

The Relationship of Available Phosphorus to Soil Inorganic Phosphorus Forms: Evaluation by Simple Correlations and Regression Analysis

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Available P extracted by different extractants viz., Olsen, Bray No. 1, Bray No. 2, Truog, Williams, Mehlich, Dyer, Morgan, Fraps and Isotopic-exchange method were related to the different forms of soil P viz., Saloid-P, Al-P, Fe-P and Ca-P. Stepwise regressions have been adopted to assess the contribution of the different forms of P to the available P extracted by the above methods. The results have shown that Al-P was the prime source of P for plant up take and Bray No. 1 extractable P. The Ca-P fraction also significantly contributed to the P uptake by plants. Fe-P was the chief source of Olsen's P and isotopic exchangeable ³²P. The greatest contribution in the variation of Bray No. 2 and Truog extractable P was from Ca-P. Al-P and Fe-P also significantly contributed to the available P extracted by the above two methods.

Many soil test methods have been developed for estimating available P in soils and supporting evidences for each method are available in literature. Several of the soil test methods commonly used for determination of available P are based on P availability to plants rather than on the estimation of P fraction. The differences in the ability of an extractant to extract P from different soils are mostly due to variations in the distribution of different forms of P in the soils. It is possible by regression analysis to estimate the relative contributions of various P fractions to P uptake by plants, P extracted by soil test methods and

isotopic exchangeable P. In the present study, an attempt has been made to find out the relationships of P extracted by different methods with the different fractions of soil inorganic P and P uptake by ragi plants by simple correlations and stepwise regression analysis.

MATERIAL AND METHODS

Thirty four surface samples (0-15 cm) representing the four major soil groups viz., red, black, laterite and alluvial collected from different parts of Tamil Nadu were used in the study. Fractionation of soil inorganic P was carried out by the modified

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procedure of Chang and Jackson (1957) after Petersen and Corey (1966). The extractants used for measurement of available P in soils were: 0.5 M NaHCO_3 , pH 8.5 (Olsen *et al.*, 1954), 0.03 N NH_4F + 0.025 N HCl (Bray No. 1, Bray and Kurtz, 1945), 0.03 N NH_4F + 0.01 N HCl (Bray No. 2, Bray and Kurtz, 1945), 0.002 N H_2SO_4 , pH 3 (Truog, 1930), 0.5 N CH_3COOH , pH 2.8 (Williams, 1950), 0.05 N HCl + 0.025 N H_2SO_4 (Mehlich's method, Nelson *et al.*, 1953), 1 per cent citric acid (Dyer, 1894), 0.5 N CH_3COOH + 0.75% CH_3COONa , pH 4.8 (Morgan, 1937), 0.2 N HNO_3 (Fraps, 1909) and Isotopic exchangeable ^{32}P (E value, Russel *et al.*, 1954). The uptake of P by *ragi* plants was estimated by conducting Neubauer test and estimating the P in the plant by tri acid digestion and vanadomolybdate method (Jackson, 1958).

RESULTS AND DISCUSSION

Simple correlation coefficient between different forms of P and available P extracted by different methods and uptake of P by *ragi* plants are given in Table I. There were high degrees of correlations between P as determined by soil test methods and the identified P fractions. It was found that the available P extracted by the above methods except that of Olsen, Bray No. 1 and E value, significantly correlated with the saloid P (NH_4Cl soluble) fraction. The findings of the present study agreed with the view of Kumaraswamy *et al.* (1973) in red

non-calcareous soils of Tamil Nadu. The trends of correlation in the present findings lend support to the finding that saloid P might be treated as an index of availability of P in soils of Tamil Nadu.

The Al-P was considered to be an important fraction of inorganic forms by many workers and it was the main source of P to plants (Smith, 1965; Payne, 1965; Singh *et al.*, 1966; Jose, 1973). It was observed that the amounts of P measured by all the methods excepting that of Dyer (1894) and Morgan (1937) significantly correlated with Al-P and the correlation coefficients were in the order: Bray No. 1 ($r = 0.659^{***}$), Olsen ($r = 0.583^{***}$), E value ($r = 0.509^{***}$), Mehlich ($r = 0.503^{**}$), Fraps ($r = 0.495^{**}$), Truog ($r = 0.492^{**}$), Bray No. 2 ($r = 0.469^{**}$) and Williams (0.391*). The high correlation values of Bray No. 1 with Al-P was understandable since the solvents were NH_4F and HCl. NH_4F known to be solvents for the extraction of Al-P. The results of the present study are in consonance with the views of Chai and Caldwell (1959) Pratt and Garber (1964) and Jose (1973).

The Fe-P significantly correlated only with Olsen's P ($r = 0.614^{***}$), E value ($r = 0.592^{***}$) and Bray No. 1-P (0.484**). With regard to the relationship of Ca-P with P extracted by different methods, it could be seen that all the acid extractants significantly correlated with the amount of Ca-P.

The magnitude of relationship was in the following decreasing order: Fraps ($r=0.629^{***}$), Williams ($r=0.613^{***}$), Mehlich ($r=0.568^{***}$), Bray No. 2 ($r=0.553^{**}$), Truog ($r=0.525^{**}$) and Dyer ($r=0.429^{**}$). This might be attributed to the acidic nature of these acid extractants which were capable of extracting more Ca-P from the soils.

The Ca-P fraction did not contribute significantly to the surface P activity as measured by E value nor to the P extracted by the Olsen and Bray No. 1 methods. These observations support the work of Pratt and Garber (1964), Westin and Butley (1966), Tripathi *et al.* (1970) and Jhon (1972).

Relationship of P fractions and available P indices shown by stepwise regression analysis

It is possible by stepwise regression analysis to estimate the relative contributions of various P fractions to the P up take by plants, isotopic exchangeable ^{32}P and the P extracted by soil test methods. Coefficients of multiple determination (R^2) by the stepwise regression procedure are given in Table II. The Al-P accounted for 38 per cent of the observed variation for the P uptake by plants. The Ca-P fraction increased R^2 by 10 per cent. Both Al-P and Ca-P contributed significantly to the pool of available P to plants. This agreed with the view of Tandon *et al.* (1971). The proportion of available P derived from Al-P source was greater than Ca-P. The effect of Fe-P and Red. sol.-P was negligible.

The Fe-P was the main source of variation in Olsen's P. The R^2 values increased by only 2 per cent and 6 per cent respectively when the Al-P and Red. sol.-P were introduced on to the regression. The introduction of Ca-P did not increase the R^2 value.

Stepwise regression for Bray No.1 extraction values indicated that 43.4 per cent by variation was due to the Al-P fraction. The introduction of Fe-P, Ca-P and Red. sol.-P values increased the R^2 by less than 6 per cent. The Al-P fraction was the dominant fraction contributing to the variation in the regression of Bray No.1 extraction values. The findings of the present study lend support to the views of Tripathi *et al.* (1970), Cholikul and Tyner (1971) and John (1972).

For the Bray No. 2 and Truog extractable P, all the three fractions viz. Ca-P, Al-P and Fe-P significantly contributed to the pool of available P. However, the proportion of available P derived from Ca-P source was greater than that of Al-P and Fe-P in both the methods. The Al-P increased R^2 by 10.6 per cent and Fe-P by 13.8 per cent in the case of Bray No. 2, whereas in the Truog's method, the increase was 12.8 and 16.4 per cent respectively for Al-P and Fe-P.

The Fe-P fraction accounted for 35.1 per cent of the observed variation (R^2) in the isotopic exchangeable ^{32}P . The effect of Al-P, Ca-P and Red. sol.-P on R^2 was negligible. The

R² values indicated that Fe-P was the chief source of variation in isotopic exchangeable ³²P. This is in conformity with the findings of Tripathi *et al.* (1970), Cholitzkul and Tyner (1971) and John (1972), who reported that the isotopic determination of available P (exchangeable ³²P-F value) was primarily accounted for by the Fe-P fraction.

The results of regression analysis have shown that Al-P was the prime source of available P and Bray No. 1-P, whereas Olsen's P and isotopic exchangeable ³²P were mainly accounted for by the Fe-P. The Ca-P fraction was the chief source of the available P extracted by Bray No 2 and Truog's methods. Both Al-P and Fe-P significantly contributed to the available P of the two methods in increasing the R² values.

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TABLE I Correlation coefficient (r) values between the determined values of available P and the inorganic P fractions in soils (n = 34)

Soil test methods	Inorganic P fractions			
	Saloid-P	Al-P	Fe-P	Ca-P
1. Olsen	0.094 ^{NS}	0.583***	0.614***	0.095 ^{NS}
2. Bray No. 1	0.242 ^{NS}	0.659***	0.484**	0.161 ^{NS}
3. Bray No. 2	0.593***	0.469**	0.104 ^{NS}	0.553**
4. Troug	0.722***	0.492**	0.085 ^{NS}	0.525***
5. Williams	0.683***	0.391*	-0.055 ^{NS}	0.513**
6. Mehlich	0.657***	0.503**	0.069 ^{NS}	0.568***
7. Dyer	0.785***	0.269 ^{NS}	-0.117 ^{NS}	0.429***
8. Morgan	0.733***	0.272 ^{NS}	-0.175 ^{NS}	0.376*
9. Fraps	0.561***	0.495**	0.059 ^{NS}	0.625***
10. E value (exch. 32p)	0.078 ^{NS}	0.509**	0.592**	-0.204 ^{NS}

* Significant at 5 per cent level

** Significant at 1 per cent level

*** Significant at 0.1 per cent level

NS Not significant

TABLE II Stepwise regression analysis for the uptake of P by plants and available P on P fraction

P fraction	Availability index R ²	R ²
P uptake by plants		
Al-P	0.3812**	
Al-P + Fe-P	0.3849	0.0037
Al-P + Fe-P + Ca-P	0.4882	0.1033**
Al-P + Fe-P + Ca-P + Red-P	0.4992	0.0110
Total R ²	0.4992**	
Olsen-P		
Fe-P	0.3769**	
Fe-P + Al-P	0.3970	0.0201
Fe-P + Al-P + Ca-P	0.3970	0.0000
Fe-P + Al-P + Ca-P + Red-P	0.4521	0.0551
Total R ²	0.4521**	
Bray No. 1-P		
Al-P	0.4343**	
Al-P + Fe-P	0.4402	0.0059
Al-P + Fe-P + Ca-P	0.4433	0.0031
Al-P + Fe-P + Ca-P + Red-P	0.4471	0.0038
Total R ²	0.4471**	
Bray No. 2-P		
Ca-P	0.3055**	
Ca-P + Al-P	0.4110	0.1055**
Ca-P + Al-P + Fe-P	0.5485	0.1375**
Ca-P + Al-P + Fe-P + Red-P	0.5503	0.0018
Total R ²	0.5503**	
Truog-P		
Ca-P	0.1558**	
Ca-P + Al-P	0.3830	0.1230**
Ca-P + Al-P + Fe-P	0.5475	0.1636**
Ca-P + Al-P + Fe-P + Red-P	0.6080	0.0605*
Total R ²	0.6080**	
E value (Exch. $\frac{1}{2}$P)		
Fe-P	0.3508**	
Fe-P + Al-P	0.3529	0.0021
Fe-P + Al-P + Ca-P	0.3776	0.0247
Fe-P + Al-P + Ca-P + Red-P	0.3781	0.0005
Total R ²	0.3781**	

** Significant at 1 per cent level.

* Significant at 5 per cent level.