

Changes in the Growth Parameters of Paddy in Soils with Varying Phosphorus Status and Doses of Phosphorus Applied

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ABSTRACT

A study was conducted in the farm soils of PAJANCOA & RI, Karaikal in order to quantify the distribution of Phosphorus (P) in different pools as well as to study the response of paddy crop to P application. A pot culture experiment was carried out with four types of soils which are differing with their P status namely (i) soils with low levels of both labile and non-labile-P (ii) soils with low levels of labile-P and high levels of non-labile-P (iii) soils with high levels of labile-P and low levels of non-labile-P and (iv) soils with high levels of both labile and non-labile-P and with four doses of P application namely 0, 50, 100 and 150 kg P₂O₅ ha⁻¹. The results indicated that the height of the plant decreased with the application of P in general. However, in soils which registered lower levels of labile and non-labile-P, the addition of P tended to increase the plant height. The number of tillers was found to be the maximum with the application of 100 kg P₂O₅ ha⁻¹, though this was significant in soils which recorded high levels of labile-P.

Keywords: Fractions of P, Labile-P, Non-labile-P, Plant height, Number of tillers

INTRODUCTION

Rice is one of the most important crop in the world, and its production is limited by soil P deficiencies in many parts of the world (Hedley et al., 1994; Raghothama 1999; Fageria et al., 2011). Rice plant responds to P

fertilization in both upland and wetland conditions. There are deficiencies of P in *Ultisols*, *Oxisols*, *Vertisols*, *Inceptisols*, *Andisols* and acid sulfate soils (Diamond, 1985).

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The water soluble P sources, such as superphosphate, are effective in all soil types except those that are extremely acid. The most commonly used P fertilizers for lowland rice are single super phosphate and triple super phosphate, di ammonium phosphate and ammonium phosphate (Sanyal & De Datta, 1991). Phosphate Rocks are also used as P fertilizers in many countries (De Datta, 1981). The application of phosphate rock to lowland rice meets with two difficulties: (1) pH of an acidic soil will rise following submergence and this may adversely affect the solubility of phosphate rock in soil; (2) the ability of rice to derive P from phosphate rock is relatively low (Sanyal & De Datta, 1991). Phosphorus fertilizers for rice should be applied at transplanting, but it may also be applied later, before the vigorous tillering stage (De Datta, 1981).

Plant roots absorb P as either of H_2PO_4^- or HPO_4^{2-} . Because the concentrations of these ions in soils are in the micromolar range, high-affinity active transport systems are required for Pi uptake against a steep chemical potential gradient across the plasma membrane of root epidermal and cortical cells is mediated by high-affinity of Pi/H^+ symporters. Most of the Pi taken up by roots is loaded into the xylem and subsequently translocated into shoots. Although 85 to 95 per cent of the cellular P is present in the vacuole, P-Nuclear Magnetic Resonance studies reveal that the Pi efflux from the vacuole is insufficient to compensate for a rapid decrease of the cytosolic Pi concentration during P starvation (Pratt et al., 2009). The phosphatase and ribonuclease genes are also induced by leaf senescence, further supporting their important role in the P remobilization process (Gepstein et al., 2003).

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 effect of varying levels of phosphorus in the selected soils and the added phosphorus on the growth attributes by rice crop.

MATERIALS AND METHODS

Selection of field's soil samples for pot culture experiment

The surface soil samples (15 cm depth) were collected during summer from PAJANCOA fields, when the fields were fallow, by adopting the standard procedure of soil sample collection and dried, malleted, sieved and preserved for further analysis. The initial samples were analyzed for P fractions. Based on the analytical values of the P fractions, the results were subjected to the descriptive statistics and four fields were selected based on that statistics. The procedure adopted was that the soil samples which recorded lower values than the mean minus standard deviation was considered as low P pool and the values higher than the mean plus standard deviation was considered as high P pool with respect to their labile and non-labile P contents. The fields were divided into low and high levels of labile and non-labile P availability. Since none of the soils contained the labile P at lower level with non-labile P also at lower status, the soil which contained the lowest labile P (but above the mean minus standard deviation values of labile P) was considered as the soil containing both labile and non-labile P at low levels for the purpose of accommodating all possible categories in the experimentation.

Treatment details

To investigate the dynamics of P, pot culture experiment was conducted during the *samba* season in the pot culture yard of the Department of Soil Science and Agricultural Chemistry, Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal. The experiment was laid out using Factorial Completely Randomized Design (FCRD).

Factor I : Soil types

S₁: Low level of Labile P and low level of non-labile P - LL

S₂: Low level of Labile P and high level non-labile P - LH

S₃: High level of Labile P and Low level of non-labile P - HL

S₄: High level of Labile P and high level of non-labile P - HH

Factor II: Levels of phosphorus (P)

P₁ : 0 kg P₂O₅ ha⁻¹; P₂ : 50 kg P₂O₅ ha⁻¹; P₃ : 100 kg P₂O₅ ha⁻¹; P₄: 150 kg P₂O₅ ha⁻¹

Pot culture experiment

The paddy crop, variety ADT (R) 46 used as the test crop. The capacity of the pot used for the experiment was 20 kg. Each pot was filled with 18 kg of processed soil sample and filled with water. Then, it was mixed with soil to a puddle condition on the day before transplanting. There were 12 pots for each soil type.

The fertilizer dose adopted was 150 kg of N and 50 kg of K₂O ha⁻¹ and the P was applied as per the treatment details furnished above. The N was applied in the form of urea, in three equal splits i.e., 50 per cent as basal, remaining 2 splits at active tillering and panicle initiation. Potassium was applied in the form of MOP in two equal splits i.e., at basal and at panicle initiation stage. Also, zinc sulphate at the rate of 25 kg ZnSO₄ per hectare was applied as basal to 48 pots. The entire quantity of P was applied as basal at the time of transplanting and thoroughly mixed with the soil along with the N and K fertilizers applies as basal. Four hills were planted diagonally in each pot. The biometric observations were carried out at active tillering stage, panicle initiation stage and at harvest. The different P fractions in soil were determined following a modified P fraction technique, as described by Bolan and Hedley (1989).

Statistical analysis

The biometrical observations data obtained in the study were subjected to statistical scrutiny following the procedures outlined by Gomez and Gomez (1976), to derive a valid

conclusion. The data were analyzed using analysis of variance (ANOVA) of IRRISTAT software. Treatments were compared using the analysis of variance at $p \leq 0.05$.

RESULTS**Initial soil sample**

The soil samples collected for the pot culture experiment were analyzed for various parameters and are presented in Table 1. The results had shown that the texture of the soils which registered low levels of labile and non-labile-P as well as low levels of labile-P and high levels of non-labile-P was sandy clay. The soil which was classified to contain high levels of labile-P and low levels of non-labile-P was found to possess a sandy loam texture, whereas clay loam was the texture of the soil which was categorized to contain high levels of both labile and non-labile pool.

It was further noticed that the CEC of the experimental soils was ranging from 24.70 cmol (p⁺) kg⁻¹ (which was found to contain high levels of labile-P and low levels of non-labile-P) to 76.50 cmol (p⁺) kg⁻¹ (soil which registered low levels of both labile and non-labile-P). In all the soils, the exchangeable Ca dominated followed by Mg, Na and K. The base saturation percentage was found a range between 74.61 and 89.92 and that of exchangeable sodium percentage from 2.83 to 9.29. The organic carbon content was found to be low in field which recorded low levels of both labile and non-labile-P and medium in all the other three soils. The pH was neutral and the EC indicated non-saline nature of all the soils selected for the experiment.

With respect to the availability of the nutrients, the KMnO₄-N was low in all the soils. As regards to the Olsen-P content the soil which contained low levels of both labile and non-labile pools was found to record medium status and the remaining three soils registered high status of Olsen-P. In the case of available K as extracted by neutral normal ammonium acetate, the soils which recorded low levels of both labile and non-labile-P and high levels of both labile and non-labile-P were found to contain medium status of

available K. The soil which recorded high levels of labile and low levels of non-labile-P was found to register low status of available K, whereas the field which contain low levels of labile-P and high levels of non-labile-P recorded high status of available K. The P fractions were found to vary significantly between the soils as the criteria for short listing the soils is based on the relative proportion of labile and non-labile-P.

Plant height

The height of the plant was recorded at different crop growth stages and is presented in Table 26. A close scrutiny of the statistical results had indicated that application of P had resulted in a marginal decrease in the plant height. The shortest plants were observed which received P at 150 kg P₂O₅ ha⁻¹. It was also seen that taller plants were associated with the soils which contained higher levels of labile and non-labile-P followed by the soils which were characterized as low levels of labile-P and high levels of non-labile-P, low levels of both labile and non-labile-P and soils with high levels of labile-P and low levels of non-labile-P. With the advancement of the crop growth, the height of the plant increased significantly.

The interaction of P and soil was significant. A close scrutiny had indicated that in soils containing low levels of both labile and non-labile-P, application of P at 50 kg P₂O₅ ha⁻¹ recorded higher plant height, though it was comparable with 100 kg P₂O₅ ha⁻¹ level. Application of P 150 kg ha⁻¹ had resulted in shorter plants and was comparable with 0 kg P₂O₅ ha⁻¹ level. It was further noticed that in the other soils which contained either labile or non-labile-P or both at higher level had clearly resulted in the decrease in the plant height, though the decrease was only marginal. At levels of P application, taller plants were seen in the soils which contained high levels of both labile and non-labile-P, though the other types of soils were only numerically different.

The interaction of P with the stage of the crop growth had indicated that irrespective of the levels of P applied, the height of the

plant increased with the advancement of crop growth. It was further noticed that effect of P application was not significant at the active tillering stage, whereas at the later stages of the crop growth, the plant height declined marginally.

The interaction of soil with the stage of the crop growth had shown the increase in plant height in all the soils as the crop attains maturity. At all stages of crop growth, taller plants were associated with the soils which possessed high levels of both labile and non-labile-P.

Number of tillers

The number of tillers monitored at various growth stages is presented in Table 31 which had shown that application of P at 100 kg P₂O₅ ha⁻¹ had resulted in significantly higher number of tillers per pot followed by all other levels of P, which were comparable. Among the soils, the soil which contained higher levels of both labile and non-labile-P produced more number of tillers followed by the soil which contain high levels of labile-P and low levels of non-labile-P. With the advancement of crop growth the number of tillers had increased significantly.

The interaction of P with soil type was significant and revealed that the effect of P was more pronounced only in soils which contained high levels of both labile and non-labile-P. Irrespective of the dose of P applied to the soil, higher number of tillers was associated with soils, containing high levels of both labile and non-labile-P.

The interaction of P with the stage of the crop had brought out the fact that in the control pots the tiller number did not show any change with the advancement of crop growth, whereas when P was applied, the number of tillers had increased significantly beyond the stage of panicle initiation. Except at harvest stage, application of P at 100 kg P₂O₅ ha⁻¹ had increased the number of tillers, while at harvest there were no marked variation due to P application.

DISCUSSION

The growth of a plant is determined by various factors in which soil plays a pivotal role. As a medium of crop growth, the soil supports the crop plants from sowing to harvest by a steady supply of water and nutrients from seed to harvest. In fact the phenomenon of seed germination triggers by the imbibition of water from the soil which induces the ejection of root and plumule. Until the roots are capable of absorbing water and nutrients from the soil, the endosperm supports the germinating seed. The subsequent growth from then on is directly controlled by the soil and therefore there is a direct impact on the rate of growth and/or the dry matter accumulation in proportion to the supply of nutrients from the soil. As the plants starts to synthesize its own food by photosynthesis, there is a mutual dependence between the roots and shoot system, the roots supplying water and nutrients to the shoot and the shoot supplying photosynthates to the roots. While it is very difficult to clearly demonstrate the dominant role of either of the two systems, it could be conveniently presumed that both are supporting each other and the growth and yield of the crop is expressed based on a positive interaction between these two systems.

In the present investigation, it was observed that the plant height was reduced due to P application, the number of tillers and dry matter production was favourably influenced by the application of P and the productive tillers and length of panicles remain unaffected. The above trend of results might

be due to the fact that P was known to positively influence the root proliferation and does not support vegetative growth like that of N. However, number of tillers indicated that the application of P could enhance a better shoot biomass production without increasing the plant height (Zaman et al., 1995). It was reported by Gebrekidan and Seyoum (2006) that the plant height was reduced when the soil P levels were above 396 Kg ha⁻¹ which supports our findings.

It was also observed that taller plants with more number of tillers, was always associated with the soils containing higher levels of both labile and non-labile-P. It is quite expected that high levels of P supply could result in better root proliferation, dry matter production and production of more number of tillers due to a favourable environment for nutrient absorption. Interestingly, it was also observed that the height of the plant increased with P application in soils which contained low levels of labile and non-labile-P which clearly proves that the P supply from the soil below a certain level would definitely affect the crop growth and any addition would increase the internode elongation and thereby the plant height. It is to be understood that when the P supply was lower than the crop requirement, the crop growth is affected and the growth parameters are reduced (Salton et al., 2004). However, in the present investigation a marginal response was noticed obviously due to the reason that the soils are highly heterogenic with respect to the labile and non-labile-P fractions.

Table 1: Characterization of surface soil samples of PAJANCOA & RI farm

Sl. No.	Particulars	LL*	LH	HL	HH
1.	Texture	Sandy clay	Sandy clay	Sandy loam	Clay loam
	Soil separates (%)				
a.	Clay	53.90	20.65	22.40	28.40
b.	Silt	7.00	8.25	8.75	40.00
c.	Coarse sand	32.79	55.28	10.01	7.01
d.	Fine sand	5.12	15.06	57.13	23.20
2.	CEC [c mol (p ⁺) kg ⁻¹]	76.50	57.60	24.70	50.40
3.	Exchangeable cations [c mol (p ⁺) kg ⁻¹]				
a.	Exchangeable Ca ²⁺	30.50	29.50	9.00	21.50
b.	Exchangeable Mg ²⁺	24.00	19.50	7.00	18.00
c.	Exchangeable Na ⁺	5.12	2.09	2.29	1.42

Sl. No.	Particulars	LL*	LH	HL	HH
d.	Exchangeable K ⁺	1.01	0.71	0.13	0.97
e.	BSP (%)	79.26	89.92	74.61	83.13
f.	ESP (%)	6.69	3.62	9.29	2.83
4.	Organic carbon (g Kg ⁻¹)	4.12	6.57	5.71	6.11
5.	Organic matter (%)	0.71	1.13	0.99	1.05
6.	pH	7.81	7.58	6.92	6.06
7.	EC (dS m ⁻¹)	0.12	0.03	0.03	0.05
8.	KMnO ₄ -N (Kg ha ⁻¹)	224.00	252.00	196.00	218.40
9.	Olsen-P (Kg ha ⁻¹)	18.42	273.80	98.26	103.38
10.	Bray I-P (Kg ha ⁻¹)	105.69	59.90	315.74	85.87
11.	Bray II-P (Kg ha ⁻¹)	100.70	26.77	231.99	20.39
12.	NH ₄ OAC-K (Kg ha ⁻¹)	257.00	342.00	89.00	144.00
13.	Total N (%)	0.031	0.077	0.038	0.060
14.	Total P (%)	0.06	0.95	0.61	0.98
15.	Total K (%)	0.322	0.322	0.246	0.152
16.	P fractions (mg Kg ⁻¹)				
a.	NaCl-P	8.28	75.39	157.32	71.76
b.	NaOH-P	361.86	132.05	417.65	469.76
c.	HCl-P	155.77	515.64	207.70	623.09
d.	Triacid-P	25.43	11.96	0.00	30.52
	Labile-P	370.14	207.44	574.97	541.52
	Non-labile-P	155.77	515.64	207.70	623.09

*LL – Low Labile-P and low Non-Labile-P

LH – Low Labile-P and high Non-Labile-P

HL – High Labile-P and low Non-Labile-P

HH – High Labile-P and high Non-Labile-P

Table 2: Effect of P levels on the plant height of paddy (cm) in soils at various stages with varying levels of P fractions

Soil types	LL	LH	HL	HH	<i>P x T mean/ P mean</i>
Levels of P /Stage					
0 Kg ha ⁻¹					
Active tillering	55.23	61.03	56.03	63.37	58.92
P I	83.27	97.10	90.47	97.23	92.02
Harvest	99.65	110.63	100.02	109.37	104.92
<i>P x S mean</i>	79.38	89.59	82.17	89.99	85.28
50 Kg ha ⁻¹					
Active tillering	56.50	62.53	55.37	65.73	60.03
P I	86.00	92.73	80.27	93.57	88.14
Harvest	103.03	103.38	93.35	108.30	102.02
<i>P x S mean</i>	81.84	86.22	76.33	89.20	83.40
100 Kg ha ⁻¹					
Active tillering	58.83	60.40	56.63	67.80	60.92
P I	89.83	86.53	77.43	90.93	86.18
Harvest	102.87	111.98	96.13	113.52	106.13
<i>P x S mean</i>	83.84	86.31	76.73	90.75	84.41
150 Kg ha ⁻¹					
Active tillering	56.00	62.47	56.40	63.73	59.65
P I	78.50	91.13	82.17	90.17	85.49
Harvest	96.43	106.98	96.15	101.88	100.36
<i>P x S mean</i>	76.98	86.86	78.24	85.26	81.83
Soil Mean	80.51	87.24	78.37	88.80	

	P	S	T	P x S	P x T	S x T
S.E _d	0.71	0.71	0.61	1.41	1.22	1.22
C.D (0.05)	1.40	1.40	1.21	2.80	2.43	2.43

Table 3: Effect of P levels on number of tillers of paddy in soils at various stages with varying levels of P fractions

Soil types	LL	LH	HL	HH	<i>P x T mean/ P mean</i>	
Levels of P /Stage						
0 Kg ha ⁻¹						
Active tillering	38.00	41.33	46.00	64.00	47.33	
P I	44.00	40.67	46.67	71.33	50.67	
Harvest	46.67	43.33	49.33	70.67	52.50	
<i>P x S mean</i>	42.89	41.78	47.33	68.67	50.17	
50 Kg ha ⁻¹						
Active tillering	32.00	34.00	32.67	65.33	41.00	
P I	36.67	42.67	52.67	86.67	54.67	
Harvest	47.33	46.00	57.67	83.33	58.58	
<i>P x S mean</i>	38.67	40.89	47.67	78.44	51.42	
100 Kg ha ⁻¹						
Active tillering	39.33	30.67	46.67	96.67	53.33	
P I	40.33	42.00	54.67	107.33	61.08	
Harvest	44.67	44.67	54.67	107.67	62.92	
<i>P x S mean</i>	41.44	39.11	52.00	103.89	59.11	
150 Kg ha ⁻¹						
Active tillering	38.00	34.67	33.33	72.00	44.50	
P I	39.00	40.00	46.67	76.00	50.42	
Harvest	46.00	45.33	54.00	70.67	54.00	
<i>P x S mean</i>	41.00	40.00	44.67	72.89	49.64	
Soil Mean	41.00	40.44	47.92	80.97		
	P	S	T	P x S	P x T	S x T
S.E _d	1.52	1.52	1.32	3.04	2.63	2.63
C.D (0.05)	3.02	3.02	2.61	6.04	5.23	NS

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