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Comparison between the Fractions and Extractants of Phosphorus of PAJANCOA and RI Farm using Different Statistical Analysis

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A B S T R A C T

Investigations were carried out in the farm soils of PAJANCOA & RI, Karaikal in order to quantify the distribution of Phosphorus (P) in different pools using different statistical analysis. For this purpose, the surface soil samples of PAJANCOA & RI farm, numbering 115, were collected from individual fields. The soil samples were also analyzed through correlation analysis, linear multiple regression analysis and path analysis in order to quantify the interrelationship between the P fractions and extractants of P. While correlating the P extracted by different extractants with that of the P fractions, it was noticed that the Olsen-P was positively related to HCl-P and Triacid-P, whereas the Bray-P was more closely related to the NaCl-P fraction. It was estimated by multiple regression analysis that 33.2 per cent of the Olsen-P, 33.2 per cent of the Bray I-P and 35.9 per cent of the Bray II-P could be significantly predicted by the different P fractions. Attempts made to isolate the direct and indirect effects of the different P fractions on the P extracted by different reagents had shown that there was a moderate to low level of contribution by HCl-P and NaCl-P respectively towards the Olsen-P and a high level of negative contribution by NaOH-P. While the Bray I-P had a positive, direct and high level of contribution by the NaCl-P, the Bray II-P had a high level of direct and positive contribution from the NaCl-P.

Introduction

Phosphorus is the second most major element among the 17 essential elements for crop growth. Indian soils have poor P content. Primary P minerals including apatites, strengite and variscite are stable, and release of available P from these minerals by weathering is too slow to meet the crop demand and relatively efficient for crop growth in acidic soils. Secondary minerals including calcium, iron and aluminium phosphates vary in dissolution rates, depending on the size of mineral particles and soil pH (Pierzynski *et al.,* 2005). One unique characteristics of P is its low availability due to slow diffusion and high fixation in soils. Phosphorus is highly mobile in plants and

when the phosphorus is deficient, it may be translocated from old plant tissues to young actively growing areas.

The P status of neutral and alkali soils is expressed in terms of Olsen-P whereas, acid soils is expressed in terms of Bray I-P and Bray II-P which refers to the available soil P (Subba *et al.,* 2015). In neutral to alkaline soils, P ions will precipitate as calcium phosphorus: dicalcium or octacalcium phosphates, hydroxyl apatite and eventually least soluble apatites and decreases P availability. In acidic soils, the inorganic soil P precipitates as Fe and Al oxide and clay minerals, which are essentially insoluble under aerobic or upland conditions.

The scientific background of these phenomena and practical consequences for soil test interpretation and fertilizer application are subject to P dynamics in the soil. Therefore in order to understand the dynamic nature of the P, various extractants can be used for extracting the different forms of P in soils. The Hedley *et al.,* (1994) method of fractionation has been widely used to characterize soil P availability. It was reported that there was a decline in NaOH-P with plant P removal. The HCl-P and residual P in the slightly weathered soils declined under cropping. The NaOH-P was the dominant P fraction in the highly weathered soils and declined in response to plant P removal. NaOH-P and NaHCO$_3$ -P are readily available to plant, whereas the HCl-P is unavailable to plants (Guo *et al.,* 2000).

However, it was realized in the recent time from the soil analytical data and as well from the yield particulars, that there is a vast variation and erratic response to applied P in various fields of PAJANCOA & RI farm. It was also noticed that in some fields there is serious decline in available P levels and some fields have very high values of available P.

This necessitated an investigation on the dynamics of soil P in the farm soils of PAJANCOA & RI with the objectives as to study the fractions of soil P in the soils and to select a suitable extractant for the soils of this farm.

In order to quantify the interrelationship between the P fractions and P extracted by different reagents, the soil samples were also analyzed through correlation analysis, linear multiple regression analysis and path analysis. The correlation and linear multiple regression is usually applied to explore the relationships between the fractions and extractants of P. Path analysis was developed around 1918 by Sewall Wright. It was usually used to decompose correlations into direct and indirect effects for interpretation.

Materials and Methods

Description of study area

The Pandit Jawaharlal Nehru college of Agriculture and Research Institute is about 9 km northwest to Karaikal and lies between $10^{°}$ 49' and $11^{°}$ 01' N latitude and between $78^{°}43'$ and $79^{°}52'$ E longitude. The study area is situated 4 m above mean sea level (MSL) having the maximum and minimum of $31.95^{°}$ C and $25.52^{°}$ C temperatures. Karaikal comes under the eleventh Agro climatic zone of India and it is classified as PC 2 – coastal deltaic alluvial plain zone. Karaikal enjoys a tropical climate and receives an annual average rainfall of 1437.17 mm in 55.83 rainy days in North East Monsoon. The college farm is located in the tail end of Cauvery delta zone, 12 km away from the Bay of Bengal seacoast. The total area of farm in which the institute located is 225 acres. Currently, the eastern farm and western farm is divided into six blocks (A, B, C, D, E and F), occupies an area of 73.95 acres and 25.25 acres respectively. Totally an area of 99.20 acre is

now taken as the study area in the present investigation. The detailed soil survey of PAJANCOA & RI farm had indicated the presence of three soil series *viz.,* (i) Sorakudy series. (ii) Thirunallar series (iii) Kottucherry series.

Collection of surface soil sample

The surface soil samples (15 cm depth) were collected during summer from PAJANCOA fields, when the fields were fallow, by adopting the standard procedures of soil sample collection from which, a composite soil sample of about one kg was collected by quartering technique. The collected soil samples were air dried, gently malleted and sieved through 2 mm sieve and preserved in polythene bags with proper labelling for further analysis.

Soil analytical methods

The surface soil samples were analyzed for available P by different extractants using 0.5 M NaHCO$_3$ of pH 8.5 (Olsen *et al.,* 1954) for Olsen-P, whereas Bray I and Bray II-P by 0.03 N NH$_4$F plus 0.025 N HCl and 0.03 N NH$_4$F plus 0.1 N HCl (Bray and Kurtz, 1945), respectively in spectrophotometer. The different P fractions in soil were determined following a modified P fraction technique, as described by Bolan and Hedley (1989). The procedure is detailed here under:

One gram soil was pre-treated with 40 ml of 0.5 M NaCl buffered with 0.5 M triethanolamine (TEA) and shaken for 30 minutes in a 50 ml centrifuge tube. This pre-treated soil was included to remove both the solution P and exchangeable calcium, which otherwise may form Ca (OH)$_2$ and CaCO$_3$ during extraction with 1 M NaOH and readsorb or co-precipitate with some of the dissolved P. After centrifuging at 8000 rpm for 10 minutes, the supernatant solution was

filtered and analyzed for solution P following Murphy and Riley (1962) method.

The soil residue were subsequently shaken end-over-end with 1M NaOH (at 1:40 soil: solution ratio) for 16 hours. After centrifuging and filtering, the solution was analyzed for P which include both solution and adsorbed P.

To the residue in the tube 40 ml of 1M HCl was added and shaken for further 16 hours and then centrifuged and filtered. The P was determined in the solution as acid soluble or apatite-P. The soil residue was then transferred to a 100 ml conical flask and digested using 10 ml of triacid at 260˚C for 45 minutes and the total P was determined as residual P.

Statistical analysis

The analytical data obtained in the study were subjected to statistical scrutiny, simple correlation and multiple regression analysis following the procedures outlined by Gomez and Gomez (1976), to derive a valid conclusion. Path analysis was made to partition and quantify the direct and indirect effects of various fractions of soil P and P extracted by different extractants (Lenka and Misra, 1973).

Results and Discussion

Phosphorus extracted by different reagents

The quantity of P that can be extracted by different extractants *viz.*, Olsen-P, Bray I-P, Bray II-P is presented in Table 1. The results had indicated that the Olsen extractant recorded the P which ranged between 4.09 to 415.15 kg ha^{-1} with a mean value of 115.12 kg ha^{-1}, when all the fields were subjected to descriptive statistics. With respect to the eastern farm soils the minimum Olsen-P content was 10.90 kg ha^{-1} and the maximum

was 414.15 kg ha^{-1} and the mean value was 132.60 kg ha^{-1}. In the case of the soils of the western farm, the minimum and the maximum values of P as extracted by Olsen reagent was 4.09 and 185.26 kg ha^{-1} respectively and the mean value was 75.17 kg ha^{-1}.

Alternatively, the P extracted by the Bray I-P reagent was found to range between 46.88 to 774.77 kg ha^{-1} with a mean value of 194.24 kg ha^{-1} on an overall farm level. As regards the soils of eastern farm the minimum and maximum values of P as extracted by Bray I-P reagent was 46.88 kg ha^{-1} and 774.77 kg ha^{-1} with an average value of 201.58 kg ha^{-1}. In the case of the soils of western farm the lowest content of P extracted by the Bray II reagent was 20.39 kg ha^{-1} and the highest value was 374.76 kg ha^{-1}. On an average an amount of 98.66 kg ha^{-1} was registered in the western farm soil.

Fractions of P

The results are presented in Table 2 which had shown that the NaCl-P content of the surface soils of the farm ranged from 8.28 to 320.95 mg kg^{-1} with a mean value of 104.75 mg kg^{-1}. In the case of the eastern farm soils the minimum and maximum NaCl-P was 8.28 and 320.95 mg kg^{-1} with a mean value of 99.21 mg kg^{-1}. With respect to the western farm the values of NaCl-P was found to range between 8.28 to 270.48 mg kg^{-1} with an average NaCl-P content of 114.28 mg kg^{-1}.

The P extracted by NaOH was found to be ranging between 40.87 to 611.42 mg kg^{-1} in the overall farm, between the same values in the eastern farm and in the western farm the minimum NaOH-P was 287.73 and the maximum was 549.77 mg kg^{-1} with an average value of 389.95 mg kg^{-1}.

With respect to the HCl-P content of the entire farm soils, the minimum value was

103.85 mg kg^{-1} and the maximum value was 623.09 mg kg^{-1} with a mean value of 383.38 mg kg^{-1}. In the case of the soils of eastern farm the HCl-P was found to vary between 103.85 mg kg^{-1} to 610.17 mg kg^{-1} with an average value of 407.85 mg kg^{-1} of HCl-P. The minimum and maximum value of HCl-P was 103.85 mg kg^{-1} and 623.09 mg kg^{-1} in the soils of the western farm. The average HCl-P content of the western farm soil was 327.58 mg kg^{-1}.

The Triacid-P content of the farm soils of PAJANCOA & RI was found to range from nil to 155.48 mg kg^{-1} with an average value of 38.50 mg kg^{-1}. While the eastern farm soil had also registered the same minimum and maximum values as quoted for the farm, the western farm soils was found to possess from nil to 45.77 mg kg^{-1} of Triacid-P with an average value of 21.09 mg kg^{-1}.

The simple correlation studies had indicated that there existed a positive and significant relationship between the Olsen-P and that of HCl-P and Triacid-P but negative relationship with NaOH-P. On the contrary, the Bray I-P and Bray II-P had recorded a highly significant and a positive relationship with the NaCl-P (r = 0.572** and 0.575**, respectively) (Table 3). However, it was noticed that the Olsen-P registered significant and positive relationship with the P extracted by Bray II reagent and the Bray I-P was very significantly correlated with Bray II-P. Interestingly, the Bray II-P had significant and positive correlation with the P extracted by the other two reagents (Table 3).

In order to quantify the contribution of the different fractions of P towards the P extracted by different reagents, multiple linear relationship was worked out between the above two parameters and presented in Table 4. It was clearly brought out that 33.2 per cent of the variation in the Olsen-P and the Bray I-

P and 35.9 per cent of the variation in the Bray II-P could be significantly explained by the different fractions of P. Further scrutiny of the regression equation had shown that all the fractions of P except the Triacid-P had significant contribution to Olsen-P. On the other hand in the case of the Bray I and Bray II-P the contribution of NaCl alone was significant as revealed by the statistical tools.

The results of the path analysis had indicated that among the different fractions of P, the HCl-P had moderate and positive contribution and that of NaCl-P, a low and positive contribution towards the Olsen-P (Table 5). However, the NaOH-P had a high level of contribution with negative influence on the Olsen-P. It was also noticed that the NaOH-P had a moderate to low level of contribution towards the Olsen-P via HCl-P and Triacid-P respectively. Among the different fractions of P, the NaCl-P alone had contributed directly to the P extracted by the Bray I reagent (Table 6).

The indirect effect was not noticed with respect to any of the fractions. With respect to the P extracted by the Bray II reagent, the NaCl-P had a high level of positive and direct contribution, whereas the NaOH-P and Triacid-P had a negative and low level of contribution (Table 7). The NaOH-P had indirectly contributed to the Bray II-P through HCl-P, though the contribution was low.

Table.1 The available P of the surface soil samples of PAJANCOA & RI farm using different extractants (kg ha^{-1})

Descriptive statistics	Olsen-P	Bray I-P	Bray II-P
Overall Farm Soil			
Mean	115.12	194.24	126.35
S.E	6.85	12.28	10.29
S.D	73.46	131.71	110.32
C.V (%)	63.81	67.81	87.31
Minimum	4.09	46.88	7.65
Maximum	415.15	774.77	605.48
Eastern Farm Soil			
Mean	132.60	201.58	138.46
S.E	8.66	16.43	13.30
S.D	77.42	146.96	118.93
C.V (%)	58.39	72.90	85.90
Minimum	10.90	46.88	7.65
Maximum	415.15	774.77	605.48
Western Farm Soil			
Mean	75.17	177.44	98.66
S.E	7.18	14.71	13.94
S.D	42.48	87.01	82.49
C.V (%)	56.51	49.04	83.61
Minimum	4.09	85.87	20.39
Maximum	185.26	387.08	374.76

Table.2 The fractions of P of surface soil samples of PAJANCOA & RI farm (mg kg^{-1})

Descriptive statistics	NaCl-P	NaOH-P	HCl-P	Triacid-P
Overall Farm Soil				
Mean	104.75	268.24	383.38	38.50
S.E	6.82	13.46	10.74	3.79
S.D	72.86	143.73	114.66	40.47
C.V (%)	69.56	53.58	29.99	105.12
Minimum	8.28	40.87	103.85	0.00
Maximum	320.95	611.42	623.09	155.48
Eastern Farm Soil				
Mean	99.21	214.12	407.85	46.41
S.E	8.04	15.46	12.13	5.14
S.D	71.47	137.39	107.84	45.72
C.V (%)	72.03	64.17	26.44	98.50
Minimum	8.28	40.87	103.85	0.00
Maximum	320.95	611.42	610.17	155.48
Western Farm Soil				
Mean	114.28	389.95	327.58	21.09
S.E	12.78	9.81	18.95	2.25
S.D	74.50	57.19	110.52	13.14
C.V (%)	65.19	14.67	33.74	62.30
Minimum	8.28	287.73	103.85	0.00
Maximum	270.48	549.77	623.09	45.77

Table.3 Results of the simple correlation studies between the fractions of P and P extracted by different extractants of the surface soils of PAJANCOA & RI farm (n=115)

Sl. No.	Particulars	Olsen-P	Bray I-P	Bray II-P
1.	NaCl-P	0.173 NS	0.572**	0.575**
2.	NaOH-P	-0.513**	0.029 NS	-0.101 NS
3.	HCl-P	0.478**	0.018 NS	0.084 NS
4.	Triacid-P	0.253**	0.008 NS	0.004 NS

Table.4 Results of the linear multiple regression studies between the fractions of P and P extracted by different extractants of surface soil samples of PAJANCOA & RI farm

Sl. No.	Dependent variable (Y)	Independent variable (X)	Equation (Ŷ)	R²
1.	Olsen-P	NaCl-P (x_1);NaOH-P (x_2); HCl-P (x_3);Triacid-P (x_4)	$Y = 90.37 + 0.170(x_1)^* - 0.194 (x_2)^{**} + 0.163(x_3)^* - 0.099(x_4)^{NS}$	0.332**
2.	Bray I-P	NaCl-P (x_1);NaOH-P (x_2); HCl-P (x_3);Triacid-P (x_4)	$Y = 69.83 + 1.024(x_1)^{**} + 0.020(x_2)^{NS} + 0.050(x_3)^{NS} - 0.224(x_4)^{NS}$	0.332**
3.	Bray II-P	NaCl-P (x_1);NaOH-P (x_2); HCl-P (x_3);Triacid-P (x_4)	$Y = 73.74 + 0.880(x_1)^{**} - 0.126(x_2)^{NS} + 0.026(x_3)^{NS} - 0.433(x_4)^{NS}$	0.359**

Table.5 Results of the Path analysis showing the direct and indirect effect of the fractions of P to the P extracted by the Olsen reagent in the surface soils of PAJANCOA & RI

Fractions of P	Direct effects	Indirect effects				Total of indirect effects
		NaCl-P	NaOH-P	HCl-P	Triacid-P	
NaCl-P	0.173^L		0.000^N	0.005^N	0.021^N	0.026
NaOH-P	-0.380^H	0.000		0.241^M	0.189^L	0.430
HCl-P	0.254^M	0.007	-0.161		0.097^N	-0.057
Triacid-P	-0.055^N	-0.007	0.028	-0.021		0.000

Table.6 Results of the Path analysis showing the direct and indirect effect of the fractions of P to the P extracted by the Bray I reagent in the surface soils of PAJANCOA & RI

Fractions of P	Direct effects	Indirect effects				Total of indirect effects
		NaCl-P	NaOH-P	HCl-P	Triacid-P	
NaCl-P	0.579^H		0.000^N	0.016^N	0.072^N	0.088
NaOH-P	0.021^N	0.000		-0.013^N	-0.011^N	-0.024
HCl-P	0.043^N	0.001	-0.027		0.016^N	-0.010
Triacid-P	-0.070^N	-0.009	0.035	-0.027		-0.001

Table.7 Results of the Path analysis showing the direct and indirect effect of the fractions of P to the P extracted by the Bray II reagent in the surface soils of PAJANCOA & RI

Fractions of P	Direct effects	Indirect effects				Total of indirect effects
		NaCl-P	NaOH-P	HCl-P	Triacid-P	
NaCl-P	0.594^H		0.000^N	0.016^N	0.074^N	0.090
NaOH-P	-0.166^L	0.000		0.105^L	0.083^N	0.188
HCl-P	0.025^N	0.001	-0.016		0.010^N	-0.006
Triacid-P	-0.162^L	-0.020	0.081	-0.062		-0.001

N = Negligible; L = Low; M = Moderate; H = High

Various methodologies involving different extractants are being test verified under differing soil environments and by growing crops of varying duration. The complexity in predicting the actual quantity of nutrient element to the growing plant is that the supply is made from various sources under the field conditions, the quantity of which is difficult to assess.

Attempts made to relate the P extracted by different reagents with that of the P fractions in this study. Among the different soil P fractions, the NaCl-P represents the solution P, which is instantaneously available, the NaOH-P indicates the adsorbed P on the exchange complex which can be made available by a simple ion exchange phenomena, the HCl-P designates the acid soluble P fraction, which is not soluble but made soluble by a simple dissolution mechanism and the Triacid-P represents the mineral P which can be released only upon weathering. In simple terms, the NaCl-P is instantaneously available and can be extracted even by water to any reagent, the NaOH-P can be made available provided there is an appropriate competing ion to desorb P from

the exchange complex, which is proportional to the type of extractant used (Tembhare, 1973). Therefore, these two fractions are designated as labile-P and easily available for crop uptake. On the other hand, the HCl-P derives its P by dissolving the insoluble precipitates of P which might not happen immediately under field conditions, but nevertheless gets released slowly. The Triacid-P is said to be the Residual-P which is not even dissolved by a strong acid like HCl and therefore is said to be relatively unavailable. Under this context, it can be inferred that irrespective of the type of reagent used to extract P and designating that amount as available P, it can be inferred that all reagents are extracting the P completely from the NaCl pool, maximum from the NaOH pool and moderate from the HCl pool and none or less from the Triacid pool. In other words the quantity of P extracted by a reagent depends on the amount of P that could be extracted from the adsorbed and acid soluble fraction of soil.

The present investigation had attempted to correlate the fractions of P with the P extracted by different reagents which brought out certain salient conclusions. For instance, the Olsen-P was not related to NaCl-P, negatively related to NaOH-P and positively to HCl-P and Triacid-P. In the case of Bray I-P and Bray II-P it was closely correlated with NaCl-P. The above information had brought out the fact that the Olsen-P values cannot be modified just because there are variations in the solution P, but however derives its P from the adsorbed pool of the soil exchange complex thereby resulting in reduction of NaOH-P. A positive correlation of Olsen-P with HCl-P and Triacid-P indicates that the NaCl-P is either precipitated or the Olsen-P is independent of the insoluble P fraction. However, as far as Bray I and Bray II-P are considered there is a good relationship with the NaCl-P. Interestingly, the multiple regression analysis had clarified this contradiction between the Olsen-P and the Bray-P, wherein there were significant variations in Olsen-P due to NaCl, NaOH and HCl-P, whereas it was only the NaCl-P which accounted the Bray I and Bray II-P (Abarna, 2012). The path analysis had yet again confirmed that the Olsen-P had a positive and direct contribution from NaCl-P and HCl-P and a negative contribution from NaOH-P. In the case of Bray I-P and Bray II-P the direct contribution was positive and high with respect to NaCl-P.

Acknowledgement

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