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Soil Phosphorus Fractions After Long-Term Fertilizer Placement in Different Kansas Soils

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Abstract

Phosphorus (P) fertilizer placement can affect the long-term dynamics and forms of P, and the overall soil P pools. These changes can vary by soil type, and affect P uptake and use efficiency by crops. The objective of this study was to evaluate the changes in the labile P fractions in three Kansas soil types under P fertilizer placements (broadcast versus deep band) after ten years of crop rotation. Three field studies were conducted at Scandia, Ottawa, and Manhattan. Three treatments were evaluated: 1) a control with no P fertilizer application and two fertilizer treatments (80 lb P_2O_5/a); 2) surface broadcast; and 3) deep band at approximately 4–6 in. depth. All treatments received strip-tillage. After ten years, soil samples were collected from the row, and between the row at two sampling depths (0–3 and 3–6 inches) and soil P pools (inorganic and organic P labile) were measured. Significant changes in soil labile P pools for treatments compared to control were observed due to the long-term effect of P fertilizer placement. The broadcast P fertilizer placement increased the total labile (Pt_{LP}) and inorganic labile P (Pi_{LP}) in the soil surface (0–3 in.) and deep band in the subsoil (3–6 in.) at all sites studied. However, the highest amount of organic labile P (Po_{LP}) was observed for the control broadcast treatments in the subsoil (3–6 in.) at the Scandia site. The total labile P was affected by maximum P adsorption capacity (MPAC) and P fertilizer placement.

Keywords

Soil fertility, phosphorus, fertilizer, corn, soybean

Soil Phosphorus Fractions After Long-Term Fertilizer Placement in Different Kansas Soils

M.J.A. Coelho and D.A. Ruiz Diaz

Summary

Phosphorus (P) fertilizer placement can affect the long-term dynamics and forms of P, and the overall soil P pools. These changes can vary by soil type, and affect P uptake and use efficiency by crops. The objective of this study was to evaluate the changes in the labile P fractions in three Kansas soil types under P fertilizer placements (broadcast versus deep band) after ten years of crop rotation. Three field studies were conducted at Scandia, Ottawa, and Manhattan. Three treatments were evaluated: 1) a control with no P fertilizer application and two fertilizer treatments (80 lb P_2O_5/a); 2) surface broadcast; and 3) deep band at approximately 4–6 in. depth. All treatments received strip-tillage. After ten years, soil samples were collected from the row, and between the row at two sampling depths (0–3 and 3–6 inches) and soil P pools (inorganic and organic P labile) were measured. Significant changes in soil labile P pools for treatments compared to control were observed due to the long-term effect of P fertilizer placement. The broadcast P fertilizer placement increased the total labile (Pt_{LP}) and inorganic labile P (Pi_{LP}) in the soil surface (0–3 in.) and deep band in the subsoil (3–6 in.) at all sites studied. However, the highest amount of organic labile P (Po_{LP}) was observed for the control broadcast treatments in the subsoil (3–6 in.) at the Scandia site. The total labile P was affected by maximum P adsorption capacity (MPAC) and P fertilizer placement.

Introduction

Fixation of plant nutrients by soils is a major concern for economical use efficiency of fertilizer. Phosphorus (P) from fertilizer can become "fixed" in some soils due to conversions into compounds of limited bioavailability for plant uptake (Coelho et al., 2019; Preston et al., 2019). Phosphorus in the soil exists in inorganic (Pi) as well as organic (Po) forms of comparable solubility, and the soil fixation of all these forms depends upon many factors (organic matter content, pH, clay types, soil maximum P adsorption capacity, and fertilizer placement). Thus, efficient P management in crop production is needed to minimize depletion of soil P reserves, environmental issues due to the waste from the higher rates, and production costs. Fertilizer P placement can affect crop P utilization in the short-term during the growing season. However, the long-term interactions of placement and plant root uptake in different soils can also affect the forms of P and the overall soil P pools, especially the residual labile P concentration at various soil depths and soil-plant interactions (Adee et al., 2016). The objective of this study was to evaluate the changes in the labile P fractions in three Kansas soils under different P fertilizer placements (broadcast versus deep band) after ten years of crop rotation.

Procedures

Field experiments were conducted at the Kansas State University research and extension centers located in Scandia, Ottawa, and Manhattan. Initial soil samples were collected in April 2006 before initiating the study by collecting a representative sample from the 0–3 and 3–6 inch layers for the characterization of soil properties of the experimental areas (Table 1). A strip-tillage operation was performed before planting corn, while soybean was planted into the corn residue with no prior tillage. Strip-tillage was used for all plots, including the control, which received no P fertilizer application. Deep-band P fertilizer application was completed with the strip-tillage operation at 30-in. row spacing and made in the same row location for ten years. Corn and soybean were planted in the center of the strip in the same row each year. The phosphorus fertilizer source for the broadcast treatment was triple superphosphate (0-45-0). The P fertilizer source for deep banding was ammonium polyphosphate (10-34-0). Treatments included a control with no P application and two treatments of 80 lb of P_2O_5/a as a broadcast or deep band. After the last crop harvest for each experiment in 2015, soil samples were collected from 0–3 and 3–6 inches depths from the row. Soil P fractions were determined by the sequential P fractionation method (Condron et al., 1985). All statistical analyses were completed in SAS Studio (version 9.3; SAS, Institute, Inc, Cary, NC). The GLIMMIX procedure was used for the analysis of variance (ANOVA).

Results

After the ten year period, significant changes in soil P labile pools for treatments compared to the control with interaction between the two factors (treatments and soil depths) were observed due to the long-term effect of P fertilizer placement across locations.

Inorganic Phosphorus Pool

Overall, the amount Pi_{LP} showed a higher amount in the soil surface (0–3 in.) for the broadcast treatment compared to the deep band and control treatments across locations (Figure 1 D, E, and F). However, the higher amount of Pi_{LP} in the 3–6 in. soil layer was observed for deep band treatment. These results suggested that P fertilizer placement for broadcast in the soil surface and deep band for subsoil may contribute to the saturation of adsorption P sites in the soil under reduced tillage with minimal soil disturbance over ten years. Since the adsorption sites are gradually saturated, the binding energy of P solubilized later is weakly adsorbed and consequently increases P availability (Rheinheimer et al., 2003).

Organic Phosphorus Pool

The P fertilizer placement affected the amount of Po_{LP} at Scandia, with no significant effects for Ottawa and Manhattan sites (Figure 1, A, B and C). The highest proportion of Po_{LP} was observed for the control and broadcast treatments at the subsoil (3–6 in.). Also, our results showed that treatments with the largest amount of Pi_{LP} showed the smallest amount of Po_{LP}, broadcast in the soil surface, and deep band in the subsoil, respectively. The Pi and Po pools act in a similar way in buffering the P absorbed by plants in soils with low or no addition of P fertilizers (Coelho et al., 2019). The Po pool is considered as the main supply of P for plant uptake when no fertilizer is added to the soil, which may explain the results found in this study.

Total Labile P Pool

In general, the Pt_{LP} showed the same tendency as Pi with higher amount in the soil surface (0–3 in.) for the broadcast and in the 3–6 in. soil layer for deep band (Figure 1, G, H, and I). In addition, preliminary results of this study suggested that the Pt_{LP} in the soil profile (0–6 in.) showed different tendencies across locations (Figure 2) and was affected by maximum P adsorption capacity (MPAC). The broadcast treatment showed a higher amount of Pt_{LP} (118 ppm) than deep band (112 ppm) and control (84 ppm) treatments at Scandia site with low MPAC (288 ppm). However, at the Ottawa location with medium MPAD (348 ppm) the higher amount of Pt_{LP} was observed for deep band (126 ppm) than broadcast (119 ppm) and control (86 ppm) treatments. In addition, at the Manhattan site with the higher MPAC (424 ppm) of this study the broadcast and deep band treatments showed the same or greater than the amount of Pt_{LP} (174 ppm) for the control treatment (84 ppm). The maximum P adsorption capacity of these soils plus the P placement may have affected these results. With lower MPAC the continuum application of P as broadcasted in a reduced tillage may have contributed to reducing large P sorption reactions and contributed to increasing labile P concentrations near the soil surface (Coelho et al., 2019; Hansel et al., 2017). In addition, the soil with a medium amount of P fixing components, when P fertilizer is deep banded in the row with lower soil volume and minimum disturbance of the soil, can contribute to reducing the high P sorption reactions, and that may have contributed to increasing the labile P levels. However, in the soil with higher P sorption reactions the effect of P fertilizer placement as broadcast and deep band on TotP are the same in soil profile after 10 years of crop rotations, or maybe the ten years of P application were not enough to saturate the adsorption P sites of the soil.

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Table 1. Initial soil parameters for three experimental sites at three Kansas soils

Site	pH	TON	TOC	K	Ca	Mg	Na	CEC	Clay	Silt	Sand	MPAC
		-------- % --------		-------------- ppm --------------				$cmol_c\ kg^{-1}$	----------- % -----------			ppm
0–3 in.												0–6 in.
Scandia	6.5	0.18	0.20	586	2159	371	31	17	21	59	20	288
Ottawa	5.5	0.18	0.20	311	2003	347	12	24	32	50	18	348
Manhattan	5.7	0.21	0.23	131	2124	377	15	22	26	60	14	424
3–6 in.												
Scandia	6.5	0.16	0.14	452	2443	426	45	21	29	55	16	
Ottawa	5.5	0.12	0.13	192	2309	407	14	26	36	48	16	
Manhattan	5.2	0.19	0.18	109	2275	344	27	27	32	58	10	

TON = total organic nitrogen. TOC = total organic carbon. K = potassium. Ca = calcium. Mg = magnesium. Na = sodium. CEC = cation exchange capacity. MPAC = maximum phosphorus adsorption capacity.

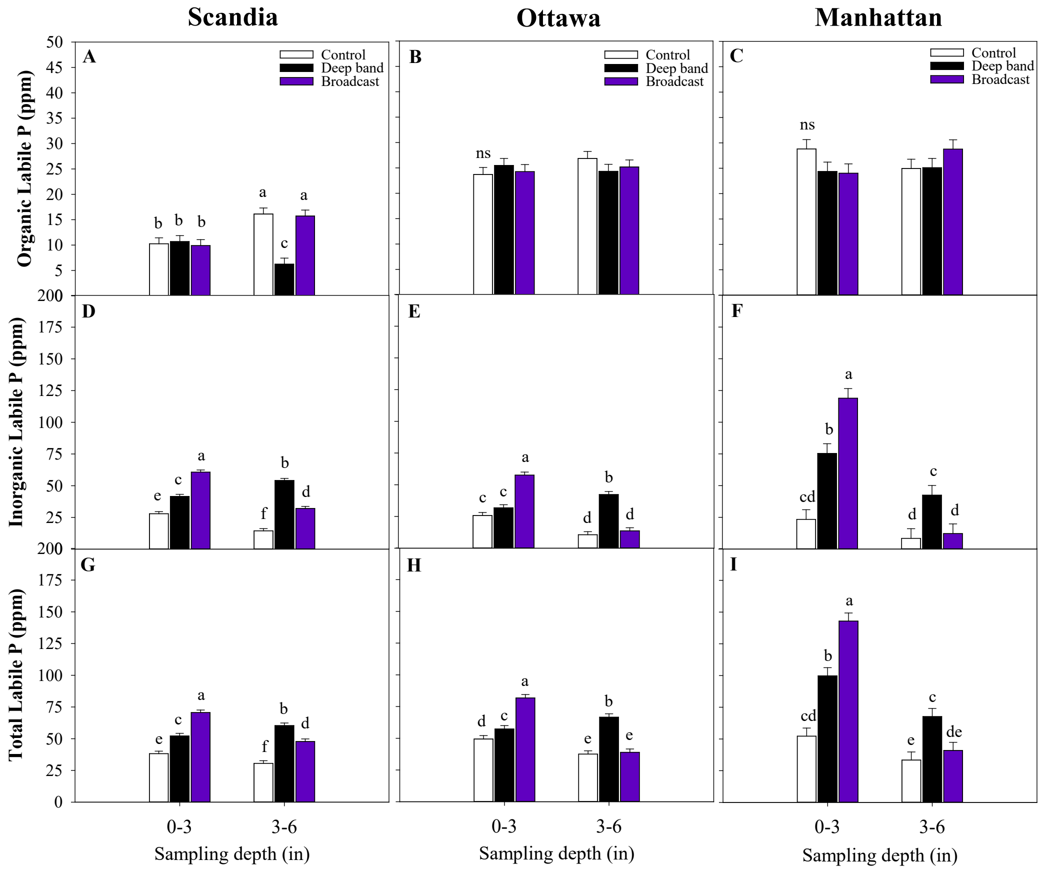

Figure 1. Labile phosphorus (P) pool: organic - Po_{LP} (A, B, C); inorganic - Pi_{LP} (D, E, F); and total - Pt_{LP} (G, H, I) for two soil sampling depths for three locations: Scandia, Ottawa, and Manhattan, respectively, as affected by P fertilizer treatments (deep-band, broadcast, and control) after 10 years of a corn-soybean rotation for Scandia and Ottawa and, corn-soybean-wheat rotation for Manhattan. Error bars indicate the standard error of the mean and mean values followed by the same letter are not statistically different (*P* > 0.05). ns = not significant.

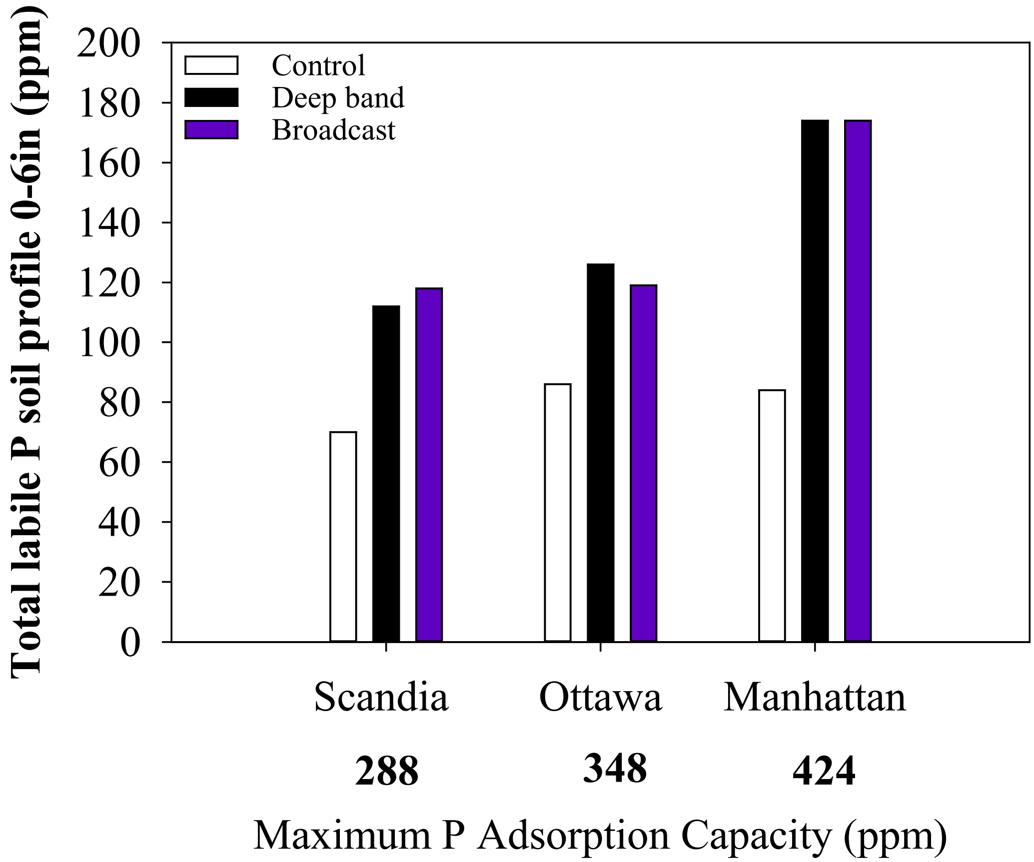

Figure 2. Total labile phosphorus (P) in the soil profile (0–6 inches) as affected by P fertilizer treatments (deep-band, broadcast, and control) after 10 years of crop rotation and maximum P adsorption capacity for three locations: Scandia, Ottawa, and Manhattan.