

Comparison of Routine Laboratory Methods for the Estimation of Plant Available Phosphorus in Soils of the Low Country Intermediate Zone of Sri Lanka

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ABSTRACT. *Nine routine laboratory methods for the estimation of plant available soil Phosphorus were compared and evaluated with respect to ten soil series located within the Low Country Intermediate Zone of Sri Lanka. Relative Yields (RY) of Panicum maximum and Pueraria phaseoloides grown in pots filled with the soils, and placed in a greenhouse with and without phosphate fertilizer, but with a basal treatment of nitrogen, potassium and magnesium fertilizer were employed as the plant index for soil phosphorus status. Soil phosphorus status of each soil prior to treatment was evaluated by the following laboratory methods, (i) Bray and Kurtz I, (ii) Bray and Kurtz II, (iii) Olsen's bicarbonate extraction, (iv) 0.01 M CaCl₂ extraction, (v) H₂O extraction (vi) Anion Exchange Resin (AER) method, (vii) Anion Exchange Resin + Cation Exchange Resin (AER+CER) method, (viii) 2.5% acetic acid (HAc) extraction and (ix) 5% acetic acid extraction.*

Soil phosphorus data obtained by each laboratory method were correlated with relative yields corresponding to each indicator plant. The suitability of the method was evaluated upon the following criteria: (i) the degree of fitness of the soil phosphorous correlation to the Cate-Nelson model and (ii) the low crop specificity of the critical soil phosphorus levels of each soil test method.

Olsen's bicarbonate extraction, 2.5% acetic acid extraction, AER method and AER+CER method were found to be the most suitable laboratory methods for the estimation of plant available phosphorus of soils of the Low country Intermediate Zone of Sri Lanka.

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INTRODUCTION

The Low Country Intermediate Zone of Sri Lanka is important as far as agricultural production is concerned. In this area, coconut is cultivated as the major plantation crop, while minor crops, such as, coffee, banana, ginger, turmeric *etc.*, are also cultivated as intercrops under coconut. Soils in this region are generally deficient in phosphorus, (Loganathan *et. al.*, 1982) and therefore an effective phosphate fertilizer recommendation programme is essential for such a wide range of crop varieties cultivated in this region. Soil phosphorus estimation by laboratory methods is of major importance in such a programme. A large number of soil phosphorus tests for plant available soil phosphorus estimation are found in literature; but none of the methods can be recommended for any soil, unless such methods are evaluated and properly calibrated with respect to a particular crop-plant combination. Therefore, the objective of the present study was to compare and evaluate different routine methods for estimation of plant available soil Phosphorus with respect to different kinds of soils located within the Low Country Intermediate Zone of Sri Lanka.

MATERIALS AND METHODS

Ten soil series were used for the study: four from the coastal plain, two from an alluvial flood plain and four from the mantled plain. Soil samples were collected from A and B horizons of each series separately. Sampling depths corresponding to A and B horizons of each series, and common soil properties of each soil are given in Table 1.

Soils were passed through a 6 mm sieve at their field moist state, filled into polypropylene pots and packed up to 1.5 L mark, by gently tapping each pot against a table-top until no further change in soil volume occurred. Constant soil volume in pots was preferred to constant soil weight, because the amount of nutrients available to a plant in the field depends on the available soil volume rather than the available soil weight. Each soil, filled into eight pots, was treated with two phosphorus levels *viz.*, four pots with no phosphorus application (-P) and four pots with phosphorus application at the rate of 1 g triple super phosphate (46% P₂O₅) per pot (+P). Each pot was treated with a basal dose of 0.16 g ammonium sulphate (20.6% N), 0.2 g muriate of potash (60% K₂O) and 0.1 g magnesium sulphate (16% MgO).

Table 1. Common properties of soils and the sampling depth.

| Soil series | Horizon | Sampling depth (cm) | pH 1:5 Soil:H ₂ O | EC μ mho /cm | Organic matter(%) | % sand | % silt | % clay |
|------------------|---------|---------------------|------------------------------|------------------|-------------------|--------|--------|--------|
| Weliketiya(WEL) | A | 0-15 | 5.18 | 34.88 | 0.22 | 94.59 | 1.85 | 3.38 |
| Weliketiya | B | 15-30 | 5.12 | 44.70 | 0.11 | 89.25 | 3.90 | 2.03 |
| Madampe (MDP) | A | 0-10 | 5.73 | 6.19 | 0.45 | 90.00 | 3.63 | 2.10 |
| Madampe | B | 10-20 | 5.19 | 35.64 | 0.22 | 87.40 | 4.95 | 3.40 |
| Rathupasa(RAT) | A | 0-18 | 5.67 | 9.2 | 10.34 | 92.55 | 4.08 | 2.15 |
| Rathupasa | B | 18-36 | 5.67 | 22.05 | 0.24 | 93.70 | 3.78 | 2.15 |
| Sudu(SUD) | A | 0-8 | 5.75 | 18.27 | 0.22 | 95.01 | 1.00 | 3.80 |
| Sudu | B | 8-16 | 5.54 | 32.62 | 0.17 | 96.00 | 1.15 | 3.58 |
| Welipelessa(WEP) | A | 0-11 | 5.33 | 28.09 | 0.34 | 87.55 | 4.15 | 3.98 |
| Welipelessa | B | 11-22 | 5.76 | 28.09 | 0.29 | 87.95 | 6.58 | 1.85 |
| Palugaswewa(PAL) | A | 0-14 | 5.55 | 28.84 | 0.25 | 88.49 | 3.80 | 3.98 |
| Palugaswewa | B | 14-28 | 5.78 | 34.13 | 0.28 | 74.85 | 11.25 | 7.93 |
| Tambarawa(TAM) | A | 0-15 | 5.35 | 39.41 | 0.47 | 89.08 | 3.65 | 4.10 |
| Tambarawa | B | 15-30 | 5.44 | 36.39 | 0.34 | 87.09 | 4.08 | 3.95 |
| Andigama(AND) | A | 0-15 | 5.90 | 45.08 | 1.27 | 60.30 | 8.40 | 26.60 |
| Andigama | B | 15-30 | 5.79 | 29.60 | 0.98 | 60.00 | 8.43 | 27.80 |
| Kurunegala(KUR) | A | 0-10 | 5.03 | 46.81 | 1.40 | 74.19 | 5.85 | 17.58 |
| Kurunegala | B | 10-20 | 4.99 | 32.62 | 0.81 | 71.29 | 5.28 | 18.68 |
| Melsiripura(mel) | A | 0-13 | 5.52 | 44.55 | 2.06 | 49.00 | 10.73 | 32.28 |
| Melsiripura | B | 13-26 | 4.62 | 19.78 | 0.82 | 54.22 | 10.45 | 30.15 |

For +P and -P treatments of each soil, pots were prepared in duplicate. Pots were kept in a greenhouse for two weeks after treatment application and their moisture status was maintained at 90% field capacity. After two weeks, pre-germinated *P. phaseoloides* seedlings were planted in 4 pots of each soil, i.e., 2 pots of -P treatment and 2 pots of +P treatment. Similarly *P. maximum* cuttings were also planted in the remaining 4 pots: 2 pots of -P and 2 pots of +P treatments. The two plants are different in their P uptake mainly due to physiological differences of each species. During their initial growth stage, legumes need more phosphorus than grasses, because of nodule formation in roots. Pots were arranged in rows according to plant species, and different soils receiving +P and -P treatments were randomized within the row. The duplicate treatment of each soil was kept in separate rows and randomized similarly.

Three months after planting, *P. phaseoloides* pots were dismantled and fresh and dry weights of stems and leaves were recorded. *P. maximum* was cut at one month intervals for four months, and fresh and dry weights of shootings were recorded. The same basal doses of N, K and Mg as at the initial stage were applied after each cutting of *P. maximum*, and pots were dismantled after four months.

According to pH measurement in 1:5 soil-water suspension (Table 1), ten soils (including A and B horizons) prior to P treatment showed moderately acidic reaction (pH 5.5-6.0), eight soils showed strongly acidic reaction (pH 5.0-5.5) and two soils showed very strongly acidic reaction (pH 4.5-5.0) (Trough, 1948). Therefore, nine routine laboratory methods with different extractants were used for P estimation: four acidic extractants (5% acetic acid, 2.5% acetic acid, Bray and Kurtz I and II) four neutral extractants (anion exchange resin + cation exchange resin, anion exchange resin, 0.01 M CaCl₂ and H₂O extraction) and one basic extractant (Olsen's bicarbonate solution).

Air dried 2 mm sieved soils prior to treatment application were used for each analysis. Phosphorus in solution resulting in each extraction was estimated by the molybdenum-blue method (Murphy and Riley, 1962).

2.5% acetic acid extraction

A sample of 2.5g of soil was shaken with 100 ml of 2.5% (v/v) acetic acid solution for 2 h. The mixture was filtered through Whatman No 42

filter paper (Anonymous, 1985); and the filtrate was analyzed for phosphorus.

5% acetic acid extraction

The same procedure as above was adopted, except that the concentration of acetic acid was 5% (v/v) (Anonymous, 1985).

Olsen's bicarbonate extraction

Five grams of soil was shaken with 100 ml of 0.5 M sodium bicarbonate solution (pH 8.5) for 30 minutes. The mixture was filtered through Whatman No 42 filter paper and polyacrylamide was added as a decolourizing agent. The pH of the filtrate was adjusted to 5 using para-nitrophenol indicator; and the filtrate was analyzed for phosphorus (Olsen *et al.*, 1954).

Bray and Kurtz I extraction

Three grams of soil was shaken with 20 ml of extraction solution (0.03M NH_4F and 0.025M HCl) for one minute. The mixture was filtered through Whatman No 42 filter paper; and the filtrate was analyzed for phosphorus (Bray and Kurtz, 1945, Olsen and Sommers, 1982).

Bray and Kurtz II extraction

Same procedure as above was adopted, except that the concentration of extracting solution was 0.03 M NH_4F and 0.1 M HCl (Bray and Kurtz, 1945).

H₂O extraction

A sample of 2.5g of soil was moistened using 5 ml of demineralized water and kept for 22 h. After 22 h, soils were shaken for 1 h with 145 ml of demineralized water, filtered through Whatman No 42 filter paper; and the filtrate was analyzed for phosphorus (Van der Paauw, 1971).

0.01 M CaCl₂ extraction

Five grams of soil was shaken for 16 h with 0.01 M CaCl₂ solution, filtered through Whatman No 42 filter paper; and the filtrate was analyzed for phosphorus (Schofield, 1955).

Anion exchange resin + cation exchange resin (AER+CER) extraction

Five grams of soil was weighed into a 250 ml polypropylene bottle, and 100 ml distilled water, 3 ml of cation exchange resin (Duolite 255, NH₄⁺) and 4 ml of anion exchange resin (IRA 400, Cl⁻) filled into separate mesh bags were added to each bottle. The contents were shaken in an end-over-end shaker for 16 h. The resin bags were recovered and washed with distilled water to make them free of soil residues. Phosphate sorbed onto resins were eluted by shaking each pair of resin bags in 50 ml 1 M NH₄Cl solution for 30 minutes; and the elute was analyzed for phosphorus (Somasiiri and Edwards, 1992).

Anion exchange resin (AER) extraction

Five grams of soil was weighed into a 250 ml polypropylene bottle, and 100 ml distilled water and 4 ml of anion exchange resin (IRA 400 Cl⁻) in a mesh bag were added to each bottle. The contents were shaken in an end-over-end shaker for 16 h. The resin bags were recovered, washed with distilled water to make them free of soil residues and absorbed phosphate onto resin was eluted by shaking each resin bag in 50 ml of 1M NH₄Cl solution for 30 minutes. The elute was analyzed for phosphorus.

Relative Yield (RY %)

Relative Yield (RY) of the two crops in each soil was calculated as:

$$RY (\%) = \frac{\text{Yield at - P treatment}}{\text{Yield at + P treatment}} (100)$$

The cumulative dry weight of shootings over the experimental period was taken as the yield of each crop.

RESULTS AND DISCUSSION

Laboratory estimates of phosphorus in different soils obtained by individual methods varied over a wide range (Table 2). Also, different methods gave different estimates for the phosphorus status of the same soil. 0.01 M CaCl₂ and H₂O extractions gave very low values for soil Phosphorus compared to other methods. Generally, values for soil Phosphorus obtained by Bray and Kurtz II method (pH 1.36) were lower than that by Bray and Kurtz I (pH 2.47) method, with the exception of A horizon of Melsiripura series. Also, P estimations by 5% acetic acid (pH 2.24) were lower than 2.5% acetic acid (pH 2.40), except for B-horizon of Palugaswewa series. It indicates that the increased acidity of individual extractants tend to decrease the Phosphorus extractability from soils. Although anion exchange resin shows a neutral reaction in the soil/solution/resin system, anion exchange resin in the presence of cation exchange resin extracted a greater quantity of soil Phosphorus than anion exchange resin alone. This tendency is very similar to previous observations by Vaidyanathan and Talibudeen (1970). Although Olsen's bicarbonate extractant is alkaline, its P values were also of a similar magnitude to those by acidic extractants, with the exceptions of high-P soils, such as, Palugaswewa and Melsiripura series.

Cate and Nelson (1971) showed that soil test correlation data fit better to two population model (Cate-Nelson model) than continuous functions, such as Mitscherlich, linear, quadratic *etc.* Cate and Nelson statistical model (Cate and Nelson, 1971) provides a method for determining the dividing line, or the critical level between two categories of soils; viz., high probability of response (low soil Phosphorus status) and low probability of response (high soil Phosphorus status) to applied phosphorus.

Each soil Phosphorus data set (Table 2) was arranged in the ascending order with corresponding RY values for each crop (Table 3), and by a simple iterative process a series of R² values were obtained for arbitrary divisions made into high and low P status made at various levels of soil Phosphorus. The R² was calculated for each arbitrary division and the division at which R² becomes maximum is taken as the critical level of soil Phosphorus for the particular soil-plant combination, with respect to the method tested. The value of R² is also an indication of the degree of fitness of the data set to the model. The calculated R² values, and the critical level for each soil Phosphorus test corresponding to two different crops are given in Table 4.

Table 2. Soil Phosphorus estimations by different laboratory techniques.

| Soil series | AER+CER | AER | 2.5% HAc | 5% HAc | Bray & Kurtz I | Bray and Kurtz II | Olsen's P | 0.01M CaCl ₂ -P | H ₂ O-P |
|-------------|---------|-------|----------|--------|----------------|-------------------|-----------|----------------------------|--------------------|
| WEL-A | 2.63 | 3.24 | 6.40 | 4.25 | 14.82 | 10.44 | 6.62 | 0.10 | 0.13 |
| WEL-B | 1.38 | 1.82 | 4.07 | 3.29 | 7.85 | 4.84 | 3.95 | 0.14 | 0.00 |
| MDP-A | 2.89 | 2.31 | 3.85 | 1.42 | 5.78 | 3.69 | 3.50 | 0.09 | 0.38 |
| MDP-B | 0.64 | 1.09 | 4.56 | 0.85 | 5.03 | 2.67 | 3.18 | 0.13 | 0.13 |
| RAT-A | 14.44 | 3.36 | 10.06 | 7.92 | 27.45 | 13.45 | 7.38 | 0.17 | 0.00 |
| RAT-B | 4.44 | 3.16 | 6.86 | 4.14 | 25.18 | 10.09 | 6.24 | 0.34 | 0.00 |
| SUD-A | 3.24 | 3.04 | 7.16 | 4.46 | 7.36 | 6.31 | 5.60 | 0.13 | 0.00 |
| SUD-B | 11.11 | 3.42 | 7.45 | 4.73 | 12.27 | 8.14 | 6.43 | 0.18 | 0.58 |
| WEP-A | 1.78 | 1.60 | 5.19 | 1.28 | 5.67 | 3.62 | 3.38 | 0.19 | 0.00 |
| WEP-B | 0.89 | 1.13 | 4.57 | 0.95 | 4.46 | 1.78 | 2.73 | 0.13 | 0.00 |
| PAL-A | 25.29 | 15.78 | 28.35 | 26.69 | 64.23 | 41.79 | 14.95 | 0.13 | 4.66 |
| PAL-B | 26.49 | 22.00 | 26.26 | 26.90 | 74.57 | 56.10 | 29.52 | 0.13 | 5.00 |
| TAM-A | 2.91 | 2.93 | 4.77 | 3.64 | 5.67 | 4.82 | 4.01 | 0.12 | 0.26 |
| TAM-B | 2.33 | 2.24 | 3.34 | 2.39 | 4.26 | 3.67 | 3.18 | 0.07 | 0.13 |
| AND-A | 1.36 | 1.87 | 2.60 | 0.53 | 3.60 | 3.16 | 2.99 | 0.12 | 0.38 |
| AND-B | 1.11 | 0.91 | 2.38 | 1.13 | 3.13 | 1.33 | 2.48 | 0.11 | 0.51 |
| KUR-A | 3.02 | 3.09 | 3.04 | 2.21 | 4.05 | 3.64 | 4.90 | 0.10 | 0.38 |
| KUR-B | 1.33 | 1.96 | 2.70 | 0.97 | 3.60 | 1.91 | 3.21 | 0.09 | 0.00 |
| MEL-A | 272.60 | 75.84 | 282.51 | 218.60 | 32.12 | 186.20 | 36.58 | 0.12 | 6.02 |
| MEL-B | 0.31 | 0.31 | 1.70 | 0.91 | 2.56 | 2.69 | 3.69 | 0.12 | 0.38 |

Table 3. Relative yield (RY %) of *P. phaseoloides* and *P. maximum* in each soil series.

| Soil series | <i>P. maximum</i> | <i>P. phaseoloides</i> |
|-------------|-------------------|------------------------|
| WEL-A | 74.96 | 54.21 |
| WEL-B | 75.49 | 23.10 |
| MDP-A | 48.51 | 19.05 |
| MDP-B | 44.76 | 16.23 |
| RAT-A | 95.48 | 80.18 |
| RAT-B | 70.13 | 59.76 |
| SUD-A | 68.89 | 122.87 |
| SUD-B | 84.83 | 125.39 |
| WEP-A | 43.83 | 9.32 |
| WEP-B | 31.41 | 5.27 |
| PAL-A | 87.93 | 83.67 |
| PAL-B | 28.26 | 73.26 |
| TAM-A | 68.69 | 42.88 |
| TAM-B | 54.37 | 20.04 |
| AND-A | 59.48 | 8.64 |
| AND-B | 39.81 | 3.09 |
| KUR-A | 73.58 | 37.72 |
| KUR-B | 60.41 | 7.47 |
| MEL-A | 102.46 | 80.80 |
| MEL-B | 101.06 | 70.48 |

R^2 values were less than 0.403 for 0.01M $\text{CaCl}_2\text{-P}$ and $\text{H}_2\text{O-P}$ correlations, but greater than 0.477 for all the other methods. The highest R^2 value of 0.619 for *P. maximum* was resulted in by Olsen's bicarbonate-P correlation, but the highest R^2 value of 0.682 for *P. phaseoloides* was resulted in by both 2.5% HAc-P and AER+CER-P correlations. It follows that the degree of fitness of 0.01 M $\text{CaCl}_2\text{-P}$ and $\text{H}_2\text{O-P}$ correlations to the Cate-Nelson model is low, but those of other methods are high.

Table 4. R² critical soil Phosphorus levels of each soil test method and difference of critical P levels between the two crops.

| Soil test method | R ² | Critical P Level | | Difference of critical P levels between the two crops | |
|--------------------------|----------------|------------------|----------|---|-------|
| | | Panicum | Pueraria | | |
| AER + CER | 0.499 | 0.682 | 4.44 | 3.02 | 1.42 |
| AER | 0.499 | 0.616 | 3.24 | 2.93 | 0.31 |
| 2.5% HAc | 0.499 | 0.682 | 7.16 | 6.40 | 0.76 |
| 5% HAc | 0.499 | 0.677 | 4.46 | 3.64 | 0.82 |
| Bray and Kurtz I | 0.477 | 0.557 | 25.18 | 5.78 | 19.40 |
| Bray and Kurtz II | 0.477 | 0.677 | 10.44 | 4.84 | 5.60 |
| Olsen's P | 0.619 | 0.677 | 3.50 | 4.90 | 1.40 |
| 0.01 M CaCl ₂ | 0.161 | 0.169 | 0.13 | 0.11 | 0.02 |
| H ₂ O-P | 0.403 | 0.337 | 0.51 | 0.51 | 0.00 |

If critical soil Phosphorus levels of a soil test method corresponding to the two crops are very close, it indicates that the method is less crop specific with respect to critical P levels. The difference between critical levels obtained for the two crops is greater for Bray and Kurtz I (19.40 mg/kg soil) and Bray and Kurtz II (5.60 mg/kg soil), but smaller for other extraction methods (less than 1.42 mg/kg soil). It follows that Bray and Kurtz I and II extractions are very crop specific with respect to critical P level, compared to other P extraction methods. According to the degree of fitness (value of R²) and the crop specificity with respect to critical P levels, 2.5% acetic acid, 5% acetic acid, Olsen's bicarbonate, AER+CER and AER methods can be considered suitable for laboratory routine analysis of phosphorus in soils of the Low Country Intermediate Zone of Sri Lanka.

Both 2.5% acetic acid and 5% acetic acid methods showed high degrees of fitness to Cate-Nelson method with low crop specificity except that the amount of P extracted by 2.5% acetic acid was greater than that of 5% acetic acid method. Therefore, it is reasonable to prefer 2.5% acetic acid to 5% acid for soil Phosphorus analysis. Two point five percent acetic acid method is a simple, rapid and much economical for soil phosphorus estimation. The 2.5% acetic acid can also be used as a multi-element extractant for the estimation of soil potassium and magnesium (Anonymous, 1985). Therefore, it is very attractive as a routine soil testing method, compared to single element estimation methods, such as, Olsen's bicarbonate extraction and anion resin extraction. However, AER+CER method is also

a multi-element routine laboratory soil testing method (Somasiri and Edwards, 1992), but is more laborious compared to 2.5% acetic acid extraction. The results also indicate that either an acidic extractant such as 2.5% acetic acid (pH 2.40) or an alkaline extractant, such as, sodium bicarbonate (pH 8.5) can be used for soil Phosphorus analysis, irrespective of soil reaction of the range of soils used for this experiment.

CONCLUSIONS

Olsen's bicarbonate, 2.5% acetic acid, AER+CER and AER methods were found to be more suitable than 0.01 M CaCl₂, H₂O, Bray and Kurtz I and Bray and Kurtz II extractions for routine soil Phosphorus analysis of soils in Low Country Intermediate Zone. As 2.5% acetic acid method is a multielement, rapid and economical extraction method, it is more attractive than other methods for routine work.

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