Soil Phosphatase Activity and Foliar Uptake of Phosphorus As Influenced by Nitrogen Fertilization Regime in a Grazed Pasture System

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Abstract 357-13

Abstract

Efficiency of P utilization from P-enriched soils may be enhanced by management practices that facilitate phytoextraction of P, and increasing activity of soil phosphatase may be an effective method for increasing P bioavailability. In October 2010, six 0.28-ha plots characterized by high soil-test P were overseeded with triticale (*Triticum secale*) and crimson clover (*Trifolium incarnatum*) into a tall fescue (*Lolium arundinacea*)/bermudagrass (*Cynodon dactylon*) sod and assigned randomly to 1 of 3 treatments (n = 2): 100% of N recommendation for tall fescue in a split-application, 50% of N recommendation, and 0% of N recommendation. In February 2011, 6 cattle (339 ± 11 kg) were randomly assigned to plots (1 animal/plot) for grazing until May; soil (0 – 20 cm) and forage samples were taken from each pasture prior to grazing by cattle. In June, plots were overseeded with cowpea (*Vigna unguiculata*) and maintained on the same N-fertilizer regimes, based on N recommendation for bermudagrass. In August, 6 cattle (361 ± 23 kg) were randomly assigned to plots (1 animal/plot) for grazing until September, at which time another set of soil and forage samples was taken. There were no differences among treatments for acid (P > 0.417) or base phosphatase (P > 0.225). Cool-season acid and base phosphatase activities were lower (9.0 and 12.5 µg *p*NP/g/h, respectively) than warm-season (22.2 and 24.3 µg *p*NP/g/h, respectively) (P = 0.034 and P = 0.045, respectively). Forage DM availability (P = 0.002) and uptake of P (P = 0.01) were greater for cool- than warm-season forage (4,441 vs. 2,311 kg/ha and 8.44 vs. 5.30 kg P/ha, respectively), but were not different among N-fertilizer treatments. Results indicate that growing season and grazing of seasonally adapted forage species greatly affected soil phosphatase activity, but these were not affected by manipulation of N fertilization regime.

Introduction

Accumulation of nutrients in soil potentially restricts its productivity and land-use options available to resource managers. Phytoextraction of P-enriched soils is not an especially new concept, and hay-cropping of forages such as bermudagrass and tall fescue have been used for many years to effectively reduce P concentrations in soils. However, phytoextraction of nutrient-enriched soils with haying systems limits the types of other agricultural practices (e.g., grazing, row crops, etc.) that might be used on these lands. In this regard, information on P phytoextraction approaches that incorporate livestock grazing is lacking. According to Williams and Haynes (1990), 70% of P that is ingested by cattle is excreted and returned back to the soil in feces; also, 88-90% of total P in livestock manure is in the inorganic form and readily plant-available (Sharpley and Moyer, 2000). Due to elevated nutrient concentrations in areas of grazed pasture receiving excreta, overall pasture growth is encouraged, and growth within the affected areas can account for up to 70% of the total pasture forage growth (Saunders, 1984).

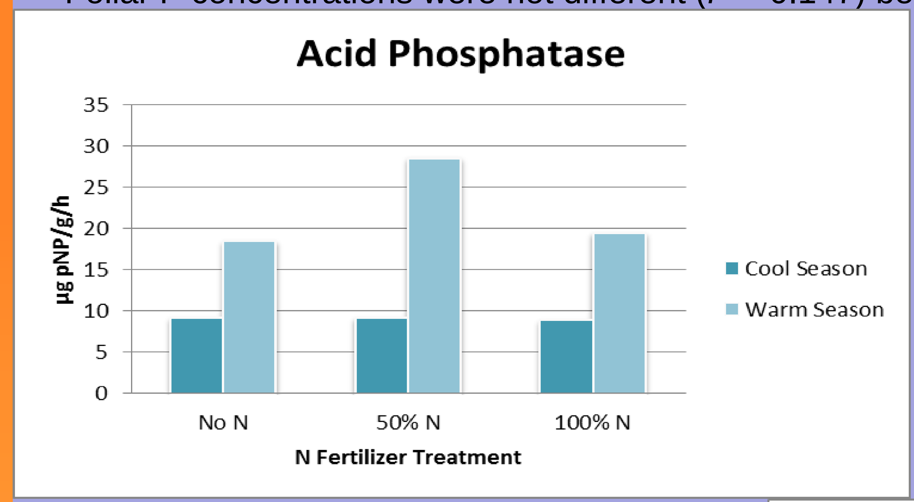
Legumes have been used for centuries in row-crop rotations and as mixtures in pasture crops because of their ability to fix N. Legumes are high in concentration of protein, which makes them a good forage crop for livestock. Also, the N/P ratio of nutrient uptake in legumes is more similar to that of animal manures than in grasses, which may help reduce soil P concentrations to the extent that legumes are able to utilize more P per unit of applied N. Overall efficiency of P utilization may be increased by implementation of management practices that facilitate phytoextraction of P from P-enriched soils, including N- fertilization practices and use of grass-legume mixtures. Whether such practices may alter P bioavailability in part as a result of modified activity of soil microbial phosphatase has not been determined. For this reasons, an experiment was conducted to determine the effect of different N-fertilization regimes on acid and base soil phosphatase activity in plots with grazing cattle and high soil-test P.

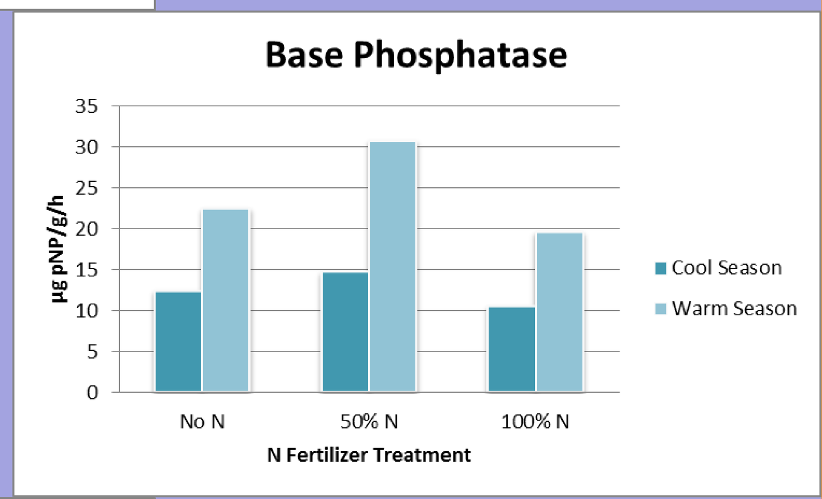
Materials & Methods

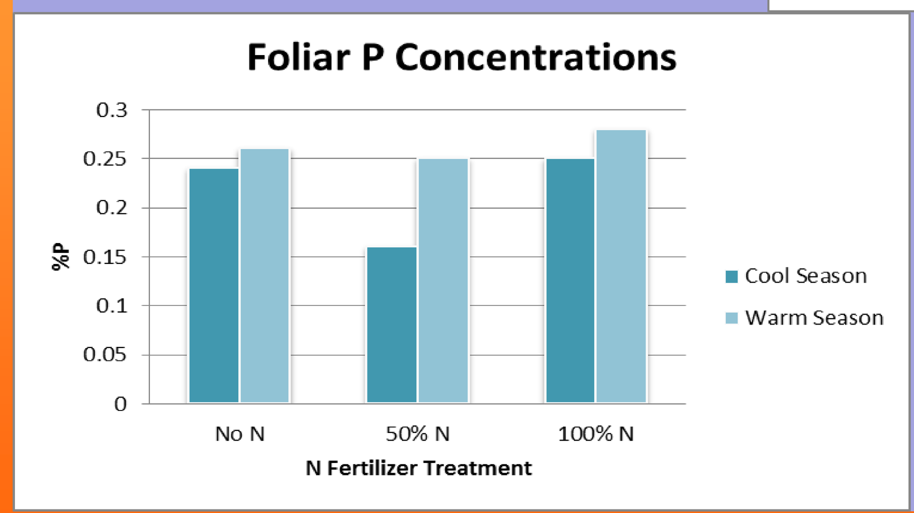
In October 2010, 6 0.28-ha plots were over seeded with triticale (*Triticum secale*) and crimson clover (*Trifolium incarnatum*) into a tall fescue (*Lolium arundinacea*)/bermudagrass (*Cynodon dactylon*) sod and assigned randomly to 1 of 3 treatments (n = 2): 100% of N recommendation for tall fescue in a split application (100N), 50% of N recommendation (50N), and 0% of N recommendation (0N). In February 2011, 6 beef cattle (339 ± 11 kg; 4 steers, 2 heifers) were randomly assigned to graze in the plots (1 animal/plot) until May; prior to grazing, soil samples were taken from each pasture. In June, plots were over seeded with cowpea (*Vigna unguiculata*) and maintained on the same N-fertilizer regimes, based on N recommendation for bermudagrass. In August, 6 steers (361 ± 23 kg) were randomly assigned to graze in the plots (1 steer/plot) until September. After cattle removal in September, 2011, another set of soil samples were taken in the pastures. Soil samples were analyzed for both acid and base soil phosphatase. Forage samples were also taken on the same dates, and forages were analyzed for concentrations of select macro- and micro-nutrients.

Results

- There were no significant differences (P > 0.417) among N-fertilization treatments for acid phosphatase activity.
- There were no significant differences (P > 0.225) among N-fertilization treatments for base phosphatase activity.
- There was a treatment × season interaction such that acid phosphatase in the 50% N treatment was lower (P = 00590) in the cool (9.2 µg pNP/g/h) than the warm-season (28.6 µg pNP/g/h).
- There was a treatment × season interaction such that base phosphatase in the 50% N treatment was lower (P = 0.0935) in the cool (14.7 µg pNP/g/h) than the warm-season (30.8 µg pNP/g/h).
- However, cool-season acid and base phosphatase activities were lower (9.0 and 12.5 µg pNP/g/h, respectively) than corresponding warm-season phosphatase activities (22.2 and 24.3 µg pNP/g/h, respectively (P = 0.034 and P = 0.045, respectively).
- Foliar P concentrations were not different (P > 0.126) among N-fertilization treatments.
- Foliar P concentrations were not different (P = 0.147) between grazing seasons.







Discussion

Values for both acid and alkaline soil phosphatase activity were lower than those reported elsewhere in the literature. Mandal et al. (2007) reported acid phosphatase activity of 20.8 µg PNP/g/h and alkaline phosphatase activity of 180.9 µg PNP/g/h, which are considerably greater than those reported in the current study. However, the soil was treated with 100% of N-P-K requirements for a wheat crop using cattle manure over 34 years in their study. Additionally, Parham et al. (2002) reported that acid phosphatase (0 – 10 cm soil depth) was 320 mg PNP/kg/h in January and 220 mg PNP/kg/h in November when cattle manure had been applied long-term (100+ years) to a winter wheat plot. However, both of these experiments involved land application of cattle manure and not actual grazing of cattle on plots. Jordan et al. (2003) reported that acid phosphatase activity was significantly reduced when soil was compacted via cattle movement; however, alkaline phosphatase activity was not affected.
Büyükburç and Karadağ (2002) reported that a 50% triticale-hairy vetch mixture could produce up to 9,590 kg DM/ha per season. Brown (2006) reported a foliar P concentration in triticale of 0.31%, and Brink et al. (2002) reported a value of 0.30% for crimson clover. Cassman et al. (1981) reported that cowpea contained up to 0.22% P, and Brink et al. (2003) reported that bermudagrass contained 0.57% P. Values for cool-season forages in the present study compare favorably with previous research; however, bermudagrass uptake of P was lower than previously reported levels, which may have been due to limitation of N fertilizer applied to forages in the current study. Foliar P concentrations were not different among N-fertilizer treatments. Coblentz et al. (2004) reported that foliar concentrations of P in bermudagrass were decreased linearly with increasing N fertilization. The authors also reported that, at N-fertilization levels of 112 kg N/ha and greater, foliar P concentrations were unchanged or decreased to levels below that of 56 kg N/ha application rate.

Summary & Conclusions

- N-fertilizer treatment did not affect either acid or base soil phosphatase activity.
- However, seasonal differences were observed in both acid and base phosphatase activity.
- Foliar P concentration was not different among N-fertilization treatments or between grazing seasons.
- Results indicate that growing season and grazing of seasonally adapted forage species greatly affected soil phosphatase activity, but these were not affected by manipulation of N fertilization regime.

Literature Cited

Brink, G.B., D.E. Rowe, K.R. Sistani, and A. Adeli. 2003. Bermudagrass cultivar response to swine effluent application. Journal of Agronomy. 95: 597–601.
Brink, G.B., G.A. Pederson, K.R. Sistani and T.W. Fairbrother. 2002. Uptake of selected nutrients by temperate grasses and legumes. Agronomy Journal. 93:887-890.
Brown, B.D. 2006. Winter cereal-corn double crop forage production and phosphorus removal. Soil Science Society of America Journal. 70:1951-1956.
Büyükburç, U. and Y. Karadağ. 2002. The amount of NO_3-N^- transferred to soil by legumes, forage and seed yield, and the forage quality of annual legume + triticale mixtures. Turkish Journal of Agriculture. 26:281-288.
Cassman, K.G., A.S. Whitney and R.L. Fox. 1981. Phosphorus requirements of soybean and cowpea as affected by mode of N nutrition. Agronomy Journal. 78: 17-22.
Coblentz, W.K., M.B. Daniels, J.L. Gunsaulis, J.E. Turner, D.A. Scarbrough, J.B. Humphry, K.P. Coffey, P.A. Moore Jr., K.A. Teague, and J.D. Speight. 2004. Effects of nitrogen fertilization on phosphorus uptake in bermudagrass forage grown on high soil-test phosphorus sites. The Professional Animal Scientist 20:146-154.
Mandal, A., A.K. Patra, D. Sing, A. Swarup, R.E. Masto. 2007. Effect of long-term application of manure and fertilizer on biological and biochemical activities in soil during crop development stages. Bioresource Technology 98: 3585-3592.
Parham, J.A., S.P. Deng, W.R. Raun, G.V. Johnson. 2002. Long-term cattle manure application in soil I. Effect on soil phosphorus levels, microbial biomass C, and dehydrogenase and phosphatase activities. Biology and Fertility of Soils 35:328-337.
Pederson, G.A., G.E. Brink and T.E. Fairbrother. 2002. Nutrient uptake in plant parts of sixteen forages fertilized with poultry litter: nitrogen, phosphorus, potassium, copper and zinc. Agronomy Journal 94:895-904.
Saunders, W.M.H. 1984. Mineral composition of oil and pasture from areas of grazed paddocks, affected and unaffected by dung and urine. New Zealand Journal of Agriculture Research 27:405-412.
Sharpley, A. and B. Moyer. 2000. Phosphorus forms in manure and compost and their release during simulated rainfall. Journal of Environmental Quality 29:1462-1469.
Williams, P.H. and R.J. Haynes. 1990. Influence of improved pastures and grazing animals on nutrient cycling within New Zealand soils. New Zealand Journal of Ecology 14:49-57.