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SOIL SCIENCE

Evaluation of some soil test methods in acid soils for available phosphorus for pea of Senapati district of Manipur (India)

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Abstract

In an field experiment conducted on pea (Pisum sativum L.) during rabi season of 2013-14 in acid soil of Senapati district, Manipur, India phosphorus was given in the form of single super phosphate and levels of P2O5 kg ha-1 (0, 40 and 60) had significant influence on total dry matter yield, phosphorus concentration in plants and phosphorus uptake by plant. Six extractants were tried viz. Bray 1, Bray 2, Mehlich 1, Mehlich 3, Troug and Olsen to assess the available phosphorus status of the acid soils. The suitability of these extractants was in the descending order: Bray 1> Troug> Bray 2> Mehlich 3> Olsen (pH-8.5)> Mehlich 1. Bray's P 1 extractable phosphorus showed the highest and positive correlations with dry matter yield (control) phosphorus content (control), phosphorus uptake (control), Bray's percent yield and uptake. Therefore this extractant may be used as an index of available phosphorus for pea (Arkel) grown on acid soils of Senapati district, Manipur, the critical level being 14 ppm (mg /kg). The critical limit of phosphorus concentration in plant at 40 days of planting was 0.42% according to the graphical procedure of Cate and Nelson (1965) using a scattered diagram.

Highlights

- Almost 85% of soils in the Northeastern region especially in Manipur are moderate to strongly acidic.
- Phosphorous (P) enhances many aspects of plant physiology, including the fundamental processes of photosynthesis, nitrogen fixation, flowering, fruiting (including seed production), and maturation.
- Pea has a relatively high requirement for phosphorus, yield and seed quality can be enhanced by phosphorus.
- Six extractants were tried viz. Bray 1, Bray 2, Mehlich 1, Mehlich 3, Troug and Olsen to assess the available phosphorus status of the acid soils.
- Bray's P1 extractable phosphorus showed the highest and positive correlations with dry matter yield (control) phosphorus content (control), phosphorus uptake (control), Bray's percent yield and uptake.

Keywords: Pea, phosphorus, acid soils, Bray's percent yield, critical limit

The Eastern Himalayan region of India, also called the North Eastern Region (NER), comprises of eight states, namely, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura. The NER of India has geographical area of 26.3 million hectors and population of 45 million. Almost 85% of soils in this region are moderate to strongly acidic (Das *et al*. 2016). Phosphorous (P) enhances many aspects of plant physiology, including the fundamental processes of photosynthesis, nitrogen fixation, flowering, fruiting (including seed production), and maturation. Root growth, particularly development of lateral roots and fibrous rootlets, is encouraged by phosphorous. P uptake by plants is about one-tenth that of nitrogen and one-twentieth that of potassium. Its deficiency is generally not as easy to recognize in plants as are deficiencies in many other nutrients. A P-deficient plant is usually stunted, thin-stemmed, and spindly, but its foliage is often dark, almost bluish, green. Thus, unless much larger, healthy plants are present to make a comparison, P-deficient plants often seem quite normal in appearance. In severe cases, P deficiency can cause yellowing and senescence of leaves. In many acidic soils in developing countries, P deficiency is the main limiting factor for crop production and, therefore, requires the application of P fertilizers for optimum plant growth and production of food and fibre (Attar 2014). However in most developing countries superphosphates, which are the commercially available phosphatic fertilizers, are not produced locally and their supplies to resource poor farmers is rather limited. Phosphorus has a key role in the energy metabolism of all plant cells and particularly for nitrogen fixation in legume crops. Pea has a relatively high requirement for phosphorus (Slinkard and Drew 1988) and yield and seed quality can be enhanced by phosphorus (Pulung 1994, Kabui *et al*. 2015). Phosphorus is needed to promote the development of extensive root systems and vigorous seedlings. Encouraging vigorous root growth is an important step in promoting good nodule development.

Table 1: Physical and chemical characteristics of the soils used for the pot study

Soil characteristic	Mean	Range
pH	5.15	4.50-5.62
Organic carbon(g $kg^{-1)}$	20.35	13.40-24.00
Total N (%)	0.14	0.09-0.22
Available N (kg ha^{-1})	335.14	208.70-423.25
Available P_2O_5 (kg ha^{-1})	39.40	18-64
Available K_2O (kg ha^{-1})	151.90	90.34-243.10
Ca [Cmol(p+)kg^{-1}]	2.74	1.25-4
Mg [Cmol(p+)kg^{-1}]	1.43	0.35-3.20
Clay (%)	53.21	37.90-67.30
Silt (%)	30.82	14.60-40.10
Sand (%)	15.92	8.10-31.30

Knowledge of relationships between soil test methods and phosphorus fractions and plant parameters helps in selecting a suitable soil test method for a particular group of soils. The most appropriate soil test method for a soil would be one which extracts predominantly that fraction of phosphorus which plays a major role in the plant uptake.

Table 2: Amount of available soil P content extracted by various methods (ppm)

Extractant	Range	Mean	References
Bray and Kurtz No.1 0.003 N NH_4F +0.025 NHCl	7.54 - 28.90	15.93	Bray & Kurtz (1945)
Bray No. 2 0.1N HCl+ 0.03N NH_4F	15.44 - 50.06	29.26	Bray & Kurtz (1945)
Mehlich1 (0.0125 MH_2SO_4+ 0.05MHCl)	7.50 - 25.00	13.49	Nelson *et al*. (1953)
Mehlich3 0.2MCH_3COOH, 0.25MNH_4	8.22 - 25.00	16.29	Mehlich (1984)
Olsen P (0.5 M $NaHCO_3$), PH-8.5	6.00 - 22.00	14.34	Olsen *et al*. (1954)
Troug (0.002 NH_2SO_4, PH-3)	11.11 - 41.00	23.67	Troug (1930)

Therefore the present investigation was undertaken to find out the most promising extractant which may predict the availability of phosphorus to pea (Arkel) grown in acid soils.

Materials and methods

The field experiment was conducted during the *rabi* season of 2013-14 at the Krishi Vigyan Kendra-Senapati, Manipur, India. The geographical area of the district is 3271 sq. km with 14.56% of the total geographical area of the state. The average temperature ranges from 4°C to 32°C and average annual rainfall varies from 671 to 1454 mm. It is located between 24° 30′N latitude and 93° 30′E longitude over the globe. The altitude of the district ranges from 800 to 4000 m above MSL. Senapati district has alluvium, lateritic black regur and red ferruginous type of soil (Anonymous 2009). Pot culture experiment was carried out with the objective of studying the critical level of the plant using pea, variety Arkel as test crop. The pot experiment was initiated during Rabi season, 2013. Soils from 20 different places of Senapati District was used and the processed samples (<2mm) were analysed for their physico-chemical characteristics using the standard procedure (Jackson 1973) and reported in Table 1.2.5 kilogram of soil was filled in pots and phosphorus was applied at 0,40 and 60 kg P_2O_5 ha^{-1} through single super phosphate. Similar procedure has also been used by Mahajan *et al*. 2013 in Wheat. The treatments were replicated thrice in a completely randomized design. A basal application of 30: 40 N: K_2O ha^{-1} was applied in the form of urea and MOP in each pot. Pea (Arkel) seeds were sown and thinning was done ten days after sowing keeping four healthy plants in each pot. The crop was harvested 40 days after germination. The plant samples were washed in water and dried in oven at 65 ºC for 48 hr and the dry matter yield was recorded. The samples were then powdered and requisite quantities of the same were digested in nitricperchlororic acid mixture. Phosphorus was determined by using Vanadomolybdophosphoric acid reagent. To test the suitability, six test methods were used (Table 2). The soil samples were shaken for two minutes with soil to solution ratio of 1:10. Extractable phosphorus was determined Spectrophotometrically.

Results and discussion

Extractable phosphorus

The available P obtained with different chemical extractants revealed that the varying amounts of P extracted from different soils depended on the nature of extractant (Table 2). The average of available phosphorus extracted by different chemical extractant varied widely from as low as 13.49 kg P_2O_5 ha^{-1}. (Mehlich 1) to a maximum of 29.26 kg ha^{-1} (Bray 2).Based on the mean values of extractable P, the extractants were arranged in the following decreasing order : Bray 2> Troug> Mehlich 3>Bray 1 > Olsen (pH-8.5)> Mehlich 1. This was in conformity with the findings reported by Jaggi *et al*. 1990, and Ravindra and Ananthanarayana 1999. The higher solubility in Bray's P_2 may be due to its relatively higher strength of acidity and complexing of Al 3+ and Fe 3+ ions with F- ions and consequent release of P adsorbed by these trivalent ions (Ballard and Fiskell, 1974). The lowest quantity of P was extracted by Mehlich 1. This might be due to the presence of weekly buffered salt solution such as acetic acid – sodium acetate solution. Similar finding was also reported by Hesse (1991).

Correlation between different chemical extractants

The data on coefficients of correlation value between various methods of phosphorus extractants (Table 3) reveal that the extractants are closely interrelated, except Olsen and Mehlich 1. Such close relationship between the different extractants suggested that these extractants extracted more or less the same forms of phosphorus indicating the existence of dynamic equilibrium among different forms of phosphorus but relatively to different degrees. Olsen and Mehlich 1 extracted phosphorus did not correlate with other extractants. The Olsen extractant is alkalizing character being poor replacer of phosphorus in acidic soils, the HCO_3^- extractant extract only the free phosphorus, as a result they generally gave poor correlation with Mehlich 3, Bray 1 and Bray 2 which has ability to extract adsorbed, labile and free phosphorus as well be complexing of Al^{3+} and Fe^{3+} with F^-, ions. This observation was corroborated by Ravindra and Ananthanarayana (1999).

Table 3: Simple correlation co-efficient among the different forms of phosphorus

Sl. No.	Forms	Bray 1	Bray 2	Mehlich 1	Mehlich 3	Troug	Olsen (Ph 8.5)
1	**Bray 2**	0.525*					
2	**Mehlich 1**	-0.311	-0.273				
3	**Mehlich 3**	0.679**	0.469*	-0.233			
4	**Troug**	0.366	0.612**	-0.254	0.567**		
5	**Olsen (Ph 8.5)**	-0.131	-0.047	0.462	-0.118	-0.152	

*Significant at 5 % level , ** Significant at 1 % level

Table 4: Simple correlation co-efficient of S P extracted by various extractants with yield and uptake of Pea (Arkel)

Extractant	Yield Parameter				
	Dry matter yield (Control)	P Content (Control)	P uptake (Control)	Bray's % Yield	Bray's % Uptake
Bray 1	0.636**	0.521*	0.773**	0.699**	0.783**
Bray 2	0.463*	0.133	0.535*	0.480*	0.517*
Mehlich 1	-0.319	-0.138	-0.326	-0.091	-0.301
Mehlich 3	0.493*	0.242	0.509*	0.469*	0.578**
Troug	0.475*	0.210	0.310	0.518*	0.308
Olsen	-0.322	-0.076	-0.141	-0.136	-0.004

*Significant at 5 % level , ** Significant at 1 % level

Correlations of soil P with yield and uptake

The simple correlation coefficients between soil test results and yield were presented in Table 4. The data revealed that different soils significantly affected the dry matter production of pea and also P uptake by pea. The relative yield ranged from 35.88-97.93 %, phosphorus content (control) 0.29-0.63 % and average P uptake from 3.42-16.30 %. Out of the six extractants, four were found to be significantly correlated with Bray's percent yield and three were also significantly correlated with phosphorus uptake by the crop. Among the extractants used for this investigation, Bray P_1 showed higher degree of co-efficient of correlation with Bray,s percent yield as well as phosphorus uptake by the pea, with ,r, values of 0.699 ** and 0.773 ** respectively than the other extractants, that is , Bray 1> Troug> Bray 2> Mehlich 3> Olsen (pH-8.5)> Mehlich 1. Simple correlation studies between available phosphorus of the soils by different methods and some selected indices of plant growth indicated that all the extractants, except Mehlich 1 and Olsen were suitable for estimation of available phosphorus for Pea plant but with varying degrees So, Bray P_1 was the most suitable test for determining available soil phosphorus in the studied soil as the degree of co- efficient of correlation between the quantities of P extracted by this extractant and yield parameters were of higher order. Base on the simple correlation, it can be suggested that for acid soils of Senapati District, Manipur, Bray-P_1 extractable phosphorus is found to be the suitable test for evaluation of available phosphorus in the soils for growing pea plants.

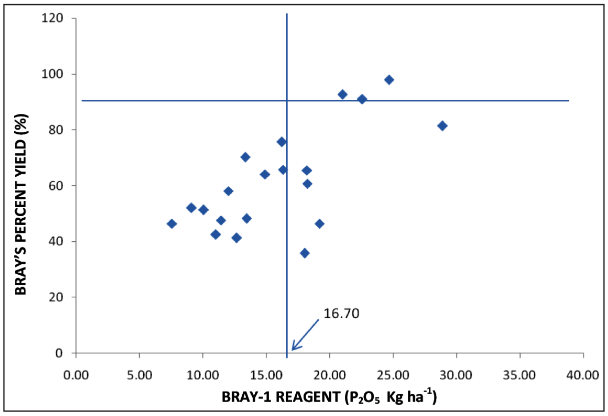

Fig. 1: Relationship between Bray 1and Bray's Per cent Yield

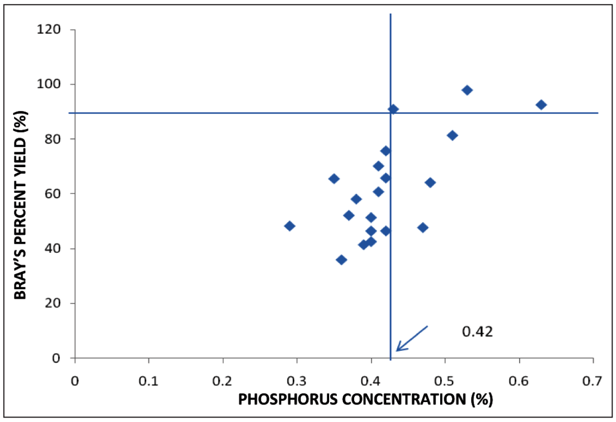

Fig. 2: Relationship between Phosphorus Concentration and Relative Yield of Pea

Critical level of phosphorus

It was observed that the critical level of phosphorus in the soils for growing of pea plants varied with the methods of phosphorus extraction. According to graphical procedure of Cate and Nelson (1965), the critical level of soils ranged from 14.30 to 25.00 kg $P_2O_5 ha^{-1}$ depending upon the methods of phosphorus extraction. Critical level of available phosphorous of the soils were 16.70 kg P_2O_5 ha^{-1} for Bray 1, 23.50 kg P_2O_5 ha^{-1} for Troug, 14.30 kg P_2O_5 ha^{-1} for Mehlich 3, 25.00 kg P_2O_5 ha^{-1} for Bray 2.

A high degree of correlation between Bray P_1 reagent extractable P and Bray's percent yield against BrayP_1 reagent extractable P was found to be 16.70 ppm (Fig 1) as the critical limit of available P in these soils for demarcating the phosphorus responsive soil from the non responsive ones. Similar observations were also reported by Tandon 1987, Gupta and Vyas 1993, Mullen et al. 2009 and La Barge (2013). The result revealed that the critical level of phosphorus concentration in pea plant was found to be 0.42 % as shown in scatter diagram (Fig 2) partitioning the dimentional percentage yield versus phosphorus content in 40 days old pea plants scattered into two groups. Similar observations were also reported by Ali et al. 2006 and Mallarino 2010. For estimating the critical plant tissue concentration of phosphorus in pea, a value of 0.42 per cent is the critical level. A value of 0.42 per cent plant tissue phosphorus concentration could distinguish the phosphorus deficient plants

Conclusion

Phosphorous (P) enhances many aspects of plant physiology, including the fundamental processes of photosynthesis, nitrogen fixation, flowering, fruiting (including seed production), and maturation. Pea has a relatively high requirement for phosphorus, yield and seed quality can be enhanced by phosphorus. Six extractants were tried viz. Bray 1, Bray 2, Mehlich 1, Mehlich 3, Troug and Olsen to assess the available phosphorus status of the acid soils. Bray's P_1 extractable phosphorus showed the highest and positive correlations with dry matter yield (control) phosphorus content (control), phosphorus uptake (control), Bray's percent yield and uptake. Therefore this extractant may be used as an index of available phosphorus for pea (rkel) grown on acid soils of Senapati district, Manipur.

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