DAIRY DIET PHOSPHORUS EFFECTS ON PHOSPHORUS LOSSES IN RUNOFF FROM LAND-APPLIED MANURE

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ABSTRACT

Phosphorus (P) losses from land-applied manure can contribute to nonpoint source pollution of surface waters. Dietary P levels influence P concentrations in animal manures and may affect P losses from land-applied manure. The objective of this study was to determine the effects of dairy diet P concentration on P losses in runoff from land-applied manure. Manures with P concentrations of 0.48 and 1.28 % P from two dietary P levels were applied to a silt loam soil 25 wet ton/a (36 and 96 lb P/a, respectively). The high P manure was also applied at 9.4 wet ton/a (36 lb P/a) to provide an equivalent P rate as the low P manure. Plots were subjected to simulated rainfall (2.83 in/hr) in June and again in October. Runoff was analyzed for dissolved reactive P (DRP), bioavailable P, total P, and sediment concentration. Natural runoff from the same plots was collected from November through May and analyzed for P as described above. At equivalent manure rates, DRP in June runoff from the high P manure was about 10 times higher (0.30 vs. 2.84 ppm) than the low P manure, and 4 times higher (0.30 vs. 1.18 ppm) when applied at equivalent P rates. Phosphorus concentrations in October runoff and November – May natural runoff were lower (0.02 – 1.69 ppm), but treatment effects were the same as for June runoff. These results show that excess P in dairy diets increases the potential for P loss in runoff from land-applied manure. Furthermore, diet P effects on potential losses in runoff from land-applied manure should be considered in P-indexing and nutrient management planning.

INTRODUCTION

Phosphorus (P) loss in runoff from cropland is an environmental concern because this P often promotes weed and algae growth in lakes and streams. When these weeds and algae die and decompose, dissolved oxygen levels in lakes and streams are depleted, which can lead to odors, fish kills, and a general degradation of the aesthetic and recreational value of the environment (Sharpley et al., 1994; Daniel et al., 1994; Carpenter et al., 1998).

Phosphorus in land-applied manure is one of the major sources contributing to soil P accumulation in Wisconsin, and there is increasing evidence that the amount of P in manure could be substantially reduced by avoiding excess P supplementation of dairy rations (Ternouth, 1989; Morse et al., 1992; Khorasani et al., 1997; Metcalf et al., 1996). Phosphorus excretion in manure depends largely on the level of P intake (Ternouth, 1989; Morse et al., 1992b; Khorasani et al., 1997; Metcalf et al., 1996). If this P

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supplementation could be reduced to the minimum concentrations needed for production, the amount of P in manure and in land applications to farmland would also decrease.

The objective of this study was to determine dairy diet effects on the amounts and forms of P in manure as well as on P losses in runoff from land-applied manure.

MATERIALS AND METHODS

Dairy diet P effects on P losses in runoff in no-till corn were determined in a field experiment at the Univ. of Wisconsin Agricultural Research Station, Arlington, WI (43^{o}17'N, 89^{o}22'E). The four treatments were: control (no manure); low P diet manure (0.48% P) and high P diet manure (1.28% P) applied at 25 wet ton/a to provide 36 and 96 lb P/a respectively (LPD-25 and HPD-25); and high P diet manure applied at 9.4 wet ton/a to provide the same P addition (36 lb P/a) as the 25 wet ton/acre of the low P manure (HPD-9.4). These treatments were hand applied in spring 1999 to a Ringwood silt loam soil (fine-loamy, mixed, mesic, Typic Arguidols) in 8 ft square plots. The experimental site was not tilled in 1999 and had corn residue from the previous year's corn crop remaining on the surface. Simulated rain applications were performed in June, 1999, immediately following manure application and again on the same plots after harvest in October, 1999. Subsamples of the runoff were obtained for sediment, dissolved reactive P (DRP), and bio-available P (BAP), and total P (TP) determinations.

Natural runoff collectors (D. Côté, personal communication) were installed in all replications of the control and 25 wet ton/acre low P diet and high P diet manure treatments in early November 1999. Runoff samples were collected within two days of each runoff event, total volumes were recorded, and a subsample analyzed for DRP.

The manures were collected from dairy cattle involved in a P feeding study. The low P diet group was fed no supplemental P, while the high P diet group had monosodium phosphate added to the low P diet, resulting in dietary P content of 0.32 and 0.48% respectively (Wu et al., 2000). These dietary P levels produced manures with P concentrations of 0.48 and 1.28% P, respectively. Samples of manure from each diet were analyzed for total P (TP), deionized water – extractable P (DI), bio-available P (BAP), and dry matter (DM). See Table 1.

Corn (Zea mays L.) was planted on all plots in the experiment following the June rainfall simulation. Six plants within each plot frame were cut near the base at physiological maturity and weighed, chopped, and subsampled to determine plant dry matter yield and nutrient uptake (Schulte et al., 1987).

Soil samples for antecedent moisture and soil P determinations were collected from field plots in both June and October. Soil P tests included Bray P-1 (Frank et al., 1998), Mehlich III (Mehlich, 1984), distilled water extraction (Pote et al., 1996), P saturation percentage (Pote, et al., 1996) and the iron oxide paper strip method (Sharpley, 1993). Phosphorus in the extracts obtained by each method was determined colorimetrically by the molybdenum-blue method (Murphy and Riley, 1962).

An analysis of variance was performed for treatment effects on antecedent soil moisture, surface residue, runoff amount, DRP, BAP, and TP concentrations and loads in runoff, and plant P concentration, dry matter yield, and P uptake using PROC ANOVA (SAS Institute, 1992). Significant differences among treatment means were evaluated using a protected least significant difference (LSD) test at the 0.05 probability level.

RESULTS

Simulated Rainfall

Both of the high P diet manure treatments (HPD-25 and HPD-9.4) increased DRP concentration in runoff relative to the control and the low P diet manure treatment (LPD-25), and runoff DRP concentration in the HPD-25 treatment was nearly ten times higher than with the LPD-25 (applied at the same manure rate (Figure 1)). When the manures were applied at equivalent P rates, DRP concentration in runoff from the high P diet manure (HPD-9.4) was about four times higher than from the low P diet manure (LPD-25). Manure treatment effects on runoff BAP concentrations and loads were not significant, but showed a trend toward higher BAP values with the high P manure treatments. Total P concentrations and loads in runoff from the HPD-25 treatment were significantly higher than the other manure treatments and the control.

Results from the October simulated rainfall application (Figure 2) showed that the high P diet treatment (HPD-25) had significantly higher DRP concentrations in runoff than the other treatments, and DRP concentration from the HPD-25 treatment was about 4 times higher than the LPD-25 (applied at the same manure rate). Manure treatment effects on BAP concentration in runoff were not significant in June but were significant in October. The HPD-25 treatment was almost 3 times higher in BAP concentration than the LPD-25 (applied at the same manure rate). In October, TP concentrations and loads followed opposite trends from those found in June. Although not significantly different, TP concentrations tended to be higher in the control and HPD-9.4 treatments which had lower residue cover. This trend occurs because TP includes sediment bound P as well as dissolved P and the control lost more sediment in runoff than the manured treatments.

Natural Runoff

Natural runoff data in Figure 3 support the simulated rainfall results in that DRP load from the high P diet manure is consistently higher than the low P diet manure and control. Individual rainfall events did not always cause significant differences in DRP concentration and load, showing the variability of the data. However the cumulative DRP loads consistently show significant treatment effects. Since both simulated rainfall and natural runoff show the same trends, we can be confident in our results.

Soil P Measurements

The mean soil test P values for the experimental area (Table 2) indicate a relatively low initial soil P status. For example, P additions would be recommended for production of most crops at the initial Bray P-1 soil test level (Kelling et al., 1998). The October soil test P results show that the manure treatments generally increased soil test P values at the 0-1 in depth. When the high P and low P diet manures were applied at the same manure rate (HPD-25 and LPD-25), Bray P-1 increased over 2 fold in the high P treatment. When the high P diet manure was applied at the same P rate as the low P diet manure (HPD-9.4 and LPD-25), Bray P-1 in the soil was not significantly different. We found the same trends for DI, M3, and BAP tests which showed a two to three fold increase in the HPD-25 treatment compared to the LPD-25 and HPD-9.4 treatments. Although not significant at the 0.05 level, the P-SAT and AOX-P values followed the same trends as the previous tests.

Corn Yield and P Uptake

Corn dry matter yields (Table 3) were increased (Pr>F=0.08) by the manure treatments. This response is consistent with the low initial soil P level at the experimental site. Corn plant analysis results showed that P concentrations and uptake were influenced by the P additions in the manure treatments. These responses are attributed to P, because a uniform nitrogen addition was made to all treatments. As shown in Table 3, plant P uptake in the manure treatments was significantly greater than in the control, and plant P concentration followed a similar trend with manured treatments having higher P concentrations than the control. In contrast to the runoff P data, corn yields and plant P uptake and concentration did not differ among the high and low P manure treatments even when the manures were applied at equivalent P rates. This suggests that the lowest P rate added in manure was adequate to maximize dry matter yield and plant P concentration.

SUMMARY

Results from this study indicate that when manures from dairy cows fed different concentrations of P are land-applied, the high P diet manure will release more P in runoff than the low P diet manure, in both simulated rainfall and natural runoff. In June, DRP concentrations were almost 10 times higher (0.30 vs. 2.84 ppm) when manures were applied at the same manure rate, and 4 times higher (0.30 vs. 1.18 ppm) when applied at equivalent P rates. In October the same comparisons showed that at equivalent manure rates DRP concentrations were almost 4 times higher (0.21 vs. 0.89 ppm) in the high P diet treatments and the same (0.21 ppm) when applied at equivalent P rates. This data emphasizes the need to avoid excess P supplementation of dairy cattle feed because of its implications for P additions to surface runoff and the effects on water quality. These findings indicate that P in diets should be considered when applying the P-index and when implementing nutrient management plans.

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