Evaluation of some soil test methods in acid soils for available phosphorus for soybean of Imphal East District, Manipur (India)

Wangkhem Herojit Meetei¹, Herojit Singh Athokpam¹*, Raj Kumar Kumarjit Singh¹, Linthoi Watham¹, Nandini Chongtham¹, Konthoujam Nandini Devi¹, Naorem Brajendra Singh¹, Khwairakpam Lenin Singh¹ and Naorem Janaki Singh²

¹Central Agricultural University, Imphal-795004, Manipur, India.
²College of Post-Graduate Studies, CAU, Barapani, Meghalaya, India.

Received 11 December, 2013; Accepted 9 February, 2015

Evaluation of nutrient status in soil is important for nutritional, environmental and economical aspects. Phosphorus is a very important nutrient for leguminous crops. In order to evaluate the phosphorus availability, six soil test methods were carried out for predicting response of soybean to phosphorus application on twenty surface soils (0 - 15 cm) of Imphal East District, Manipur were studied. The suitability of these extractants was in the descending order: Bray P 1 > Mehlich P1 > Bray P2 > Troug P > Olsen P > Morgan P. Bray’s P, extractable phosphorus showed the highest and positive correlations with 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 soybean (JS-335) grown on acid soils of Imphal East District, Manipur, the critical level being 13 ppm (mg kg⁻¹). The critical limit of phosphorus concentration in plant at 40 days of planting was 0.22%.

Key words: Phosphorus, acid soils, Bray’s percent yield, soybean, critical limit.

INTRODUCTION

Phosphorus deficiency in plants has been reported from various parts of India. The responses of oilseeds to applied phosphorus, particularly soybean had been reported by many workers. Soil testing allows one to access a soil’s current nutrient status and decide on appropriate fertilizer rates to maximize crop production. But no information is available on the status of available phosphorus in these soils. The knowledge of relationship between soil test methods and soil phosphorus fractions help in selecting a suitable soil test method for a particular soil to grow the crop profitable. The most appropriate soil test method for a soil would be one which extracts predominantly that fraction of phosphorus playing the major role towards plant uptake. Therefore, the present investigation was planned to select the most promising extractant which may predict the availability of

*Corresponding author. E-mail: hathokpam@yahoo.in
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Table 1. Physical and chemical characteristics of the soils used for the pot study.

| Soil characteristic | Mean  | Range          |
|---------------------|-------|----------------|
| pH                  | 5.43  | 4.50 - 5.97    |
| Organic carbon g kg\(^{-1}\) | 16.30 | 9.80 - 23.00   |
| Total N (%)         | 0.26  | 0.10 - 0.41    |
| Available N (kg ha\(^{-1}\)) | 322.60 | 245.10 - 389.39 |
| Available P\(_2\)O\(_5\) (kg ha\(^{-1}\)) | 41.47 | 9.92 - 66.46  |
| Available K\(_2\)O (kg ha\(^{-1}\)) | 208.64 | 163.29 - 252.67 |
| Ca\([cmol(p^+) kg\(^{-1}\) soil] | 3.21  | 1.50 - 5.20    |
| Mg\([cmol(p^+) kg\(^{-1}\) soil] | 3.10  | 1.41 - 5.10    |
| Clay (%)            | 51.62 | 26.50 - 74.32  |
| Silt                | 24.12 | 11.84 - 34.00  |
| Sand                | 24.26 | 7.00 - 61.66   |

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

| Extractant            | Range       | Mean   | References               |
|-----------------------|-------------|--------|--------------------------|
| Bray’s P\(_1\)        | 4.43-29.67  | 18.49  | Bray and Kurtz (1945)    |
| Bray’s P\(_2\)        | 7.71-27.32  | 20.17  | Bray and Kurtz (1945)    |
| 0.5 M NaHCO\(_3\)     | 5.45-30.02  | 17.40  | Olsen et al. (1954)      |
| Truog-P Truog P       | 12.10-30.64 | 19.29  | Truog (1930)             |
| Morgan reagent        | 3.67-12.79  | 8.81   | Morgan (1937)            |
| Mehlich-P Mehlich P\(_1\) | 2.17-22.51  | 16.59  | Mehlich (1978)           |

phosphorus to soybean (JS-335) grown in acid soils.

MATERIALS AND METHODS

Twenty soils samples (0 -15 cm) were collected from various cultivated fields of Imphal East District, Manipur. The physical and chemical characteristics of these soils were determined by standard methods (Jackson, 1973) and reported in Table 1. Four kilograms of soil was filled in earthen pots and phosphorus was applied at 0, 60 and 90 kg P\(_2\)O\(_5\) ha\(^{-1}\) through single superphosphate. The treatments were replicated thrice in a completely randomized design. A basal dose of 20:60 kg NK ha\(^{-1}\) was applied in the form of urea, and muriate of potash in each pot. Soybean (var.JS-335) seeds were sown and thinned to six plants after ten days of sowing. The pots were irrigated with distilled water as and when required. The crop was harvested 40 days after germination.

The plant samples were washed in water and dried in oven at 65°C for 48 h and the dry matter yield was recorded. The samples were then powdered and requisite quantities of the same were digested in nitric-perchloric acid mixture. Phosphorus was determined by using vanadomolbdophosphoric acid reagent.

To test the suitability, six soil 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). Based on the mean values of extractable P, the extractants were arranged in the following decreasing order: BrayP\(_2\) > Truog P > BrayP\(_1\) > Olsen P > Mehlich P\(_1\) > Morgan P. This was in conformity with the findings reported by Jaggi et al. (1990) and Ravindra and Ananthanarayana (1999). The higher solubility in Bray 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 Morgan reagent. 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 (1971).

Correlation between different chemical extractants

The data on the simple correlation coefficients among the different methods of phosphorus extractants (Table 3) revealed that the extractants were closely interrelated. Such a close relationship between the different extractants suggested that these extractants were able to extract more or less the same forms of phosphorus indicating the existence of dynamic equilibrium among different forms of phosphorus but relatively to different
Table 3. Simple correlation coefficients among the different methods of phosphorus extraction.

| Extractants      | Bray-P1 | Bray-P2 | Olsen-P | Mehlich-P1 | Truog-P | Morgan-P |
|------------------|---------|---------|---------|------------|---------|----------|
| Bray-P1          | Bray P1 | 1       | 0.732** | 0.680**    | 0.731** | 0.704**  |
| Bray-P2          | Bray P2 | 1       | 0.511*  | 0.721**    | 0.572** | 0.539**  |
| Olsen-P          | Olsen P | 1       | 0.677** | 0.713**    | 0.978** |
| Mehlich-P1       | Mehlich P1 | 1       | 0.658** | 0.698**    |
| Truog-P          | Truog P | 1       | 0.630** |
| Morgan-P         | Morgan P | 1 |

*Significant at 5% level; ** Significant at 1% level.

Table 4. Simple correlation coefficient of S P extracted by various extractants with yield and uptake of soybean (JS-335).

| Extractants      | Yield parameter |
|------------------|-----------------|
|                  | P content (control) | Total P uptake (control) | Bray’s % yield | Bray’s % uptake |
| Bray’s P1        | 0.573**          | 0.687**                | 0.670**        | 0.709**         |
| Bray’s P2        | 0.507*           | 0.563**                | 0.482*         | 0.451*          |
| 0.5 M NaHCO3     | 0.433            | 0.512*                 | 0.429          | 0.476*          |
| Truog-P          | 0.445*           | 0.532**                | 0.463*         | 0.439           |
| Truog P          | 0.434            | 0.491*                 | 0.381          | 0.467*          |
| Morgan reagent   | 0.497*           | 0.502*                 | 0.563*         | 0.525*          |
| Mehlich-P1       | 0.497*           | 0.502*                 |               |
| Mehlich P1       | 0.497*           | 0.502*                 |               |

*Significant at 5% level; ** Significant at 1% level.

degrees. Significant correlation between extractable phosphorus by all the procedures indicates that they extract similar pool of phosphorus in the soils but with varying degree. Similarly, Bhattacharya et al. (1990) and Jaggi (1991) reported that the transformation and availability of P in the soils was dependent on its various forms.

Correlations of soil P with yield and uptake

The simple correlation coefficients of 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 soybean and also P uptake by soybean. The relative yield ranged from 46.70 to 95.32%, P content (control) 0.16 to 0.45%, and average P uptake from 6.81 to 24.67 mg pot⁻¹. Out of the six extractants, four were found to be significantly correlated with Bray’s percent yield and five were also significantly correlated with P uptake by the crop. Among the extractants used for this investigation, Bray P1 showed higher degree of co-efficient of correlation with Bray’s percent yield as well as phosphorus uptake by the soybean, with ‘r’ values of 0.670** and 0.709**, respectively than the other extractants, that is, Bray P1 > Mehlich P1 > Bray P2 > Truog P > Bray P1 > Morgan P. So, Bray P1 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 Imphal East District, Manipur, Bray-P1 extractable...
phosphorus is found to be the suitable test for evaluation of available phosphorus in the soils for growing soybean plants.

**Critical level of phosphorus**

It was observed that the critical level of phosphorus in the soils for growing of soybean plants varied with the methods of phosphorus extraction. According to graphical procedure of Cate and Nelson (1965), the critical level of soils ranged from 13 to 20.2 ppm phosphorus depending upon the methods of phosphorus extraction. A high degree of correlation between Bray P\(_1\) reagent extractable P and Bray’s percent yield against Bray P\(_1\) reagent extractable P was found to be 13 ppm (Figure 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 LaBarge (2013).

The result revealed that the critical level of phosphorus concentration in soybean plant was found to be 0.22% as shown in scatter diagram (Figure 2) partitioning the dimensional percentage yield versus phosphorus content in 40 days old soybean plants scattered into two groups. Similar observations were also reported by Ali et al. (2006) and Mallarino (2010).
Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGEMENT

The authors are thankful to the Dean, College of Agriculture, Central Agricultural University Imphal for financial help in conducting the research experiment.

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