OnLine Journal of Biological Sciences 1 (10): 908-911, 2001

Extractable Phosphorus in a Range of Bangladesh Soils and its Critical Limits for Chickpea

[2]A. B. M. S. Islam, M. Q. Haque, [1]M. H. Rahman, [3]M. A. Hoque and [2]M. K. Alam
[1]Division of Soil Science, P. O. Box, 4, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh. [2] Soil Resources Development Institute, Jamalpur, Bangladesh, [3]Department of Soil Science, Bangladesh Agricultural University, Mymensingh, Bangladesh

Abstract: The experiment was conducted at BINA net house with 17 extensively cultivated soils of Bangladesh to evaluate P extractability of four extractants and to determine its critical limit for chickpea. The soils were analyzed for P status by four extraction methods. The mean extractable P in soils was found to be in the order of Nelson > Olsen > Hunter > Bray. Influence of soil pH was the most dominant factor in P extraction. For the soils with low pH (<6.0), the amounts of P removed by different extractants except Bray-P were positively correlated with organic matter content whereas such correlation was negative for high pH soils (>6.0) indicating the stability of phosphorus organic matter complex formation at elevated pH. Dry matter yields were remarkably increased with addition of increasing rate of phosphatic fertilizer and the soils having low extractable P responded better to the applied P. In high pH soils, dry matter yield gave a positive relationship with extractable phosphorus. The P content and P uptake were also positively and significantly correlated with extractable P in these soils. In all and low pH soils, relative dry matter yield was positively correlated with extractable P, whereas such correlation was negative in high pH soils. The critical limit of soil extractable P for chickpea for Olsen, Bray, Nelson and Hunter extraction methods was found to be 14.0, 9.0, 23.0 and 11.0 (graphical approach) and 14.5, 12.5, 23.0 and 15.0 ppm (statistical approach) respectively.

Key words: Chickpea, extractable phosphorus, relative yield, critical limit

Introduction

Chickpea is a major pulse crop, occupying the third position both in acreage and production among the pulses grown in Bangladesh. The average yield of chickpea in Bangladesh is low (0.7 t ha^{-1}on an average) compared to many other chickpea growing countries (FAO, 1998). Nutrient deficiency might be a major reason for lower productivity of chickpea in this country. The essentiality of phosphorus for plant growth had been recognized in 1903 (Tamhane *et al.*, 1970). Phosphorus deficiency is becoming widespread and acute in many soils of Bangladesh and also in many other countries of the world. Indian Council of Agricultural Research (1971) reported that the use of phosphate fertilizers not only assured the best performances of the pulse crop but also economize the use of nitrogen fertilizer to the following crops. Phosphorus significantly increases dry matter production as well as yield and yield contributing characters of chickpea (Parihar and Tripathi, 1989). Phosphorus has significant role in increasing the nitrogen content in legumes (Raut and Kothire, 1991). Soil testing has been recognized as a effective tool for determining fertilizer need of a crop under all situations, but its importance is by far the greatest in circumstances when the fertilizer is scarce and costly commodity with respect to the farmer's investment ability. The main objectives of soil test crop response correlation study is to obtain a basis for precise quantitative adjustment of fertilizer doses for varying soil test values in farmer's fields as well as to help cultivators to increase their production and profit considerably through economic and judicious use of fertilizers. It is admissible that when P application is made on the basis of existing soil fertility class, crop response to added P is not always obtained. As such the information on P fertilizer use emanating from soil testing laboratories must primarily be based on critical limits of extractable P for different crops and soils. This study was undertaken with the objectives to evaluate the P extractability of four extractants and to determine its critical limit for chickpea.

Materials and Methods

Seventeen top soils (0-15 cm) were collected from different soil series and Agroecological zone (AEZ) of Bangladesh. Each of the soils represented a soil series. The selected soil series were Sonatala, Silmondi, Tarakanda, Lokdeo, Gerua, Ekdala, Noadda, Amnura, Lauta, Ranishankail, Gangachura, Pirgacha, Jamun, Chilmari, Sara, Dumuria and Barisal. The soil samples were air dried, ground and passed through a 2 mm sieve and were analyzed for pH, organic matter content, clay content, total N, exchangeable K and available S using standard procedure.

The experiment was conducted with each soil to evaluate the efficiency of the P extractants and also to determine the critical level of soil P for chickpea by four extraction methods: (I) 0.5 N $NaHCO_3$ (pH 8.5, Olsen *et al.*, 1954) (ii) 0.03 N NH_4F + 0.025 N HCl (Bray & Kurtz, 1945) (iii) 0.05 N HCl + 0.02 N H_2SO_4 (Nelson *et al.*, 1953) and (iv) 0.25 N $NaHCO_3$ + 0.01 N EDTA + 0.1N NH_4F (Hunter, 1984). There were three levels of P viz. 0, 25 and 50 ppm P for each soil. The experiment was laid out in randomized complete block design with three replications (Gomez and Gomez, 1984). A basal application was made with 10 ppm N, 30 ppm K, 20 ppm S and 5 ppm Zn. The elements N, P, K, S, and Zn were added through solution from NH_4NO_3, KH_2PO_4, KCl, $CaSO_4.2H_2O$ and $ZnCl_2$, respectively. One kilogram soil was taken in each pot and Hypochola a released variety of chickpea was used as the test crop. Five plants were allowed to grow until they were harvested at 45 days of growth. Dry matter yield was recorded from each pot. Plant samples were analyzed for P content (Olsen *et al.*, 1954).

The critical limit of extractable P for chickpea was determined by two different approaches, the one was graphical and the other statistical. In graphical approach, the critical levels of extractable P as determined by four extraction procedures were calculated separately using the procedure developed by Cate and Nelson (1965). Accordingly the relative yield (known as Bray's per cent yield) was calculated from the following relationship.

$$\% \text{ Relative yield} = \frac{\text{Yield without P}}{\text{Yield with P}} \times 100$$

In the statistical technique (Waugh *et al.*, 1973) of determining critical level of P, coefficient of determination (R^2) was calculated. Accordingly the coefficient of determination (R^2) was computed from the following relationship:

$$R^2 = \frac{TCSS - (CSS^1 + CSS^2)}{TCSS}$$

Where, TCSS = Total corrected sum of squares
CSS^1 = Corrected sum of squares for population 1
CSS^2 = Corrected sum of squares for population 2

Results and Discussion

Extractable phosphorus and correlations: The pH of the soils varied from 5.1 to 7.9%, organic matter content from 1.05 to 2.80%, clay from 10.0 to 37.3%, total N 0.06 to 0.14%, exchangeable K 0.08 to 0.28 me/100g soils and available S 8.0 to 24.5 ppm (Table 1). The highest organic matter and clay content was obtained from Barisal where extractable P was low due to salinity. The amount of extractable P varied markedly depending on the soils and extractants used. The maximum amount of P (10.0-70.0 ppm) was extracted by Nelson method (HCl + H_2SO_4) and the minimum (3.0-27.0 ppm) by Bray method (NH_4F + HCl). The mean values of P extracted by different extractants ranked in the order of Nelson (0.05N HCl + 0.02N H_2SO_4) > Olsen (0.5N $NaHCO_3$) > Hunter (0.25N $NaHCO_3$ + 0.01N EDTA + 0.01N NH_4F) > Bray (0.03N NH_4F + 0.025N HCl) (Table 2). The differences in the amounts of P extracted by various extractants are mainly due to their selectivity in solubilizing different fractions to varied extent. As per as individual soils are concerned the highest extractable P was obtained from Sonatola and the lowest from Barisal. A paired t-test was performed to compare the mean differences of P removed by different extractants. The mean values of extractable P differed significantly between the extraction methods except in one case (Olsen-P vs. Hunter-P). The mean value of P extracted by ($NaHCO_3$ + EDTA + NH_4F) was not significantly different from $NaHCO_3$. Correlation analysis revealed that the amounts of P solubilized by extractants were significantly and positively correlated with each other except between Bray-P and Hunter-P (Table 3). The best correlation (r = 0.917***) was found between Nelson-P and Olsen-P followed by Nelson P and Hunter-P(r = 0.916***), Olsen-P and Hunter-P(r = 0.907***) and Olsen-P and Bray-P (0.584*). This result indicates that although the ability of P extraction was different for different extractants, their trends of P displacement from soil into solution were similar. This is in agreement with the findings of Rahman *et al.* (1995) and Rahman *et al.* (2000).

Correlation between extractable P and soil properties: Correlations between extractable P and soil properties (e.g. pH, organic matter and %clay) indicate that the extractable P levels over the soils did not correlate with any of the soil properties (Table 4). For low pH soils, Bray-P or Nelson-P was positively correlated with pH. There was a positive correlation between Olsen-P, Nelson-P or Hunter-P and organic matter content while Bray-P was negatively correlated with organic matter content. The amount of P extracted by different methods did not show positive correlation with clay. For high pH soils, all the extractable P were negatively correlated with pH. The highest significant and negative correlation (r = 0.805*) was found between Bray-P and organic matter in high pH soils. There was a positive correlation between Olsen-P and organic matter content but other correlations were negative. Negative correlation was also observed between extractable P by four extractants and clay contents in all soils. Rahman *et al.* (1995) reported that the amounts of P removed by different extractants were positively correlated with organic matter content in low pH soil whereas such correlation was negative in high pH soil.

Dry matter, relative yield, and phosphorus content of chickpea: The application of phosphorus increased the dry matter yields of chickpea. The dry matter yield in control ranged from 0.45 to 1.1 g/pot as compared to 0.60 to 1.55 g/pot in the P treated pots (Table 5). In general the soils having low extractable P responded better to the applied P. Such soils were Gerua, Ekdala, Noadda, Chilmari, Sara and Dumuria. Thepercent relative yield varied from 66.7 to 83.3. The highest percent relative yield was observed from Lokdeo soils where extractable P was high and the lowest was observed from Noadda where extractable P was low. The P content in chickpea was increased due to application of phosphorus to soil. The P concentration of chickpea varied from 0.15% in control to 0.37% in P treated pots. The observed differences in these characteristics are due to the variations in available P status and other physiochemical properties of soils. Rahman *et al.* (1995) and Rahman *et al.* (2000) also reported similar results.

Correlation between extractable P and biological parameters of chickpea: None of the extractable P by different extractants showed significant correlation with various biological parameters of chickpea in some cases (Table 6). Correlation between extractable P and dry matter yield was positive for high pH group of soils and such correlations were negative in low or all pH soils. In high pH soils, extractable P was positively and significantly correlated with P uptake. In low and all pH soils, there were positive correlation between extractable P and relative dry matter yield while in high pH soils, extractable P was negatively correlated with relative dry matter yield.

Critical limit of phosphorus : An attempt was made to find out the critical level of extractable P for chickpea by using the scatter diagram procedure of Cate and Nelson (1965) and statistical procedure by Waugh *et al.* (1973). By the scatter diagram critical P level of chickpea for Olsen, Bray, Nelson and Hunter extraction methods was 14.0, 9.0, 23.0 and 11.0 ppm, respectively (Table 7).

In the statistical method, 14.5, 12.5, 23.0 and 15.0 ppm were found to be critical levels for Olsen, Bray, Nelson and Hunter extractable P, respectively (Table 7). Considering the principle, higher is the R^2 value, better is the fit. The highest R^2 value (0.48) was recorded in Nelson's procedure (Table 7). This suggests that the Nelson's procedure of P extraction is the best for predicting P response of chickpea.

It may be said that the amount of extractable P varied

Table 1: Some important physiochemical properties of different soil series

Soil series	USDA Soil family	pH	Organic matter (%)	Clay (%)	Total N (%)	Exchangeable K (me/100g soil)	Available S (ppm)
Sonatala	Aeric Haplaquept	5.5	1.80	14.3	0.08	0.11	13.0
Silmondi	Do	6.8	2.00	16.3	0.11	0.11	10.7
Tarakanda	Typic Fluvaquent	5.2	1.10	16.3	0.06	0.09	8.0
Lokdeo	Aeric Haplaquept	5.3	2.28	11.2	0.09	0.12	13.4
Gerua	Aquic Haplustult	5.4	1.84	10.0	0.07	0.08	14.0
Ekdala	Aeric Albaquept	5.1	1.34	35.3	0.08	0.09	13.8
Noadda	Ultic Uxtocherept	5.4	1.25	24.3	0.08	0.09	10.7
Amnura	Aeric Albaquept	5.2	1.47	16.3	0.08	0.09	12.0
Lauta	Do	5.3	1.25	16.3	0.08	0.14	16.0
Ranishankail	Udic Ustocherpt	5.3	1.10	12.3	0.06	0.08	10.0
Gangachura	Typic Haplaquept	5.3	1.37	16.3	0.07	0.10	11.6
Pirgacha	Udic Ustocherpt	6.1	1.42	12.0	0.08	0.12	16.0
Jamun	Typic Haplaquept	5.8	1.05	14.3	0.06	0.09	13.4
Chilmari	Do	5.8	1.35	14.0	0.09	0.14	20.0
Sara	Aquic Eutrocherpt	7.9	1.85	12.0	0.10	0.09	15.0
Dumuria	Aeric Haplaquept	7.2	2.72	28.3	0.14	0.26	24.5
Barisal	Typic Haplaquept	6.9	2.80	37.3	0.10	0.28	22.5

Table 2: Extractable phosphorus of the soils by using different extractants

Soil series	Extractable P (ppm)			
	Olsen-P	Hunter-P	Bray-P	Nelson-P
Sonatala	40	36	14	70
Silmondi	15	13	08	21
Tarakanda	17	11	15	18
Lokdeo	16	16	10	42
Gerua	12	09	11	18
Ekdala	12	10	08	17
Noadda	06	04	05	10
Amnura	17	12	12	17
Lauta	14	14	11	20
Ranishankail	25	32	17	46
Gangachura	38	31	13	52
Pirgacha	15	12	10	25
Jamun	19	08	27	31
Chilmari	10	10	07	18
Sara	06	07	04	14
Dumuria	08	04	04	13
Barisal	04	06	03	14

Table 3: Coefficients of correlation and t-statistics for comparison of P results from different extraction methods

Extractable P	't' value `	'r' value
Olsen-P vs. Bray-P	2.78**	0.584*
Olsen-P vs. Nelson-P	5.30***	0.917***
Olsen-P vs. Hunter-P	0.80NS	0.907***
Bray-P vs. Nelson-P	4.58***	0.493*
Bray-P vs. Hunter-P	2.21*	0.425NS
Nelson-P vs. Hunter-P	5.46***	0.916***

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; NS = Not significant

Table 4: Coefficient of correlation (r value) of extractable P and selected soil properties

Extractable P	Soils	pH	Organic matter	Clay
Olsen-P	All soils	-0.455	-0.318	-0.374
	Low pH soil	-0.012	0.098	0.262
	High pH soil	-0.672	0.691	-0.635
Bray-P	All soils	-0.509*	-0.607**	-0.457
	Low pH soil	0.325	-0.333	-0.360
	High pH soil	-0.737	-0.805*	-0.671
Nelson-P	All soils	-0.331	-0.117	-0.395
	Low pH soil	0.097	0.329	-0.361
	High pH soil	-0.809*	-0.763	-0.585
Hunter-P	All soils	-0.432	-0.248	-0.418
	Low pH soil	-0.143	0.219	-0.322
	High pH soil	-0.534	-0.755	-0.672

Total soil (n=17), pH 5.1-7.9; Low pH soil (n=12), pH <6.0; High pH soil (n=5), pH > 6.0; *$P<0.05$; **$P<0.01$

Table 5: Effect of phosphorus application on dry matter yield, relative yield and P content in chickpea plant

Soil series	Dry matter yield (g/pot)			Relative yield (%)	Phosphorus content (%)		
	P_0	P_{25}	P_{50}		P_0	P_{25}	P_{50}
Sonatala	0.80	1.05	0.90	76.2	0.17	0.18	0.19
Silmondi	0.84	1.12	1.20	70.0	0.25	0.26	0.29
Tarakanda	0.85	1.05	0.92	81.1	0.28	0.32	0.30
Lokdeo	0.75	0.90	0.85	83.3	0.25	0.26	0.27
Gerua	0.85	1.15	1.23	69.1	0.27	0.30	0.29
Ekdala	1.00	1.40	1.45	69.0	0.25	0.26	0.27
Noadda	0.80	0.95	1.20	66.7	0.21	0.25	0.28
Amnura	0.86	1.32	1.15	76.0	0.19	0.22	0.25
Lauta	1.10	1.45	1.55	71.0	0.23	0.23	0.26
Ranishankail	0.75	0.72	0.95	78.9	0.21	0.25	0.27
Gangachura	0.64	0.80	0.74	80.0	0.31	0.35	0.37
Pirgacha	0.96	1.08	1.19	80.7	0.25	0.29	0.31
Jamun	0.60	1.65	0.75	80.0	0.25	0.28	0.27
Chilmari	0.95	1.30	1.30	73.0	0.15	0.17	0.22
Sara	0.93	0.35	1.25	68.9	0.17	0.20	0.22
Dumuria	0.45	0.60	0.65	69.2	0.25	0.27	0.26
Barisal	0.92	1.05	1.15	80.0	0.18	0.20	0.22

Table 6: Coefficients of correlation (r value) of extractable P and dry matter yield, P content, P uptake and relative dry matter yield of chickpea

Extractable P	Soils	Dry matter yield	P content	P uptake	Relative dry matter yield
Olsen-P	All soils	-0.374	0.216	-0.178	0.014
	Low pH soil	-0.559	0.069	0.495	0.514
	High pH soil	0.1258	0.930*	0.710	-0.600
Bray-P	All soils	-0.368	0.272	0.066	0.009
	Low pH soil	-0.649*	0.136	-0.432	0.579*
	High pH soil	0.304	0.867*	0.834*	-0.559
Nelson-P	All soils	-0.424	0.023	-0.322	0.144
	Low pH soil	-0.614*	-0.126	-0.636*	0.553
	High pH soil	0.323	0.841	0.841	-0.580
Hunter-P	All soils	-0.200	0.070	0.022	0.004
	Low pH soil	-0.401	-0.080	-0.317	0.476
	High pH soil	0.545	0.657	0.921*	-0.798

Total soil (n=17), pH 5.1-7.9; Low pH soil (n=12), pH <6.0; High pH soil (n=5), pH > 6.0; *P<0.05; **P<0.01

Table 7: Critical soil P levels using different extractants as determined by graphical and statistical approaches

Soil P test method	Methods of determining critical P level		R^2
	Graphical (ppm)	Statistical (ppm)	
Olsen-P (0.5 N $NaHCO_3$)	14.0	14.5	0.35
Bray-P (0.03 N NH_4F+0.025 N HCl)	9.0	12.5	0.27
Nelson-P (0.05 N HCl + 0.02 N H_2SO_4)	23.0	23.0	0.48
Hunter-P (0.25 N $NaHCO_3$-0.01 N EDTA-0.1N NH_4F	11.0	15.0	0.25

markedly depending on the soils and extractants used. The extracting power of different extractants was in the order of Nelson > Olsen > Hunter > Bray. Influence of soil pH was the most dominant factor in phosphorus extraction. Dry matter yields of chickpea were remarkably increased with the addition of increasing rate of phosphatic fertilizer and the soils having low extractable P responded better to the applied P. The highest R^2 value was recorded in Nelson's procedure. Thus, the Nelson's procedure of P extraction is the best for predicting P response of chickpea.

References

Bray, R. H. and L. T. Kurtz, 1945. Determination of total, organic and available forms of phosphorus in soils. Soil Sci., 59: 39.

Cate, R. B. Jr. and L. A. Nelson, 1965. Int. Soil Testing Serv., Tech. Bull. 1, North Carolina, USA.

FAO (Food and Agriculture Organization), 1998. FAO Production Year Book, 52: 99.

Gomez, K. A. and A. A. Gomez, 1984. Statistical procedures for agricultural research (2nd edn.). John Wiley Sons, New York, Chichester, Brisbane, Toronto, Singapore.

Hunter, A. H., 1984. Soil Fertility Analytical Services in Bangladesh. Consultancy Report, BARC, Dhaka, Bangladesh.

Indian Council of Agricultural Research, 1971. Handbook of Manures and Fertilizers. New Delhi, pp: 307-308.

Nelson, W. L., A. Mehlich and E. Winters, 1953. The development, evaluation, and use of soil tests for phosphorus availability. Agron. J., 4: 153.

Olsen, S. R., C. V. Cole, F. S. Watanable and L. A. Dean, 1954. Estimation of available phosphorus in soils by extraction with sodium carbonate. U.S. Dept. Agric. Cric., pp: 939.

Parihar, S.S. and R. S. Tripathic, 1989. Dry wet nodulation and nutrient uptake in chickpea (*Cicer arietinum*) as influenced by irrigation and phosphorus. Experiment Agric., 25: 349-355.

Rahman, G. K. M. M., M. Jahiruddin, M. I. Ali, M. S. Hoque and M. Q. Hoque, 1995. Effect of soil properties on the extractions of phosphorus and its critical limit for rice. J. Indian Soc. Soil Sci., 43: 452-456.

Rahman, M. H., M. Q. Haque and M. I. Ali, 2000. Effect of phosphorus on dry matter production, uptake and its critical limit for mungbean in different soils of Bangladesh using ^{32}P as traces. Bangladesh J. Soil Sci., 26: 59-95.

Raut, R. S. and O. D. Kothire, 1991. Phosphorus response in chickpea (*Cicer arietinum*) with *Rhizobium* inoculation. Legume Res., 14: 78-82.

Tamhane, R. V., D. P. Motiramani, Y. P. Bali and R. L. Donahue, 1970. Soils: their chemistry and fertility in tropical Asia. Prentice Hall of India Pvt. Ltd., New Delhi, pp: 272.

Waugh, D. L., R. B. Jr. Cate and L. A. Nelson, 1973. International Soil Fertility. Evaluation and Improvement Program. Tech. Bull. No. 7.