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Transformation of Phosphorus in Rice Soils Under Field Capacity and Flooded Conditions

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The moisture regimes had a profound influence over the distribution of soil inorganic phosphorus and among the moisture regimes flooded condition was found to cause substantial effect on the reduction of ferric phosphate to ferrous form, hydrolysis of Al-P and release of occluded phosphates. Flooding had increased Fe-P, Al-P and decreased reductant soluble Fe-P. There was no change in Ca-P. Fe-P fraction as determined in airdried soils, in I and II stage samples, was found to correlate with the P uptake under flooded condition and it failed to produce any significant correlations in field capacity. The other fractions did not produce any significant correlation with P uptake under both the moisture conditions. This shows that Fe-P has played a key role in P availability in waterlogged soils.

In rice farming the availability of phosphorus to crop is more complicated due to many chemical transformations taking place under different moisture regimes. The phosphorus nutrition of low land rice differs from upland crops in certain important respects like the uptake of phosphorus and the dynamism of oxidation reduction conditions in soils which facilitate the release or fixation of phosphorus in different moisture levels. The redox-potential changes with the reduction of iron and manganese compounds. This leads to the break up of many binding forces and phosphorus becomes released slowly. Owing to the above reasons, the soil test methods developed to assess the fertility of soil in relation to phosphorus have failed to be of universal application. In order to have an ideal soil test to assess the phosphorus availability in rice soils, a study on the behaviour of the different fractions of phosphorus in different moisture levels during the crop growth is necessary. With these points in view, the present study was under taken to investigate the transformation of phosphorus undergoing in soils at various moisture levels and the possible use of fractionation study of P to trace the transformation and availability.

MATERIALS AND METHODS

A pot experiment using eleven representative soils of Tami Nadu was laid out with two moisture treatments, viz. field capacity and flooding. Water was allowed to stagnate in flooding treatment upto a depth of 5 cm above the soil and the same condition was maintained thoroughout the experiment. In the case of field capacity treatment calculated quantity of water (60 per cent water holding capacity) was added and the soils were mixed thoroughly.

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They were then weighed soon after transplanting and thereafter irrigation was given on alternate days by finding the differences in weights of pots.

Soil samples were collected on 15th day, 35th day (tillering) and 55th day (flowering) after transplanting and they were immediately analysed for the various fractions of inorganic phosphorous by the method of Chang and Jackson (1957). Immediately after collection of soil samples, they were stored in a refrigirator and the extraction completed on the same day of collection. The moisture in the wet samples was estimated separately and the fractions of phosphorus were calculated as ppm of phosphorus on moisture free basis.

Phosphorus in plant sample (grain and straw) was determined and the total uptake calculated. The exprimental data collected were subjected to statistical scrutiny and the uptake of phosphorus was correlated with different fractions of phosphorus and based on this conclusions were drawn.

RESULTS AND DISCUSSION

As reviewed from the literature on rice soils, it is felt that different fractions of phosphorus have to play an active role in the availability of phosphorus. In the present investigation various forms like Fe-P. Al-P, Ca-P and reductant soluble Fe-P were estimated in all the air dried soils and at different stages of crop growth under different moisture levels. The moisture regimes affected the distribution of the fractions of phosphorus and in this paper the transformation of phosphorus undergone in field capacity and flooded moisture conditions in relation to the availability to crop are discussed.

i. **Iron Phosphate** (Fe-P): Moisture regimes had a significant influence in the Fe-P fraction in general and among the moisture regimes flooding increased the Fe-P to a large extent. The values were double almost in flooded soils as compared to the air dried soils (Table I). As the number of days under submergence increased, the Fe-P also increased. Reduction condition prevails under waterlogged soils and the Ferric compounds undergo significant transformations and as a result phosphorus in soil solution dynamically changes. This is in accordance with the results of Davide (1960), Valencia (1962), Tyner and Davide(1962) Chiang *et al.* (1963) Al-Abbas and Barber (1964) and Mahapatra and Patric(1969). All these works revealed that Fe-P had played a key role in phosphate availability and when the soils were kept under field capacity, there was no significant change in ferric form and as a result the availability is not influenced due to this fraction. Fraction as determined in air dried soils and I stage samples were found to correlate with the phosphorus uptake under flooded condition and it failed to produce any significant correlation in field capacity conditions.

ii. **Aluminium Phosphate** (Al-P): This fraction also had the same trend as Fe-P (Table II) and undergoes considerable changes under the influence of moisture levels. Though in both the moisture conditions there was an increase in the Al-P content, the flooding had a significant effect than the field

TABLE I. Changes of Aluminium Phosphate with stages (ppm of P on moisture free basis)

Soils	Air dry soils	Flooding		Field capacity	
		15th day	55th day	15th day	55th day
S_1	10.57	19.25	21.30	11.85	13.2[illegible]
S_2	18.40	15.16	16.25	21.75	26.3[illegible]
S_3	25.40	40.35	38.51	28.39	29.4[illegible]
S_4	210.57	295.16	301.75	227.20	239.3[illegible]
S_5	273.05	265.75	275.00	275.20	290.3[illegible]
S_6	127.00	128.35	131.51	137.00	141.5[illegible]
S_7	16.80	40.25	36.25	20.85	21.5[illegible]
S_8	22.17	34.25	41.20	26.17	27.[illegible]
S_9	17.50	29.55	39.25	26.40	21.7[illegible]
S_{10}	69.12	125.06	131.50	71.95	79.4
S_{11}	43.20	86.20	70.51	52.75	59.5

1. Comparison of moisture canditions :

	M_1	M_2	S.E.	C.D.
Mean	94.24	113.31	0.755	2.09

M_1 : Field capacity M_2 : Flooding

2. Comparison of stages :

	I	II	S.E.	C.D.
Mean	101.74	105.81	0.755	2.09

I = 15th day II = 55th day

Soils : 1, 2, 3 — Red soils of Theni, Kappalur and Dindigul
4, 5, 6 — Black soils of Thirumangalam, Koilpotti and Dindigul
7, 8, 9 — Alluvial soils of Cholavandan, Cumbum and Ambasamudram
10 & 11 — Laterite soils of Pannaikkadu and Madurai respectively.

capacity. The change in the concentration of this fraction under flooded condition as compared to the air dried soils and field capacity conditions, is a supporting evidence to the dynamism of flooded soils. This is in agreement with the findings of Valencia (1962) who observed that soon after flooding, phosphate increased apparently through the hydrolysis of $AlPO_4$ and the reduction of $FePO_4$. None of the correlations studied among Al-P and uptake of phosphorus in both the moisture regimes and in all the stages were found to be significant.

iii. **Reductant soluble iron phosphate (RS.Fe-P):** Recent works in rice

TABLE II. Changes of Iron phosphate with stages (ppm of P on moisture free basis)

Soils	Air dry soils	Flooding 15th day	Flooding 55th day	Field capacity 15th day	Field capacity 55th day
S_1	49.97	94.20	99.07	60.26	71.70
S_2	46.80	85.24	89.75	55.30	60.70
S_3	89.25	112.75	123.60	93.25	103.90
S_4	10.70	52.25	73.85	13.27	19.83
S_5	45.20	75.95	93.12	57.65	63.82
S_6	2.65	35.94	43.70	3.17	16.35
S_7	66.30	120.20	143.90	72.92	88.77
S_8	79.77	92.30	91.65	83.15	79.85
S_9	26.42	72.57	118.07	34.20	44.25
S_{10}	74.65	111.68	155.90	90.61	105.87
S_{11}	28.60	98.80	120.20	39.97	43.01

1. Comparison of moisture conditions:

	M_1	M_2	S.E.	C.D.
Mean	82.98	115.20	2.650	7.36

2. Comparison of stages

	I	II	S.E.	C.D.
Mean	94.71	103.56	2.650	7.36

soils report the special significance of this fraction (Mahapatra and Patric 1969, Islam 1970). Reduction of this hydrated ferric oxide coating to the more soluble ferrous hydroxide as a result of waterlogging release the occluded phosphates. Fe-P released in this manner is available to the crop only when it is reduced to more soluble ferrous phosphate.

A close examination of the results (Table III) showed that there was a significant decrease of reduction of this fraction due to flooding and field capacity though the reduction was found to be high in flooded condition than the field capacity and air dried soils. This clearly indicates the reduction of hydrated ferric oxide coating of this fraction due to flooding and the resultant increase of ferrous form thereby increasing the higher concentration of available phosphorus in the soil solution. In the case of field capacity no such realization was felt and that is the reason why this fraction is not believed to contribute towards phosphate fertility in well drained soils but its importance in waterlogged soils has been realised in recent years.

TABLE III. Changes of Reductant soluble iron phosphate with stages (ppm of P on moisture free basis)

Soils	Air dry soils	Flooding		Field capacity	
		15th day	55th day	15th day	55th day
S_1	68.74	48.25	40.35	60.12	58.26
S_2	51.26	32.16	29.17	45.72	40.36
S_3	130.37	93.75	83.74	126.71	116.50
S_4	49.65	40.30	42.71	42.37	39.27
S_5	83.29	60.51	51.25	80.64	73.60
S_6	95.70	62.65	59.07	80.20	79.60
S_7	452.66	315.01	325.00	409.00	395.16
S_8	109.37	83.66	71.15	108.24	99.25
S_9	28.25	20.75	18.71	26.75	20.75
S_{10}	165.74	95.30	81.60	161.72	155.20
S_{11}	79.29	50.25	41.71	69.30	60.10

1. Comparison of moisture conditions:

	M_1	M_2	S.E.	C.D.
Mean	104.75	78.09	0.438	1.21

2. Comparison of stages

	I	II	S.E.	C.D.
Mean	94.70	88.14	0.438	1.21

iv **Calcium phosphate (Ca-P)**: The calcium phosphate fraction was found to be unchanged by the effect of moisture regimes and stages. Usually Ca^{++} ion does not undergo any changes under redox conditions and hence no influence in the availability of the phosphorus in flooded soils.

In general the moisture regimes had a profound influence over the distribution of soil inorganic phosphorus and among the moisture regimes flooded condition was found to cause substantial effect on the reduction of ferric phosphate to ferrous form, hydrolysis of Al-P and release of occluded phosphates. Flooding had increased Fe-P, Al-P and decreased reductant soluble Fe-P. There was no change in Ca-P. The decrease in available phosphorus concentration in waterlogged soils with the progress of crop growth indicated that the regeneration or the transformation of the various insoluble fraction into soluble form. The Fe-P, Al-P and reductant soluble Fe-P are important fractions to be considered under flooded soils in relation to the availability of phosphorus. The existence of a continuous stream of soil water in the soil under flooded condition in which the root interface and soil particles are constantly bathed, increase the concentration of phosphate ion which is an important factor in the acceleration of ion uptake. The replenishment of ions at the active root surface is carried out through progressive dissolution of the above discussed insoluble fractions under the influence of soil water.

The moisture level in the soil is therefore intimately linked with the phosphate transformation and its eventual supply to the crop. Low moisture status under field capacity enhances fixation of phosphate and reduce diffusivity of ions due to liberal oxygen diffusion, while high moisture status as in the case of flooded condition is condusive for rapid mass flow.

The results showed that as the number of days under flooding increased, the concentration of Fe–P and Al-P increased while the reductant soluble Fe-P fraction decreased. It is logical to argue that since the reductant soluble Fe-P fraction had been reduced during the crop growth, this must directly or indirectly form the source for the availability of phosphorus in flooded soils. When the total phosphorus uptake of the plant was correlated with different fraction it was found that only Fe-P in air dried samples, 15 days flooding (tillering) and 55 days after flooding (flowering) correlated well. The correlation coefficients were $r = 0.458^{*}$, $r = 0.442^{**}$ and $r = 0.426^{**}$ respectively. No significant correlations were obtained with the other fractions. If the reductant soluble Fe-P fraction forms direct source of available phosphorus to the plant there must be a negative correlation with the uptake of phosphorus to support its importance. The non-significant correlation of this fractions with the uptake of phosphorus indicate that it does not form the direct source but its indirect action may be thought of.

According to Chang and Jackson (1958) and Mahapatra (1966), it was found that the occluded phosphates Fe-P and Al-P) are released by reduction of hydrated ferric oxide coating when the soils are flooded. This makes the RS-Fe-P fraction to be reduced and the Fe-P and Al-P fraction are to be increased. As discussed earlier only the Fe-P fraction was found to correlate with the uptake of phosphorus in all the stages of analysis. This showed that Fe-P had played a key role in phosphate availability. This is in accordance with the work of Gupta and Singh (1969) in which they observed the uptake of phosphorus by plants was highly correlated with the amount of Fe-P but not with other fractions. Workers like Tyner and Davide (1962) and Chang and Juo (1963) have also emphasised the importance of Fe-P when selecting a soil test for available phosphorus for low land rice soils. Srivastava and Pathak (1968) have also reported that the available phoshorus determined by both the Olsens and Bray II methods correlated well with Fe-P.

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