.15	0.25	0.04 B	0.02 B	3.46	7.51 A

A, B Treatments with a common letter are not significantly different by Least Significant Differences ($p<0.05$).

CONCLUSION

In conclusion, during the first two years of this study, treatment effects were not clearly related to nutrient application amounts. However, by the end of the 4-yr cycle, soil test P, earleaf P, and soluble P in runoff concentrations closely reflected the total amount of P_2O_5 applied during the previous 4-yr period. Nitrogen revealed some similar trends, but did not follow application rates as closely.

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