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Extractable phosphorus in some soils of Bangladesh and its critical limits for mustard

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Abstract

A pot experiment was conducted at glasshouse of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, with 18 extensively cultivated soils of Bangladesh to evaluate extractable P and to determine its critical limit for mustard. The available P contents in soils were extracted by four methods viz. Olsen, Hunter, Bray II and Nelson. The mean extractable P in soils was found to be in the order of Nelson > Bray 11 > Hunter > Olsen. Considerable variation was found in the amount of extractable P depending on the soils and extractants used. Dry matter yields were remarkably increased with addition of increasing rate of phosphatic fertilizer and the soil having low extractable P responded better to applied P. All extractable P except Nelson correlated positively and significantly with relative yield. Extractable P of all extractants except Nelson was positively and significantly correlated with P content of mustard in all and low pH soils. Phosphorus uptake was also positively correlated with all extractants in all and low pH soils. The critical limits of soil extractable P for mustard for Olsen, Hunter, Bray II and Nelson method were estimated as 8.6, 9.5, 14.5 and 20.0 ppm (Graphical method) and 10.5, 12.5, 16.5, and 16.5 ppm (Statistical method) respectively. Based on B^2 value it may be concluded that Nelson method of P extraction was found to be the best method for estimating P response of mustard.

Keywords: Extractable phosphorus, Relative yield, Dry matter yield, Critical limit, and Mustard

Introduction

Mustard is one of the most important oil crops, occupying the third position in terms of production after soybean and cotton in the world. The average yield of mustard in Bangladesh is very low (0.735 t/ha) compared to many other mustard growing countries (FAO, 2000). Deficiency of nutrition might be a major reason for poor yield of mustard in this country. Phosphorus deficiency is becoming widespread and acute in many soils of Bangladesh as well as in many other countries of the world. Application of phosphorus significantly increased the yield parameters, seed and stover yields, oil and protein content and net return of mustard (Patel and Shelke, 1999). Application of phosphorus also significantly increased plant height, dry matter accumulation / meter row, number of siliqua/ plant, seeds/siliqua, length of siliqua and test weight (1000-seed weight) of mustard (Baldev et. al. 1999). Soil testing and crop response has been recognized as an 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 farmers' 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 farmers' field as well as to help cultivators to increase production and profit considerably through economic and judicious use of fertilizers. In Bangladesh application of fertilizer is being recommended on the basis of different soil fertility classes (BARC, 1997). 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 limits for mustard and to predict the response of mustard to applied P.

Materials and Methods

Eighteen top soils (0-15 cm depth) were collected from 18 soils series of different Agroecological Zones (AEZs) of Bangladesh. The soil series were; Atwari, Manda, Menanagar, Pirgacha, Ranishankail, Gangachara, Jamun, Melandaha, Ghatail, Silmandi, Sonatala, Sara, Barisal, Dumuria, Burichong, Ekdala, Noada and Belabo. The soil samples were air dried, ground and passed through a 2 mm sieve and were analysed for soil texture, pH, organic matter, total N, exchangeable K, Ca and Mg and available S following standard procedures. Available P of soil was measured by using four different extraction methods; (i) 0.5 N $NaHClO_3$, solution at pH 8.5 (Olsen, et. al. 1954) (ii) 0.03 NH_4F + 0.1 N HCl (Bray and 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 M EDTA + 0.1 N NH_4F (Hunter, 1984). There were three levels of P viz. 0, 20 and 40 ppm for each soil. The experiment was laid out in a Randomised Complete Block Design with three replications. A basal application was made with 50 ppm N, 25 ppm K, 15 ppm S, 2 ppm Zn and 1 ppm B. The elements N, P, K, S, Zn and B were applied in the form of solution at the rate of 20ml/pot through NH_4NO_3, KH_2PO_4, KCl, K_2SO_4, $ZnCl_2$ and H_3BO_3 respectively. One Kg soil was taken in each pot and SAFAL a released variety of mustard (developed by BINA) was used as test crop. Nine seeds in each pot were sown on 28.11.2001. Plants were cut at 45 day of growth, dried and dry matter yield was also recorded. Plant samples were analysed for P content (Barton, 1984). The critical limit of extractable P for mustard was determined by two separate methods namely graphical and statistical. In graphical approach the critical levels of extractable P was determined by four extraction procedures and were calculated individually using the method developed by Cate and Nelson, (1965). 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 method (Waugh et. al. 1973) 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 different soil series ranged from 4.5 to 7.57, organic matter content from 0.76 to 1.90% clay from 6.5 to 35.6%, total N 0.07 to 0.26%, available S 6.0 to 40.0 ppm, and exchangeable K^+ from 0.03 to 0.31 m.e% (Table1). The amount of extractable P varied considerably depending on the extractants and soils used (Table 2). The maximum and the minimum amount of P (52 ppm mean of 18 soils)and (13.11 ppm mean of 18 soils) were extracted by Nelson extractant (HCl+H_2SO_4) and by Olsen method ($NaHCO_3$) respectively.

Similar results were also reported by Egashira and Yasmin (1990) for Olsen extractant. The mean values of P extracted by different extractants ranked in the order of Nelson (0.05 N HCl + 0.025 N H_2SO_4) > Bray 11 (0.3 N NH_4F + 0.1 N HCl) > Hunter (0.25 N $NaHCO_3$ + 0.01 M EDTA + 0.01 N NH_4F) > Olsen (0.5 N $NaHCO_3$ + 03 M H_2SO_4) (Table 2).

Table 1. Some important physiochemical properties of different soil series under study

Soil series	USDA Soil Family	% Clay	pH	Organic matter (%)	Total N(%)	Exchangeable K (m.e%)	Available S (ppm)
Atwari	Typic Haplumbrepts	12.0	4.66	1.45	0.15	0.03	24.8
Manda	Aeric Fluvaquents	6.50	6.00	1.40	0.15	0.07	8.0
Menanagar	Typic Fuvaquents	9.50	6.30	1.80	0.12	0.09	8.0
Pirgacha	Udic Ustochrepts	15.2	5.10	1.25	0.12	0.09	10.8
Ranishankail	-Do-	8.0	6.00	1.40	0.14	0.10	6.0
Gangachara	Typic Haplaquepts	14.0	5.15	1.49	0.13	0.11	18.6
Jamun	Aeric Haplaquepts	12.5	5.86	0.90	0.09	0.10	13.9
Melandaha	Aeric Fluvaquents	15.2	5.97	0.76	0.08	0.10	16.1
Ghatail	Aeric Haplaquepts	18.7	5.65	0.97	0.16	0.15	14.9
Silmondi	-Do-	21.1	6.16	1.14	0.26	0.09	11.5
Sonatala	-Do-	17.0	6.23	1.19	0.09	0.12	10.0
Sara	Aquic Eutrochrepts	10.8	7.57	1.03	0.07	0.20	11.3
Barisal	Typic Haplaquepts	35.6	6.60	1.07	0.12	0.25	15.2
Dumuria	Aeric Haplaquepts	28.3	7.00	1.90	0.18	0.31	40.0
Burichong	-Do-	12.5	5.74	1.07	0.11	0.15	12.9
Ekdala	Aeric Albaquepts	35.0	4.80	1.00	0.08	0.09	13.8
Noadda	Ultic Ustochrepts	24.3	4.50	1.63	0.08	0.09	10.7
Belabo	-Do-	14.8	5.50	1.14	0.10	0.12	13.2
Range		6.5-35.6	4.57-7.57	0.76-1.9	0.07-0.26	0.03-0.31	6.0-40.0
Mean		17.83	5.82	1.26	0.12	0.13	14.43

The differences in the amounts of P extracted by different extractants were mainly due to their selectivity in solubilizing different fractions of P to varied extent. Considering the individual soil series, the highest extractable P was found in Ranishankail (123 ppm) and the lowest in Sonatala (3 ppm). Correlation analysis showed that the amount of p extracted by different extractants was positively and significantly correlated with each other except Nelson P (Table 3). The results showed highly positive and significant correlation in between Olsen P and Hunter P (r=0.992**), Olsen P and Bray II P (r=0.977**), Hunter P and Bray II P (r=0.983**), whereas the correlation between Nelson P and Olsen P, Hunter Pand Bray II P were positive but not significant. The results indicated that although the ability of P extraction was different for different extractants, there was a similar trend of P displacement from soil into the solution. This is in agreement with the findings of Rahman *et. al.* (2000) and Islam *et. al.* (2001).

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

Soil series	Extractable P (ppm)			
	Olsen-P	Hunter-P	Bray II-P	Nelson-P
Atwari	9	11	17	88
Manda	9	11	16	20
Menanagar	11	13	18	20
Pirgacha	44	55	72	22
Ranishankail	68	92	123	51
Gangachara	11	12	15	21
Jamun	7	10	20	43
Melandaha	4	5	19	106
Ghatail	5	8	8	91
Silmondi	9	11	21	74
Sonatala	3	4	18	73
Sara	6	8	22	39
Barisal	6	10	10	79
Dumuria	11	7	21	82
Burichong	5	10	15	56
Ekdala	8	8	13	38
Noadda	10	7	9	13
Belabo	10	10	15	20
Range	3-68	4-92	8-123	13-106
Mean	13.11	16.22	25.11	52.0

Table 3. Correlation (r value) among the P results from different extraction methods

	Olsen P	Hunter P	Bray II P	Nelson P
Hunter P	0.992**	-	-	-
Bray II P	0.977**	0.983**	-	-
Nelson P	0.220^{ns}	0.176^{ns}	0.110^{ns}	-

**= Significant at 1% level of probability
NS= Not significant

Correlation between extractable P and soil properties

For low pH soils all the extractable P correlated positively with soil pH and organic matter content except Nelson P. Olsen P, Hunter P and Bray II P correlated negatively with clay content, total N, available S, exchangeable K^+, Ca^{2+} and Mg^{2+} while Nelson P correlated positively with clay, available S, exchangeable K^+ and Mg^{2+}, but the correlation between Nelson P and Ca^{2+} was positive and significant. For high pH soils, Olsen P, Hunter P and Nelson P correlated negatively while Bray II P correlated positively with soil pH (Table 4). Hunter P and Bray II P correlated positively and Olsen P correlated positively and significantly (r=0.771) while Nelson P correlated negatively with organic matter content of soil. In all soils, negative correlation were observed between Olsen P, Hunter P and soil pH whereas the correlations were positive in case of Bray II P and Nelson P. Positive correlations were also found between Olsen P, Bray II P and organic matter. Nelson P correlated positively with other soil properties and positively significantly with clay content (r=0.824*) and Mg^{2+} (r=0.892**). These results are in partial agreement with the findings of Islam *et. al.* (2001).

Table 4. Relationship (r value) of extractable P with selected soil properties

Extractable P	Soils	pH	Organic matter (%)	Clay (%)	Total N (%)	Available S (ppm)	Exchangeable K (m.e %)
Olsen P	All soils	-0.104	0.213ns	-0.288	-0.120	-0.258	-0.165
	Low pH soils	0.145ns	0.317^{ns}	-0.323	-0.160	-0.529	-0.102
	High pH soils	-0.016	0.771^{ns}	-0.016	0.547^{ns}	0.440^{ns}	0.098^{ns}
Hunter P	All soils	-0.275	0.132^{ns}	-0.314	-0.122	-0.316	-0.177
	Low pH soils	0.216^{ns}	0.265^{ns}	-0.351	-0.156	-0.525	-0.062
	High pH soils	-0.223	0.182^{ns}	-0.100	0.343^{ns}	-0.288	-0.311
Bray II P	All soils	0.021^{ns}	0.110^{ns}	-0.353	-0.146	-0.273	-0.140
	Low pH soils	0.264^{ns}	0.201^{ns}	-0.381	-0.171	-0.516	-0.083
	High pH soils	0.303^{ns}	0.230^{ns}	-0.598	0.235^{ns}	0.174^{ns}	-0.175
Nelson P	All soils	0.260^{ns}	-0.326	0.323^{ns}	-0.179	0.446^{ns}	0.295^{ns}
	Low pH soils	0.254^{ns}	-0.529	0.068^{ns}	-0.235	0.479^{ns}	0.041^{ns}
	High pH soils	-0.155	-0.193	0.824*	0.429^{ns}	0.518^{ns}	0.459^{ns}

Total soil (n=18), pH 4.5-7.57;Low pH soil (n=12), pH< 6.0;High pH soils (n=6),>6.0;
**=Significant at 1% level,
*=Significant at 5% level,
ns = not significant

Dry matter yield, relative yield and phosphorus content of mustard

The application of different levels of phosphorus remarkably influenced the dry matter yield of mustard. The dry matter yield in control and phosphorus treated pots ranged from 4.05 to 5.31, 4.42 to 6.02 and 4.61 to 6.12 g/pot respectively (Table 5). The soils having low extractable P responded better to applied P and such soils were Manda. Ghatail,Silmandi, Sonatala, Sara, Barisal, Burichong, Ekdala and Belabo. The relative yield varied from 69.44 to 98.15 percent. The highest percent relative yield was observed from Pirgacha (98.15%) soil where extractable P was high and the lowest was found from Ekdala (69.44%) where extractable P was low. Application of phosphorus considerably influenced the P concentration of mustard (Table 5). The P concentration of mustard varied from 0.31 in control to 0.40% in P treated pots. The differences in these parameters may be due to the variations in available P status and other physicochemical properties of soils. The results are also in agreement with the findings of Rahman and Ali (1994).

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

Soil series	Dry matter yield (g/ pot)			P content (%)			Relative yield (%)
	P_0	P_{20}	P_{40}	P_0	P_{20}	P_{40}	
Atwari	4.28	4.42	4.87	0.26	0.28	0.30	87.89
Manda	4.15	5.06	5.15	0.30	0.30	0.36	80.58
Menanagar	4.14	5.06	5.43	0.30	0.31	0.37	76.24
Pirgacha	5.31	5.41	5.29	0.37	0.43	0.43	98.15
Ranisankail	4.31	4.62	4.61	0.39	0.57	0.70	93.29
Gangachara	**4.42**	5.09	5.10	0.30	0.35	0.34	86.67
Jamun	5.28	5.67	5.42	0.41	0.49	0.50	93.12
Melandaha	4.92	1.93	5.09	0.39	0.42	0.51	96.66
Ghatail	4.05	5.12	5.28	0.28	0.30	0.44	76.71
Silmondi	4.35	5.23	5.47	0.33	0.35	0.36	79.53
Sonatala	4.62	6.02	6.09	0.30	0.32	0.34	75.86
Sara	4.18	5.70	5.32	0.35	0.38	0.48	73.33
Barisal	4.61	5.25	5.07	0.33	0.24	0.27	87.81
Dumuria	4.48	5.37	5.40	0.24	0.33	0.36	82.96
Burichong	4.49	5.67	5.59	0.28	0.32	0.33	79.19
Ekdala	4.25	5.30	6.12	0.30	0.32	0.50	69.44
Noada	4.55	5.10	5.67	0.20	0.25	0.35	80.25
Belabo	4.06	4.97	4.93	0.27	0.28	0.28	81.69
Range	4.05-5.31	4.42-6.02	4.61-6.12	0.2-0.39	0.24-0.57	0.27-0.70	69.44-98.15
Mean	4.47	5.22	5.33	0.31	0.35	0.40	83.30

Correlation between extractable P and biological parameters of mustard

Extractable P of different extractants did not show significant correlation with dry matter yield except Nelson P in High pH soils (r=0.865*), in control pot (Table 6). All extractable P except Nelson P correlated positively and significantly with relative yield for all soils and such correlation was positive in low and high pH soils except Bray II P in high pH soils. Extractable P of all extractants except Nelson P for all & low pH soils was positively and significantly correlated with P content of mustard and in high pH soils such correlation was positively significant only in Bray II P extractant (Table 6). Negative correlation between extractable P and P content of mustard was found in Hunter and Nelson P for high pH soils. Extractable P and P uptake of mustard was positively and significantly correlated only with Bray II P for all and high pH soils and such correlation was positive in all extractants for all and low pH soils.

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

Extractable P	Soils	Dry matter yield	P content	P uptake	Relative dry matter yield
Olsen P	All soils	-0.450	0.610**	0.436^{ns}	0.496*
	Low pH soils	-0.452	0.626*	0.449^{ns}	0.484^{ns}
	High pH soils	-0.432	0.071^{ns}	-0.066	0.165^{ns}
Hunter P	All soils	-0.468	0.633**	0.452^{ns}	0.499*
	Low pH soils	-0.470	0.655*	0.471^{ns}	0.487^{ns}
	High pH soils	-0.626	-0.062	-0.244	0.148^{ns}
Bray II P	All soils	-0.432	0.688**	0.515*	0.504*
	Low pH soils	-0.484	0.699**	0.512^{ns}	0.545^{ns}
	High pH soils	0.322^{ns}	0.799*	0.844*	-0.681
Nelson P	All soils	-0.086	0.039^{ns}	0.007^{ns}	0.155^{ns}
	Low pH soils	-0.224	0.242^{ns}	0.186^{ns}	0.171^{ns}
	High pH soils	0.086^{ns}	-0.570	-0.512	0.659^{ns}

Total soil(n=18), p^H4.5-7.57;Low p^H soil (n=12),p^H<6.0; High p^H soil (n=6), p^H>6.0;
*=Significant at 5% level,
NS = Not significant

Critical limit of phosphorus

The critical level of extractable P for mustard were determined by Graphical method of Cate and Nelson (1965) and Statistical method of Waugh *et al.* (1973). In the Graphical method critical P levels of mustard for Olsen, Hunter, Bray II and Nelson extraction methods were 8.6, 9.5, 14.5 and 20.0 ppm respectively (Table 7). Similar values were also reported by Singh and Bishnoi (1991) for Olsen method and by Kumar and Rao (1994) for Bray II method. In statistical method 10.5, 12.5, 16.5 and 16.5 ppm were found to be critical levels for Olsen, Hunter, Bray II and Nelson extractable P respectively (Table 7). The principle may be considered as higher is the R^2 value, better is the fit. The highest R^2 value (0.17) was obtained from Nelson procedure (Table 7). This suggests that the Nelson's procedure of P extraction is the best for predicting P response of mustard.

Table 7. Critical soil P limits using different extractants as determined by graphical and statistical methods

Soil P extracting methods	Methods for measuring critical P limits		R^2
	Graphical (ppm)	Statistical (ppm)	
Olsen (0.5 N $NaHCO_3$)	8.6	10.5	0.10
Hunter (0.25 N $NaHCO_3$+0.01M EDTA+0.1N NH_4F)	9.5	12.5	0.12
Bray II (0.03N NH_4F+0.1N HCl)	14.5	16.5	0.15
Nelson(0.05N HCl +0.025N H_2SO_4)	20.0	16.5	0.17

Conclusion

The amount of extractable P varied markedly depending on the soils and extractants used. The extracting power of different extractants was in the order of Nelson > Olson > Hunter > Bray II. Influence of soil pH was the most dominant factor in phosphorus extraction. Dry matter yields of mustard were considerably increased with the addition of increasing rate of phosphatic fertilizer and the soils having low extractable P responded better to the applied P. Based on R^2 value it may be concluded that Nelson method of P extraction is the best for estimating P response of mustard.

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