Original research paper

Testing Selected Soils from Bamyan Center Agricultural Research Farms for Initial Macro and Micro Nutrients with Focus on Phosphorus Availability

ABSTRACT

Phosphorus (P) and micronutrients deficiencies are common in alkaline soils. Alkaline soils make up some of the most productive agricultural lands in the Bamyan centre of Bamyan province in central Afghanistan and little is known about the phosphorus fertility status of these soils. Our objectives were to determine the soil fertility status of 4 soils collected from the four research farms in Bamyan centre and also to conduct P incubation studies on these soils to determine the fixation and availability of added P. The experimental design was a randomized complete block with 3 replications of each treatment. Soils used in this study had pH > 8.0, free $CaCO_3$ contents of 9.3-10% and texture ranged from silty clay loam to sandy loam. Seven rates of P (0, 5.6, 10.9, 16.4, 21.8, 32.8, 43.7 mg kg^{-1}) were added as monocalcium phosphate [Ca $(H_2PO_4) \cdot 2H_2O$]. Soils were incubated at approximately 0.03 MPa soil tension for 15, 30, 45, 60, 75 and 90 days at 25° C and the Mehlich 3 soil test was used to determine available P. Mehlich 3 extractable P did not change consistently with time so data were averaged over all 6 sampling periods to determine the effects of P rate on Mehlich 3 P soil test levels. Soils segregated into two groups of two soils each that responded similarly in their response to P applications. Approximately70 percent of the applied P remained available in one group of soils, while in the other group of soils, approximately 50 percent of the applied P remained available.

Key words: Bamyan soil characteristics, calcareous soil, phosphorus, Mehlich 3 soil test.

Introduction

Phosphorus (P) is an essential nutrient for plant growth and its deficiency is common in calcareous soils. Soil P is often not available at the minimum level needed for plant growth and available soil P can be improved by adding P fertilizers (Jalali and Ranjbar, 2010). Because P is a finite resource, proper management of fertilizer P is necessary to maximize crop production while minimizing the risk of P loss to the environment. Phosphorus in agricultural soils appears in three fractions: organic P (25-30%), insoluble inorganic P (about 75%) and a small soluble P fraction. Less than 10% of the total P in soil is available in the plant-animal life cycle (Ozanne, 1980).

Phosphorus makes up approximately 0.2% of plant dry weight and P is a component of key molecules such as phospholipids, nucleic acids and ATP, so plants cannot grow well without a sufficient supply of P (Schachtman et al., 1998). Although the total amount of P in soils can be relatively high, because most of this P is not present in plant-available forms it is important to make sure that optimum P fertilizer management strategies are developed to ensure plant productivity.

Little research has been conducted on calcareous soils of Afghanistan, and these are the most highly productive agricultural lands in the country.

Not all of the P fertilizer applied to soils is available to plants due to surface adsorption and precipitation processes, particularly in calcareous soils (Afif et al., 1993). For example, there was a negative correlation between P fertilizer and $CaCO_3$ content when available P was measured as resin extractable P in 20 calcareous soils of the continental USA (Jones et al., 1984). For another group of calcareous soils from several countries, researchers found that P availability after both 30 and 180 days of incubation was closely correlated to $CaCO_3$ content (Sharpley et al., 1989). Larsen and Widdowson (1970) reported that P sorption in calcareous soils increased with increased $CaCO_3$ content.

Ryan et al. (1985) found that solid phase $CaCO_3$ proved to be the most dominant phase controlling P reactions in the soils they studied. However, some studies argue that the reactivity of $CaCO_3$ could be more dependent on the specific surface area, which is related to$CaCO_3$ particle size distribution, than total $CaCO_3$ when relating soil properties to P reactions in calcareous soils (Holford and Mattingly, 1975). The same idea has been confirmed by Borrero et al. (1988).

Soil pH affects P solubility and plant uptake (Ortas and Rowell. 2000). Researchers suggest that phosphate adsorption capacity increases as pH decreases (Bolan and Hedley, 1990). According to some researchers, it is important to understand the effect of pH on P partitioning to explain differences in observed P sorption levels in soil (Tunesi et al., 1999). Tunesi et al. (1999) found that in Na-saturated soils, phosphate partitioning into the solid phase decreased as pH increased. Moreover, according to these researchers, at higher pH values lower P sorption can be observed at the initial portion of the isotherm. Tunesi et al. (1999) also suggested that a higher pH value could decrease the solubility of Ca-P mineral phases and increase precipitation, which would further decrease solution P.

An incubation study on three calcareous soils of the UK indicated that decreasing soil pH could increase soil P solubility (Ortas and Rowell, 2000).They also pointed out that the formation of insoluble Ca minerals was the key factor in decreasing P availability, particulary in higher pH soils. Laboratory studies also have indicated that P sorption can vary with pH (Zhou et al., 2005). These researchers also believe that P sorption decreases as pH increases and as a result, the surface charge becomes more negative.

The effect of soil pH on the dissolution of phosphate rocks and the availability of inorganic P to plants has been studied by many researchers. For example, Bolan and Hedley (1990) showed an increase in plant-available P from phosphate rocks with decreased soil pH.

Keeping in mind on the above information about the low P availability in alkaline soil, the present investigation has been planned to carry out during 2016 -2017 at soil science laboratory, Bamyan university, in Bamyan center, with the following objectives.

1).To determine the soil fertility status of soils to be collected from the Bamyan University farms and Department of Agriculture Research Farms and;

2). To conduct P incubation studies on these soils to determine the fixation and availability of added P.

Research Methodology

Routine Soil Analyses

Four soils will be collected from four agricultural research farms of Bamyan. Soil samples will be air dried and ground to pass through a 2-mm sieve for all laboratory analyses.The Bamyan University soil fertility laboratory will be used to conduct all the analysis. All the equipments (reagents, filter papers, beakers etc.. which are necessary to conduct this experiment are available inside the soil fertility lab of Bamyan University) and the reference book that will be used for each of the necessary test is " Recommended Chemical Soil Test Procedures for The North Centeral Region , Agricultural Expereiment Stations of Illinois, Indiana, Iowa, Kensas, Michigan, Minnesota, Missouri, Nebraska and the U.S. Department of Agiculture, No 221).

3.2. Phosphorus Incubation Study

The incubation experiment will be a split plot design with three blocked replicates. Whole unit treatments will be 4 soils from Bamyan, with P applied at 7 different rates (0, 5.6, 10.9, 16.4, 21.8, 32.8, 43.7 mg P kg^{-1}). Subsamples will be taken 6 times after 15, 30, 45, 60, 75and 90 days of incubation and Mehlich 3 P will be measured on each sample. Finally, the statistical analysis (ANOVA) will be conducted to analyze the data.

Result and Discussion

Soil Chemical and Physical Properties

The 4 soils used in this experiment varied in their initial P contents and other soil chemical and physical properties (Table 1 and Table 2). The soils' initial total P ranged from 19.5 to24.6 mg kg^{-1} (Table 1). Soils pH and percent $CaCO_3$ ranged from 8.3 to 8.7 and 9.3 to 10.7%, respectively. Soil textural class ranged from silty clay loam to sandy loam and clay content ranged from 18-36% (Table 2).

Effect of Applied Phosphorus on Mehlich 3 Phosphorus

Mehlich 3 soil test P increased with P additions at all sampling times, but the magnitude of increase in soil test P varied among incubation times and did not follow any pattern that could be explained based on soil properties or time. Therefore, we averaged treatment response over time and considered only the effect of P rates on the change in Mehlich 3 soil P test level. Soils 1and 2 responded similarly to each other, but significantly different ($P < 0.01$) from soils 2 and 4, with respect to the change in Mehlich 3 soil test P with P additions (Table 3). Even though soils 1 and 2 differed in texture, pH, and initial P content responded similarly in P application rate (Table 1, Table 2, and Table 3). These soils all had greater initial soil test P levels compared to soils 2 and 4 (Table 1).

The predicted values for the increase in Mehlich 3 soil test P with P addition for these two soils were described by the following equation:

$Y= 8.97+ 0.01X^2$

Where Y equals the change in soil test P and X equals P addition with both variables expressed in mg P kg^{-1} soil. The slope and intercepts were different from zero ($P < 0.0001$) and the correlation between P application and change in Mehlich 3 soil test P level was highly significant ($r^2 = 0.93$; $P < 0.0001$; Table 3). At the greatest P addition of 43.7 mg P kg^{-1}, The Mehlich 3 soil test P value changed approximately 30 mg P kg^{-1}. Approximately 70% of the added P remained available in these soils.

Bolan and Hedley (1990) suggested that phosphate adsorption capacity increases as pH decreases. Moreover, Ortas and Rowell (2000) reported that soil pH affects P solubility and plant uptake. Soil 2 had a lower clay content (18%) compared to soils 1 (36%). We expected that less P might have been sorbed by soil 1 compared to all other soils. Fox and Kamprath (1970) reported a positive correlation between the clay content and P adsorption capacity of soils and Jones et al. (1984) found a negative correlation between P fertilizer and CaCO3 content and changes in resin extractable P with P additions in 20 calcareous soils of the continental USA. Sharply et al. (1989). Also found that P availability after 30 and 180 days of incubation was closely correlated to the $CaCO_3$ content of calcareous soils from several countries. Soils 3 and 4 also responded similarly to P additions as expressed by the change in Mehlich 3 soil test P values. Soils 3 and 4 were both silty clay loam with a pH ranges from 8.6-8.7 (Table 1).

The predicted values for the increase in Mehlich 3 soil test P with P additions for these two soils were estimated by the following equation:

$Y = 2.90 + 0.01X^2$

Where Y equals the change in soil test P and X equals P addition with both variables expressed in mg P kg^{-1} soil. The slope and intercepts were different from zero ($P < 0.0001$) and the correlation between P application and change in Mehlich 3 soil test P level was highly significant ($r^2 = 0.93$; $P < 0.0001$; Table 3). In these soils we found roughly a 21 mg P kg^{-1} increase in Mehlich 3 soil P test level after adding 43.7 mg P kg^{-1} Approximately 50% of the added P remained available in these soils, which was significantly less than in soils 1 and 2. These results were not unexpected and Soils 3 and 4 had lesser initial soil test P values than Soils 1 and 2. Soil 4 had the greatest pH. In an incubation study on three calcareous soils of the UK, Ortas and Rowell (2000) found that decreasing soil pH could increase soil P solubility, and Fox and Kamprath (1970) found a positive correlation between clay content and soil P adsorption capacity.

The percent free $CaCO_3$ for Soils 3 and 4 also were ranged from 10.1-10.6 % and according to previous researchers, P sorption in calcareous soils increased with increased $CaCO_3$ content (Larsen and Widdowson, 1970).

Conclusion

The 4 calcareous soils from Bamyan center varied in their initial macro and micro nutrients content and many other soil properties. The rate and time effects varied among all 4 soils and time effect on change in Mehlich 3 soil test P levels were not consistent. Soil Mehlich 3 P increased with added P and the availability of added P differed between two groups of soils. These two groups of soils were separated between high P testing soils and low P testing soils.

Recommendation

1) Based on results, the organic content in Bamyan soil is low, so recommended to apply the different sources of organic fertilizers, especially decomposed animal manures on the cultivated land.

2) According to many studies, the application of both chemical and organic fertilizers highly increasing the efficiency of chemical fertilizers. So, it is recommended to apply both chemical and organic fertilizer simultaneously on the field.

3) In mechanical agriculture, the application of fertilizers must be according to availability and amount of essential nutrients in the soil and needs of cultivated plants. So, the results in this research will be at least a raw data for correct applying doses of chemical fertilizers.

Table 1: Origin and selected Properties of soils collected from the Bamyan centre in the Bamyan province of Central Afghanistan.

Soil ID	Soil Origin	pH	EC	CEC	OM	N	P	K	Ca	Mg	$CaCO_3$
			dS/m	cmol kg^{-1}	%	------------mg kg^{-1}--------------					%
1	Bamyan Uni. Ag. Farm A.	8.4	0.5	29.1	0.9	51.4	24.6	92.5	4900	780	9.3
2	Bamyan Uni. Ag. Farm B.	8.3	1.3	30.4	1.1	44.8	23.7	106	5300	685	10.7
3	Mollagholam A.	8.6	0.6	26.1	0.6	48.2	22.1	86.4	5150	700	10.1
4	Mollagholam B	8.7	0.3	25.6	0.5	44.7	19.5	94.2	5400	650	10.6

Table 2: Origin and selected Properties of soils collected from the Bamyan centre in the Bamyan province of Central Afghanistan.

Soil ID	Soil Origin	S	Mn	Fe	Cu	Zn	Sand	silt	Clay	Textural Class
		------------mg kg^{-1}--------------					--------%------------			
1	Bamyan Uni. Ag. Farm A.	9.3	64	27	4	3	48	16	36	Sandy clay
2	Bamyan Uni. Ag. Farm B.	12.7	71	23	6	2	65	17	18	Sandy loam
3	Molla gholam A.	9.5	65	25	7	3	18	50	32	Silty clay loam
4	Molla gholam B	7.8	67	18	5	4	19	52	29	Silty clay loam

Table 3: Analysis of variance and regression coefficients for the effect of applied phosphorus on Mehlich 3 P in 4 Bamyan Centre soils.

R-Square	Pr>F	Coeff Var	Root MSE	M-3 P	
0.93	<0.0001	16.84	2.12	12.52	
Source	Df	Type Ⅱ SS	Mean square	F Value	Pr>F
Soil	1	330.28	330.28	73.52	<0.0001**
R^2	1	1657.1	1657.1	368.52	<0.0001**
Parameter	Estimate	Stand Error	T Value	Pr> t	
Soil 1 2	8.960	0.60824	14.73	<0.0001**	
Soil 3 4	2.902	0.60824	14.76	<0.0001**	
R^2	0.0102	0.00052	19.2	<0.0001**	

** = significant at $P \leq 0.01$, * = significant at $P \leq 0.05$, and ns = non-significant

References:

Afif, E., A. Matar, and J. Torrent. 1993. Availability of phosphate applied to calcareous soils of est Asia and North Africa. Soil Sci So,. Am. J. 57:756-760.

Berrero, C., F. Pena, and J.Torrent. 1988. Phosphate sorption by calcium carbonate in some soils of the Mediterranean part of Spain. Geoderma. 42:261-269.

Bolan, N.S., and M.J. Hedley. 1990. Dissolution of phosphate rocks in soils 2.Effect of pH on the dissolution and plant availability of phosphate rock in soil with pH dependent charge. Fertilizer and lime research. Massey University, New Zealand.125-134.

Fox, R.L., and E.J.Kamprath.1970. Phosphate sorption isotherms for evaluating the phosphate requirements of soils.Soil Sci.Soc.Am.Proc.34:902-907.

Jalali, M., and F. Ranjbar. 2010. Aging effects on phosphorus transformation rate and fractionation in some calcareous soils. Geoderma. 155:101-106.

Jones, C.A.,C.V.Cole, A.N.Sharpley, and J.R.Williams.1984. A simplified soil and plant phosphorus model:I.Documentation.Soil Scie Am.48:800-805.

Holford, I.C.R., and G.E.G. Mattingly. 1975. Phosphate sorption by jurassic oolitic limestones. Geoderma.13:257-264.

Larsen, S., and A.E. Widdowson. 1970. Evidence of dicalcium phosphate precipitation in a calcareous soil. Soil Sci. 21:364-367.

Ortas, I., and D.L. Rowell. 2000. Effect of pH on amount of phosphorus extracted by 10 mM calcium chloride from three rothamsted soils. Comm. in Soil Sci. and Plant Anal. 31:2917-2923.

Ozanne, P.G., 1980. Phosphate nutrition of plants-a general treatise. pp.559-589. In F.E. Khasawneh, E.C. Sample, and E.J. Kamprath (ed.).The role of phosphorus in Agriculture. Am. Soc. of Agron. Madison,WI.

Ramirez, R., S.M. Fernandez, and J.I.Lizaso. 2001. Changes of pH and available phosphorus and calcium in rhizosphere of aluminum-tolerant maize germplasm fertilized with phosphate rock. Comm. in Soil Sci. and Plant Anal. 32:1551-1565.

Ryan, J., D. Curtin, and M.A. Cheema. 1985. Significance of iron oxides and calcium carbonate particle size in phosphate sorption by calcareous soils. Soil Sci. Soc. Am. J. 49:74-76.

Schachtman, D.P., R.J. Reid, and S.M. Ayling. 1998. Phosphorus uptake by plants: from soil to cell. Department of Botany. University of Adelaide, SA, Australia.116:447-453.

Sharpley, A.N., U. Singh, G. Uehara, and J. Kimble. 1989. Modeling soil and plant phosphorus dynamics in calcareous and highly weathered soils. Soil Sci. Soc. Am. J. 53:153-158.

Tunesi, S., V. Poggi, and C. Gessa. 1999. Phosphate adsorption and precipitation in calcareous soils: the role of calcium ions in solution and carbonate minerals. Nutrient Cycling in Agroecosystems. 53:219-227.

Zhou, A.M., H.X. Tang, and D.S. Wang. 2005. Phosphorus adsorption on natural sediments: modeling and effects of pH and sediment composition. Water Res. 39:1245-1254.