Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.4, No.15, 2014

Effect of Applied Phosphorus on the Availability of Micronutrients in Alkaline-Calcareous Soil

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Abstract
The present experiment was carried out to study the effect of applied phosphorus on the availability of micronutrients in alkaline-calcareous soil. For this purpose an incubation experiment was conducted in the laboratory of Soil and Environmental Sciences Department, The University of Agriculture Peshawar Pakistan during 2009 with variable amounts of phosphorus, i.e. 0, 30, 60, 90, 120 and 150 kg P ha^{-1} in the form of single super phosphate. The experiment was conducted in completely randomized block design with three replications consisted of 100 g of soil in each pot. The experiment was incubated for 28 days under normal conditions. The soil was kept moist up to field capacity condition throughout the incubation period. Results regarding the effect of phosphorus application on the availability of micronutrients showed non-significant differences in the treatments of applied phosphorus, but the trend of each micronutrient was obvious. The overall results showed that as the application of phosphorus increases, the concentrations of B, Zn and Cu gradually decreases, which indicate negative interactions, while the concentrations of P, Fe and Mn increases perhaps due to positive interactions with applied phosphorus during incubation period. Results further showed as the applied P (from single super phosphate) increases the pH-values gradually decreases, which resulted significantly negative correlation with one another (r^2 = 0.83). These results indicate that with the application of P as single super phosphate reduced the pH of soil and has favorable effect on the solubility of micronutrients, specifically Fe and Mn in the alkaline-calcareous soils.
Keywords: Phosphorus, Micronutrients availability

INTRODUCTION

Phosphorus is the second major essential element and is required by plants for root development, cell division, flowering seed and fruit formation (Brady, 1984). Phosphorus in soils occurs in the form of primary and secondary orthophosphate. Most possibly all crops take up $H_2PO_4^-$ more readily than HPO_4^{--} and above pH 7.0 the relative concentration of the divalent ion is greater than that of monovalent ion.

In Pakistan, farmers are using various phosphatic fertilizers such as single super phosphate, triple super phosphate, di-ammonium phosphate and nitro phosphate for getting the increase yield of various crops. On the other hand, excess and imbalance use of P-fertilizers may effect the solubility of micronutrients (Zn, B, Cu, Fe and Mn), which cause reduced crops yield. A number of field and green house experiments on the micronutrients status in soils and their response to various crops have indicated that some of the areas of Khyber Pakhtunkhwa are deficient in one or more trace elements (Khattak *et al.*, 1983). The deficiency or unavailability of these micronutrients are probably the result of various factors, such as calcareous nature and alkaline reactions soils, introduction of high yielding varieties, heavy application of high grade fertilizers, low organic matter, and imbalance use of nutrient or excess of certain phosphatic fertilizers, which not only suppress the crops yield, but also reduced the availability of micronutrients, perhaps due to chemical or physiological interactions in soil-plant systems. However, these interactions are designated as phosphorus induced micronutrients disorders (Timmer and Teng, 1990), though phosphorus induced micronutrients deficiency is not common to all soils, crop species and environmental conditions, but it has been proved in various soils and crops (Haldar and Mandal, 1981; Badhe and Mundwaik, 1982; Cakmak and Marschner, 1987; Wang *et al.*, 1990; Moustaoui *et al.,* 1991; Ajouri *et al.,* 2004; Stanislawska-Glubiak and Korzeniowska, 2005).

So, it is evident from the literature that phosphorus interfere in the availability of micronutrients in soils and uptake by plants, but no detail study have been carried out to find out the balance application of various phosphate fertilizer on the availability of micronutrients in alkaline-calcareous soils. Therefore, the main aim of the present project is to investigate the relationship and availability of micronutrients with phosphorus in soil by applying phosphate fertilizer to soil with the following main objectives were to investigate the effect of applied phosphorus on the availability of micronutrients (Zn, Cu, Fe, Mn and B) in alkaline-calcareous soils.

MATERIALS AND METHODS

Experimental description

A pot experiment was carried out in the laboratory of Soil and Environmental Sciences Department, The University of Agriculture Peshawar Pakistan, with variable amounts of phosphorus, i.e. 0, 30, 60, 90, 120 and 150 kg P ha^{-1} in the form of single super phosphate. The experiment was conducted in completely randomized block design with three replications consisted of 100 g of soil in each pot. The experiment was incubated for 28 days under normal conditions. The soil was kept moist up to field capacity condition throughout the incubation period. Before phosphorus fertilizer application the original soil sample was analyzed for various physico-chemical characteristics and the desired nutrients status by the routine standard procedures.

Soil analysis of incubated pots

After termination of the experiment, soil from each incubated pot was collected and analyzed for pH in 1:5 soil water suspension, the method as suggested by McLean (1982). AB-DTPA extractable P, Zn, Fe, Cu and Mn was determined by the procedure as described by Soltanpur and Schwab (1977) and the readings for P (after color development procedure) and Zn, Fe, Cu and Mn were taken on spectrophotometer and atomic absorption spectrophotometer, respectively. While, B in soil was extracted with hot water followed by Azomethine-H color development method as suggested by Bingham (1982).

Statistical analysis

Statistical analysis was performed by computer using MSTAT-C package. The collected data was analyzed using ANOVA and the means were compared by LSD-test of significance (Steel *et al*., 1997).

RESULTS AND DISCUSSION

Physico-chemical characteristic of experimental soil

Before conducting the incubation experiment in the laboratory the experimental soil was analyzed for various physico-chemical characteristics and nutrient status (Table 1). Results showed that the experimental soil was silt loam in texture, alkaline in reaction, non-saline and calcareous in nature, low in organic matter, AB-DTPA extractable phosphorus, zinc and iron, while copper, manganese and HWS-boron, contents were adequate as reported the critical limits in soil for these nutrients by Soltanpur and Schwab (1977) and Sillanpaa (1982), respectively.

Table 1: Physico-chemical characteristics of experimental soil

Properties	Units	Values
Sand	%	33.4
Silt	%	58.2
Clay	%	8.40
Textural class	---	Silt loam
PH_s (1:5)	---	7.73
EC_s (1:5)	dSm-1	0.33
Organic matter	%	0.65
Lime	%	11.50
HWS-boron	mg kg^{-1}	0.70
AB-DTPA extractable P	mg kg^{-1}	4.08
AB-DTPA extractable Zn	mg kg^{-1}	1.05
AB-DTPA extractable Cu	mg kg^{-1}	3.43
AB-DTPA extractable Fe	mg kg^{-1}	2.78
AB-DTPA extractable Mn	mg kg^{-1}	3.30

Micronutrient concentrations of incubated soil

Results of the incubated soil showed that as the phosphorus application increases the concentration of P in soil significantly increases in a linear fashion (Table 2). Although the P concentrations in some incubated treatments were still not reached to the sufficiency level with applied graded P, which indicate that the test soil was poor in available P (Soltanpour and Schwab, 1977), or may be due to the adsorption of phosphate ions in the soil due to alkaline reaction and calcareous nature of the incubated soil.

Table 2: Effect of phosphorus supply on the availability of micronutrients in soil

Applied P (kg ha^{-1})	Concentration ---------- mg kg^{-1} ----------					
	P	**B**	**Zn**	**Cu**	**Fe**	**Mn**
0	4.14	0.75	1.96	4.20	2.28	3.73
30	4.24	0.77	1.55	3.89	2.44	4.20
60	5.75	0.65	1.61	3.99	3.17	4.57
90	7.65	0.55	1.32	3.79	3.06	4.50
120	8.72	0.65	1.01	3.59	3.92	4.67
150	9.91	0.53	1.02	3.25	3.46	4.71
LSD (P<0.05)	1.72	NS	NS	NS	NS	NS
CV %	14.00	19.58	29.29	17.78	26.21	24.52

Results regarding the effect of phosphorus application on the availability of micronutrients showed non-significant differences but the trend of each micronutrient was obvious (Table 2). Boron showed a decreasing trend with applied phosphorus. The decreasing trend of B in soil seems to be due anion competition between P and B, which reduced the availability of B in soil. These results are in line with the previous work of Gunes and Alpaslan (2000) who reported that B was more toxic in the absence rather than the presence of P and this toxicity could be alleviated with the application of P in the calcareous soils of semi-arid areas.

Micronutrients (cations) such as Zn and Cu also showed a decreasing trend with increasing the graded phosphorus application to soil (Table 2). This reduced availability due to interference of applied phosphorus is very common in soils. Perhaps due to the formation of insoluble forms of zinc and copper, such as Zn-phosphate and Cu-phosphate, respectively. Similar negative interactions between phosphorus and these micronutrients were reported by Mandal and Haldar (1980) they noted that applied phosphorus decreased the content of DTPA-extractable Zn and Cu in soils, the rate of decrease gradually declining with the progress of the incubation period.

Rest of the micronutrients (cations) such as Fe and Mn showed an opposite trend with regard to applied phosphorus (Table 2). It is evident from the results as the applied phosphorus increases the concentrations of Fe and Mn also increased, perhaps due the positive interactions between applied phosphorus and these two micronutrients in the soil. Because increased applied phosphorus increased the extractable Fe and Mn and lowered the soil pH, causing these metals to be more soluble during incubation period. Similar results were reported by Shuman (1988).

The overall results showed that as the application of phosphorus from single super phosphate increases, the soil pH gradually decreases (due to the acidic pH of the fertilizer) along the concentrations of B, Zn and Cu, which indicate negative interactions, while the concentrations of P, Fe and Mn increases may be due to positive interactions with applied phosphorus during incubation period.

Soil pH of incubated soil

Soil pH of the incubated soil was determined at the termination of experiment. Results showed as the graded applied P (from single super phosphate) increases the pH-values gradually decreases, which resulted significantly negative correlation with one another (Figure 1). However, statistical analysis showed that the differences in the pH-values among various treatments were not very large. These results indicate that with the application of P as single super phosphate reduced the pH of soil and has favorable effect on the solubility of micronutrients in the alkaline-calcareous soils.

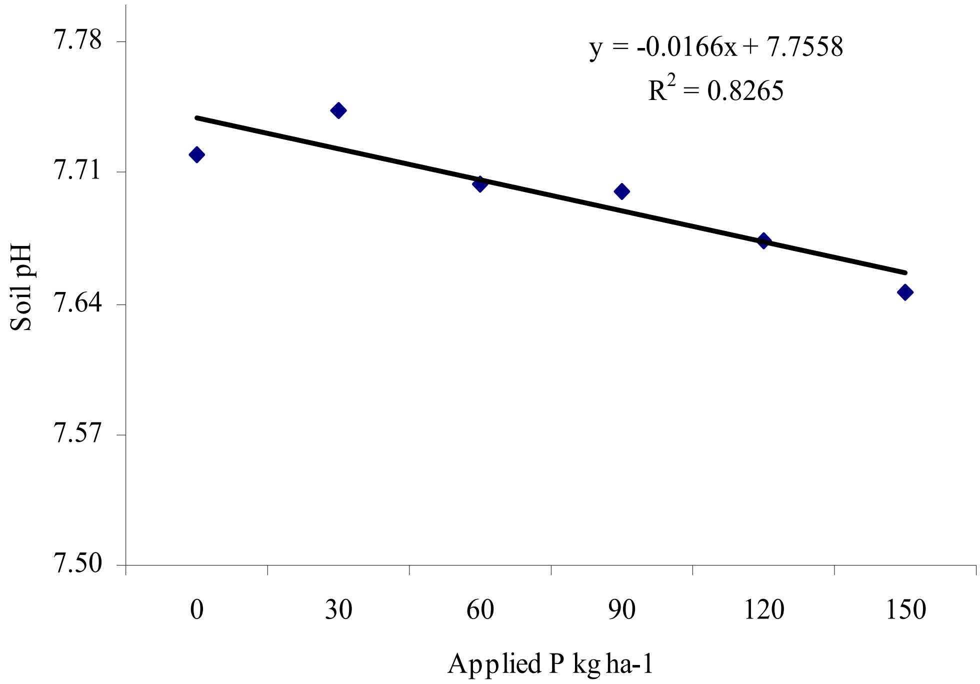

Figure 1: Relationship between applied P and soil pH

SUMMARY

An incubation experiment was conducted in the laboratory of Soil and Environmental Sciences Department, The University of Agriculture Peshawar Pakistan, with variable amounts of phosphorus, i.e. 0, 30, 60, 90, 120 and 150 kg P ha^{-1} in the form of single super phosphate. The experiment was conducted in completely randomized block design with three replications consisted of 100 g of soil in each pot. The experiment was incubated for 28 days under normal conditions. The soil was kept moist up to field capacity condition throughout the incubation period. Before phosphorus fertilizer application the original soil sample was analyzed for the desired nutrients status and the results showed that AB-extractable P, Zn and Fe were low, while HWS-B, Cu and Mn were adequate.

Results regarding applied phosphorus on the availability of micronutrients showed non-significant differences, but the trend of each micronutrient were obvious. Boron showed a decreasing trend with applied phosphorus. The decreasing trend of B in soil seems to be due to anion competition between P and B, which reduced the availability of B in soil. Micronutrients (cations) such as Zn and Cu also showed a decreasing trend with increasing the graded phosphorus application to soil. This reduced availability perhaps due to the formation of insoluble forms of zinc and copper, such as Zn-phosphate and Cu-phosphate, respectively. While, micronutrients (cations) such as Fe and Mn showed an opposite trend with regard to applied phosphorus. Results showed as the applied phosphorus increases the concentrations of Fe and Mn also increased, perhaps due the positive interactions. Because applied phosphorus increased the extractable Fe and Mn and lowered the soil pH, causing these metals to be more soluble during incubation period.

The overall results showed that as the application of phosphorus from single super phosphate increases, the soil pH gradually decreases (due to the acidic pH of the fertilizer) along with the concentrations of B, Zn and Cu, which indicate negative interactions, while the concentrations of P, Fe and Mn increases may be due to positive interactions with applied phosphorus.

CONCLUSIONS

The following conclusions were drawn from the present piece of work

i. The experimental soil was silt loam in texture, alkaline in reaction, non-saline and calcareous in nature, low in organic matter, AB-DTPA extractable phosphorus, zinc and iron, while copper, manganese and HWS-boron, contents were adequate compared with the reported critical limits in soil for these nutrients in the literature.
ii. The overall results showed that as the application of phosphorus from single super phosphate increases, the soil pH gradually decreases (due to the acidic pH of the fertilizer) along with the concentrations of B, Zn and Cu, which indicate negative interactions, while the concentrations of P, Fe and Mn increases may be due to positive interactions with applied phosphorus during incubation

period.

iii. As the applied P (from single super phosphate) increases the pH-values gradually decreases, which resulted significantly negative correlation with one another ($r^2 = 0.83$). These results indicate that with the application of P as single super phosphate reduced the pH of soil and has favorable effect on the solubility of micronutrients, specifically Fe and Mn in the alkaline-calcareous soils.

iv. Further comprehensive studies are warranted to find out the effect of applied phosphorus on the availability of micronutrients on various soils under controlled conditions.

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