Studies on the Factors Governing the Available Phosphorus Status of the Acid soils of Kerala State*

1. EVALUATION OF DIFFERENT METHODS FOR DETERMINING AVAILABLE PHOSPHORUS IN RELATION TO SOIL CHEMICAL CHARACTERISTICS

S. P. NAIR[1] AND R. S. AIYER[2]

Division of Chemistry, Agricultural College & Research Institute, Vellayani

Received for publication August 18, 1966

Kuttanad, a major rice growing tract of Kerala, covers an area of approximately 400 sq. miles. The highly acid soils of this tract are submerged under water during the greater part of the year. The present study is directed towards the evaluation of different methods for determination of available phosphorus in relation to the peculiar chemical characteristics of these soils.

Liebig (1840) and Way (1850) demonstrated that phosphorus might be retained in the soil in an unavailable form. Since then soil chemists have attempted to estimate the amount of available phosphorus in soils by various methods. Olsen (1954) proposed the use of 0.5 N sodium bicarbonate solution for tropical soils. Saunders (1956) developed a method using hot 0.1N sodium hydroxide and obtained satisfactory results for Rhodesian soils. Bray and Kurtz (1945) and Dickman and Bray (1940) developed two methods for determining available phosphorus using dilute acids of different concentrations containing ammonium fluoride.

Mack and Barber (1960) observed that incubating the soil for 74 days at 23°C under 40, 70, and 100 percent water holding capacity considerably increased phosphate availability. Basak and Bhattacharya (1962) found in the puddled soils of Chinsura, West Bengal, that available phosphorus content increased during the growing period of the rice crop when the soils were water-logged. This, however, registered a steep decrease during the non-crop dry period. They concluded that water-logged soils would thus tend to show an unique capacity of regeneration of available phosphoric acid. Shapiro (1958) and Islam and Elahi (1954) observed that flooding the soil increases water solubility of phosphorus. Moisture status of

---

* Condensed from the thesis submitted by S. P. Nair to the University of Kerala in partial fulfilment of the requirements for the M. Sc. (Agri.) degree, 1965. Published by kind permission of the University of Kerala, Trivandrum.

1 Present address : Research Scholar, Sheila Dhar Institute of Soil Science, Allahabad.

2 Junior Professor.

soil is closely linked with phosphate transformations and its eventual supply to the crops. It is found that in water logged soils with low test values for available phosphate the rice crop often grows satisfactorily. This anomaly is probably due to the drying of soil samples during testing which induces fixation of phosphates. Hanaway (1964) has emphasised the need for testing undried soil samples and has observed that there is better correlation between soil test data on undried soil and crop response.

Materials and Methods

34 samples of surface soils (0-6") typical of the three soil types in Kuttanad, viz.. river–borne alluvium (*Karapadom*), peat (*Kari*) and lake bed soil (*Kayal*) were collected for the present study. The soils showed wide variations in characteristics, the pH values ranging from 3.9 to 5.9 and organic carbon content from 0.9% to 16.63%. Exchangeable aluminium, hydrogen and iron were determined by the methods of Yuan (1959), water soluble aluminium and iron were determined by the methods described by Cate and Sukhai (1964), organic carbon by the Walkley and Black's method and cation and anion exchange capacities by the method outlined in Piper (1950). The conductivity of 1:5 extracts was determined using the solu–bridge (USDA hand book No. 60). Total phosphorus was determined by wet ashing 1 g of the soil with 10 ml sulphuric acid, 20 ml nitric acid and finally two or three ml of perchloric acid to give a clear solution. Phosphorus was determined colorimetrically by using stannous chloride as reducing agent (Jackson, 1958). Four extractants, viz., Bray No. 1. Bray No. 2, Olsen's and Saunder's were used to evaluate the available phosphorus status in these soils. Phosphorus concentrations in all the extracts were determined by the molybdenum blue method of Dickman and Bray (1940). Boric acid was added to Bray No. 1 and Bray No. II. extracts prior to colour development to reduce the interference of the fluoride ion. In Saunder's method (Saunder, 1956) in which 0.1 normal hot alkali is used as extractant, clear extracts were obtained by adding a pinch of activated charcoal to the soils prior to extraction and coagulation of organic matter by acidification of the extract. A combination of both these methods gave clear extracts despite the fact that many of the soils used in the present study were high in organic matter.

To study the effect of continuous submergence of the soils on the release of available phosphorus, 100 g of each soil was moistened with distilled water to water holding capacity and incubated for 15 days at 30+ 1°C in plastic containers, giving due consideration to maintaining the moisture status. Available phosphorus was determined in these soils by the methods explained earlier.

The available phosphorus in all the thirty four samples was determined by the standard Neubauer technique. 100 good quality (germination 100 percent) Swiss summer rye seeds were grown in 100 g of soil for 17 days The plants were grown under flourescent lamp for 10 hours daily. They were harvested after 17 days, dried, weighed and analysed for phosphorus.

Results and Discussion

The major criterion for the evaluation of the 4 different extractants for assessing the available phosphorus status in soils was the correlation of the actual phosphorus taken up by plants in Neubauer experiment with the amounts extracted by each of the extra-

ctants. The influence of various soil chemical characteristics that affect the amount of phosphorus extracted by the extracting reagent, as well as their influence on the quantities of phosphorus taken up by the plants in Neubauer experiments were also employed as criteria for finally choosing the method.

The available phosphorus extracted by the four extractants, *viz.*, Olsen's, Bray's No. 1, Bray's No. 2, and Saunder's from 34 samples of the water logged rice soils conditioned by air drying in the laboratory were correlated with the actual plant available phosphorus as determined by the Neubauer technique (Table I)

TABLE I

Correlation coefficient of available P determined by different methods with Neubauer method (Dry soil)

Sl. No.	Method	Correlation coefficient
1.	Bray No. 1	0.255
2.	Bray No. 2	0.142
3.	Olsen's	0.278
4.	Saunder's	No correlation

None of the soil test methods show any significant correlation, though Olsen and Bray No. 1 indicate a positive trend. This lack of significant correlation when viewed in the light of the works of Shapiro (1958), Islam and Elahi (1954) and Basak and Bhattacharya (1962) reveals that the amounts of these forms extracted may be considerably less, whereas, the same soils after submergence show considerable increase in available phosphorus.

To clarify this point the soils were incubated at waterholding capacity for 15 days and available phosphorus determined by the four extractants were correlated with the actual phosphorus taken up in Neubauer experiment.

TABLE II

Correlation coefficient of available P determined by different methods with Neubauer method (Incubated soil)

Sl. No.	Method	Correlation coefficient	Regression equation
1	Bray No. 1	No relation	
2	Bray No. 2	No relation	
3	Olsen's	0.753 **	$y = 16.84x + 28.76$
4	Saunder's	0.664 **	$y = 24.6x + 192.00$

** Significant at both levels.

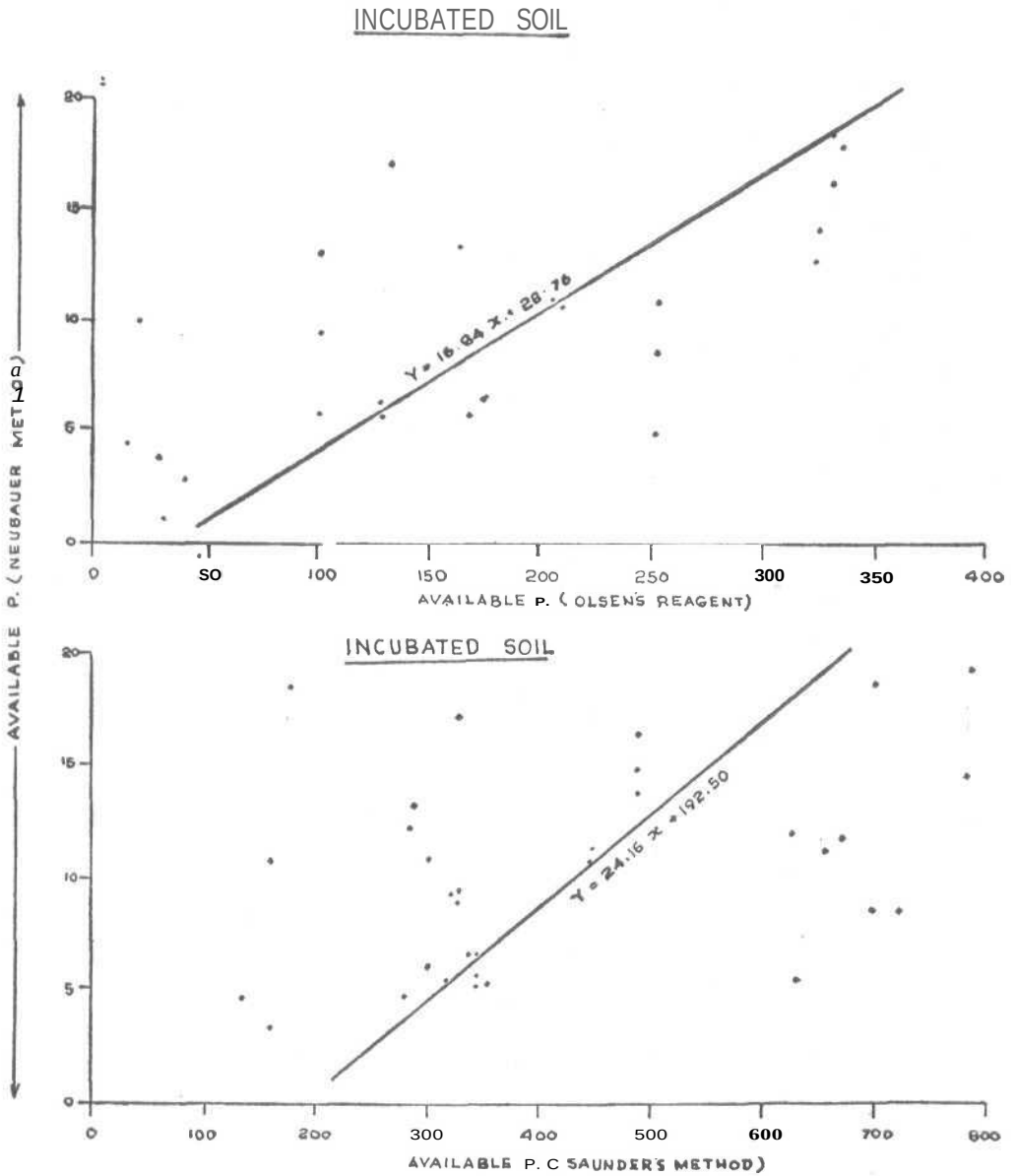

Fig. 1. Correlation between available P as determined by the Neubauer's method and P extracted by Olsen's and Saunder's methods.

phosphorus uptake in decreasing order. High water soluble aluminium has direct toxic effects on plants and is known to retard the uptake of phosphorus (Cate and Sukhai, 1964).

In the present study only two methods were significantly correlated with the actual phosphorus uptake in Neubauer experiment. From linear correlation coefficients alone the superiority of one method over the other cannot be conclusively established. Besides, a number of soil factors affect the extraction and readsorption of phosphorus. For this reason, a partial correlation analysis was conducted to nullify the effect of these independent variables in the linear correlation coefficient already obtained for the two methods on the one hand and the Neubauer technique on the other.

TABLE III

Comparison of linear correlation coefficients and partial correlation coefficients

Method	Linear correlation coefficient	Partial correlation coefficient
Olsen's	0.75	0.70
Saunder's	0.66	0.78

It could be seen that there is greater degree of closeness between the linear correlation coefficient for the Olsen's method. In the case of Saunder's reagent there is considerable increase in the partial correlation coefficient indicating that soil factors adversely or erratically affect the extraction of phosphorus From this, it can be safely concluded that the soil chemical characteristics do not much influence the extraction of phosphorus by Olsen's method as it does for Saunder's

The multiple regression analysis to study the comparative effects of various soil chemical factors on the extraction of phosphorus by Olsen's and Saunder's method gave the following equations:

$$y_1 = 30.264x_1 + 19.109x_2 - 4.347x_3 + 1.5019x_4 + 0.816x_5 - 1.1115x_6 + 5.6286x_7 + 13.6285x_8 + 13.6285.$$

Where y_1 is the phosphorus extracted by Olsen's reagent and x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8 are the different soil chemical characters mentioned earlier.

$$y_2 = 211.60x_1 + 60.5x_2 - 12.97x_3 + 2.93x_4 + 3.5x_5 + 1.793x_6 + 7.916x_7 - 31\,5x_8 - 875.6087.$$

Where y_2 is the phosphorus extracted by the Saunder's reagent.

A study of the regression coefficients shows that the amount of available phosphorus extracted by Olsen's method is positively influenced by pH, conductivity and water soluble iron in the decreasing order. The lower the pH, the greater is the exhaustion of alkaline bicarbonate solution and hence lesser the extraction.

From the regression coefficients of equation relating the phosphorus extracted by Saunder's reagent with soil characteristics it can be seen that the amount extracted is affected in a positive manner by pH, conductivity and water soluble iron.

Thus in the multiple regression analysis both the alkaline extractants follow the same trend. Olsen extractant is less affected by soil chemical factors as revealed by partial correlation coefficients and so can be safely recommended for soils of widely varying chemical characteristics.

Summary

The phosphorus extracted by 4 different chemical extractants from 34 samples of rice soils (both dry and incubated at water holding capacity for 15 days) were studied in relation to both phosphorus uptake by plants, as well as eight important chemical characteristics of soils. Among the 4 extractants (Bray No. 1, Bray No. 2, Olsen's method and Saunder's method), Olsen's method was found to give better correlation with actual phosphorus taken up by plants. A multiple regression analysis of soil chemical characteristics with the amount of phosphorus extracted by the different extracting reagents showed that efficiency of extraction by the alkaline extractants is positively influenced by pH, exchangeable and soluble iron. Olsen's reagent is also found to be least affected by the variations in the different soil chemical characteristics. It is also revealed that the form of phosphorus taken up by plants may be the iron phosphates.

Acknowledgement

The authors are thankful to Dr. C. K. N. Nair, Principal and Additional Director of Agriculture (Research), Agricultural College & Research Institute, Vellayani, and Dr. N. Subramoney, Head of the Division of Chemistry, for the interest evinced in this work.

References

1. Anonymous (1954) Diagnosis and reclamation of saline and alkaline soils. USDA *Handbook No. 60*, U. S. Salinity Laboratory

2. Akoi, M. (1941) Studies on the behaviour of soil phosphoric acid under paddy field conditions /. *Sci. Soil Man. Japan, 15*: 182-202.

3. Al–Abbas and Barber, S. A. (1964) Soil test for phosphorus based upon fractionation of soil phosphorus: 1. Correlation of soil phosphorus fractions with plant available phosphorus. *Soil Sci. Soc. Am. Proc. 26:* 218-221.

4. Alban, L. A., Vacharotayan, S. and Jackson, T. L. (1964) Phosphorus available in reddish brown laterits soils 1. Laboratory studies. *Agron. J. 56:* 555-558.

5. Basak, M. N. and Roma Bhattacharya (1962) Phosphate tranformations in rice soil. *Soil Sci. 94*: 258-262.

6. Blanchar, R. W. and Caldwell, A. C. (1964) Phosphorus uptake by plants and readily extractable phosphorus in soils. *Agron. J. 56*: 218-221.

7. Bray, R. H. and Kurtz, L. T. (1945) Determination of total organic and available forms of phosphorus in soils. *Soil. Sci. 59*: 39-45.

8. Cate, R. B. and Sukhai, A. P. (1964) A study of aluminium in rice soils. *Soil Sci. 98*: 48–51.

9. Chi MooChu, and Caldwell, A. C. (1959) Forms of phosphorus and fixation in soils. *Soil Sci. Soc. Am. Proc. 23*: 459-462.

10. Cooke, O. W. (1951) Fixation of phosphate during the acid extraction of soils. /. *Soil. Sci. 2:* 254-262.

11. Datta, N. P. and Kamath, M. B. (1959) Evaluation of soil tests for available phosphorus, *Indian J. Agric. Sci. 29*: 42-48.

12. Dickman, S. R. and Bray, R. H. (1940) Colorimetric determination of phosphorus. *Ind. Eng. Chem. Anal. Ed. 12*: 665-668.

13. Hanway, J. J. (1964) Test undried soil samples, Better crops with plant food. *Potash Review.*

14. Hesse, P. R. (1962) Phosphorus fixation in mangrove swamp muds. *Nature 193*: 295-296.

15. Islam, M. A. and Elahi, M. A. (1954) Reversion of ferric iron to ferrous iron under water logged conditions and in relation to phosphorus. *J. Agr. Sci. 45*: 1-2.

16. Mack, A. R. and Barber, S. A. (1960) Influence of temperature and moisture on soil phosphorus. 11. Effect of prior to and during cropping on soil phosphorus availability for Millet. *Soil. Sci. Soc. Am. Proc. 24*: 482-484.

17. Olsen, S. R. (1954) Estimation of available phosphorus by extraction with sodium bicarbonate. *USDA. Circular* 939.

18. Pa Ho Hsu. (1964) Adsorption of phosphate by aluminium and iron in soils. *Soil Sci. Soc. Am. Prof. 28*: 474-478.

19. Pratt, P. F. and Garber, M. J. (1964) Correlations of phosphorus availability by chemical tests with inorganic phosphorus fractions. *Soil Sci. Soc. Am. Proc. 28*: 23-26.

20. Saunder, D. H. (1956) Determination of available phosphorus in tropical soils by extraction with sodium hydroxide. *Soil Sci. 82*: 457-463.

21. Shapiro, R. E. (1958) Effect of flooding on availability of phosphorus and nitrogen. *Soil Sci. 85*: 190-197.

22. Yuan, T. L. (1959) Determination of exchangeable hydrogen in soils by a titration method. *Soil Sci. 88*: 164-168.