The Effect of Long-Term Application of P Fertilizer on Soil Grown Forage Plants

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Abstract

Phosphorus (P) fertilization does not always increase crop yields but the repeated use of P may modify the biological properties of soils. The objective of the present study, therefore, was to investigate the effect of long term applications of P fertilizer on soil biological properties. We used an experimental site located in Swift Current in which different amounts of P (0, 20 and 40 kg P_2O_5 ha^{-1}) were applied annually for the past 8 years on alfalfa and alfalfa-Russian wild rye hay crops. Our hypothesis was that repeated application of P influences soil microbial biomass and various soil enzymes. Microbial biomass C in the 0-7.5 cm soil layer was determined by fumigation-extraction at each of three harvest dates, and dehydrogenase, acid phosphatase and urease activities were assayed. Application of P to soil increased soil available P, dissolved organic C and available NO_3-N, but did not significantly affect crop yields or soil microbial biomass C. Arbuscular mycorrhizal colonization of crop roots, and dehydrogenase and urease activities were decreased, suggesting that P reduced soil microbial activity. Acid phosphatase activity remained unchanged with P fertilization, suggesting that P availability was not limiting in these systems. While 8 years of application of P had little effect on hay yields, it generally reduced the activity of the soil microbial biomass.

Introduction

Phosphorus is added to soil to maintain soil fertility, optimum plant growth and to enhance crop productivity. To make the P available for plants throughout the cropping season, more of synthetic fertilizers are being added to soil, but the repeated use of these synthetic fertilizers may influence the biological properties of the soil. Soil microorganisms are responsible for mineralization of organic P. The constant use of P fertilizers may influence the soil microbial community and soil biological processes. Various studies have emphasized on the environmental factors in relation to microbial growth, numbers, biomass and respiration (Wynn-Williams, 1982; Bolter, 1992; Bolter et

al., 1997) but little emphasis has been put to the impact of long-term P application on soil microbial processes. We demonstrated the impact of 8 years of application of P on crop yield and enzyme activities of soil grown under forage plants.

Method

Experimental design

The experiment was conducted on a Brown Chernozem (loamy clay) located at the South Farm of the Semiarid Prairie Agricultural Research Centre in Swift Current Saskatchewan, Canada. Different amounts of P (0, 20 and 40 kg P_2O_5 ha^{-1}) were applied annually for the past 8 years on alfalfa and alfalfa-Russian wild rye hay crops. Anion exchange members (AEM) were inserted in soil in spring and were replaced three times during the entire season. Plant samples were analysed for mycorrhizal colonization and dry matter yield whereas soil samples (0-7.5 cm) were subjected to enzyme (dehydrogenase, phosphatase and urease) assays and microbial biomass carbon. Table 1 gives the information on the methods used for different soil and plant parameters.

Table1. Methods used for various soil and plant analyses

Analysis	Sample	Evaluation	Method
Anion exchange membranes	Soil	N and P	Modified from Ziadi et al; 1999
Root colonization	Root	Percent root colonization by AMF	Staining (Vierheilig et al, 1998); Grid intersect method (McGonigle et al, 1990)
Plant P	Plant	Nutrient uptake from soil	Digestion of tissue on autoanalyser (Thomas et al; 1967)
Dehydrogenase	Soil	Microbial activity	Casida et al; 1964
Phosphatase	Soil	Enzyme activity	Tabatabai & Bremner, 1969
Urease	Soil	Enzyme activity	Modified at SPARC

Results and Discussions

Soil P as determined by phosphate flux measurements was significantly enhanced by P application and was highest at 40 kg P_2O_5 ha^{-1} indicating increase in soil available P with increase in P fertilization (data not shown). Application of P to forage crops did not significantly effect dry matter yield (DMY) of alfalfa mono crop but it significantly increased DMY of plant mixture at 40 kg P_2O_5 ha^{-1} (Fig. 1). The reason for lower DMY for plant mixture as compared to mono culture at 0 and 20 kg P_2O_5 ha^{-1} could not be well understood but the increase in DMY in plant mixture at 40 kg P_2O_5 ha^{-1} could be associated with arbuscular mycorrhizal colonization (AMF) suggesting less carbon (C)

drain from plants to AMF and hence more C was available for plant to contribute to DMY.

Arbuscular mycorrhizal fungal colonization was recorded using grid intersection method and AMF colonization decreased with increase in P fertilization (Fig. 2). The decrease was significant from 0 to 20 kg P_2O_5 ha^{-1} but no significant differences were observed thereafter suggesting that higher levels of P decrease root-mycorrhizal symbiosis. These observations are in conformity with many reports indicating negative impact of P fertilization on AMF colonization.

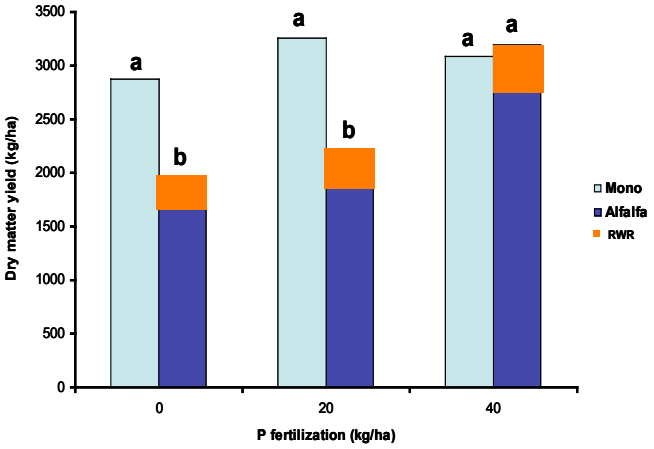

Figure 1. Effect of P fertilization on dry matter yield of mono and mixed cropping

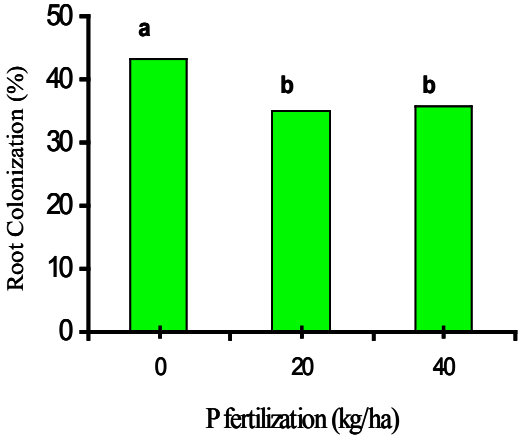

Figure2. Effect of P fertilization on Arbuscular mycorrhizal fungi

Microbial biomass C (MBC) and dehydrogenase, acid phosphatase and urease activities were assayed to study the impact of P treatments on biological processes. No significant difference in MBC was observed with P treatments (data not shown), instead there was more of dissolved organic C (data not shown) at 40 kg P_2O_5 ha^{-1}. These observations suggest the negative effect of 40 P fertilization rate on soil microbial activity. Dehydrogenase activity (Table 2), indicative of biological oxidation processes of soil microorganisms (Nanniperi 1994) decreased significantly at 40 kg P_2O_5 ha^{-1} as compared to 0 and 20 kg P_2O_5 ha^{-1} suggesting decrease in microbial community with P fertilization.A similar trend was observed for urease activity. Urease activity was not affected from 0 to 20 kg P_2O_5 ha^{-1} but thereafter declined significantly at 40 kg P_2O_5 ha^{-1} further suggesting that high P level decrease microbial activity. On the other hand phosphatase activity did not show any significant change with P treatments indicating that P shortage was not the reason for yield decline at 0 kg P_2O_5 ha^{-1}.

P Fertilization $kgha^{-1}$	Phosphatase (ug PNP/g/h)	Dehydrogenase (ug/TPF/day)	Urease (ug/g/2hr)
0	61.46^a	88.03^a	11.51^a
20	55.65^a	83.97^a	11.13^a
40	57.85^a	69.79^b	9.96^b

Significant at 0.05 level of significance

Table 2. Effect of P fertilization on soil enzyme activity

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