

## Influence of Wetting and Drying Cycles on Inorganic P-Fractions in an Acid Soil Amended With or Without Rock Phosphate

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**Abstract** Drying-induced soil aeration and reflooding periodically alters redox conditions and therefore stimulate redox-sensitive processes influencing P binding forms. The release of available P from indigenous rock phosphate under this situation is another area of study. Drying stimulated mineralization of organic P and increased reductant soluble P into available pool. Addition of rock phosphate further accentuates release pattern of inorganic P particularly where soils were subjected to 2<sup>nd</sup> drying and remoistening phase. Furthermore, all fractions of inorganic P are closely related in fixation and release phenomena.

**Keywords** Inorganic P fractions, Drying and remoistening phases, Acid soil, Mussoorie rock phosphate.

### Introduction

Phosphorus is one of the essential nutrients for crop production. P-deficiency leads to incomplete reproductive growth, hindrance in energy transformations

in metabolic and physiological processes and ultimately lower yield in terms of quantity and quality. Inorganic phosphorus compounds in soils are of 2 types, (a) calcium phosphates (apatites) starting from most soluble mono-calcium to most complex tri-calcium phosphate ; (b) iron and aluminium phosphates.

The available P in Indian soils is generally 120 to 2166 kg ha<sup>-1</sup> [1], much lower than the need of the plants. Among the phosphatic fertilizers superphosphates (mono and/or di calcium phosphates) are considered to be best. Its production requires rock phosphate as raw material, which is mainly imported (around 65%) [2]. Recently deposits of high grade rock phosphate (33–35% P<sub>2</sub>O<sub>5</sub>) in Rajasthan and low grade rockphosphates (< 23–25% P<sub>2</sub>O<sub>5</sub>) mainly in Uttar Pradesh, Himachal Pradesh are found. Many trials have been conducted to assess the feasibility of RP for direct application to soil [3]. Acid soils generally exhibit poor crop yield due to low available P content. Much of the added P is fixed (adsorbed on surfaces of Al and Fe hydrous oxides) and is not available for crops.

Changes in P-availability during drying and reflooding have been widely studied in agricultural sites. Drying of soil decreases the solubility of amorphous Fe and Al oxides and P sorption affinity [4].

Keeping above information in view, the present investigation was conducted to study the changes in

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**Table 1.** General physical and chemical properties of the soil used for the experiment. Al-P = Aluminium P, Fe-P = Iron P, S-P = Saloid bound P, Ca-P = Calcium P, O-P = Occluded P, R-P = Reductant soluble P.

Parameters analyzed	Results	Methods adopted
Sand (%)	43.50	Hydro meter [5]
Silt (%)	40.00	
Clay (%)	16.50	
Water holding capacity (%)	32.50	Keen Rackzaw Ski [6]
Bulk density (g cc <sup>-1</sup> )	1.43	Keen Rackzaw Ski [6]
Particle density (g cc <sup>-1</sup> )	2.32	Keen Rackzaw Ski [6]
pH (1 : 25 w/v) in water	5.13	Glass Electrode pH meter [7]
Electrical conductivity (dSm <sup>-1</sup> )	0.40	Conductivity Bridge [7]
CEC [Cmol (p <sup>+</sup> ) kg <sup>-1</sup> soil]	6.61	Jackson [8]
Oxidizable organic carbon (%)	0.34	Walkley and Black [9]
Total nitrogen (mg kg <sup>-1</sup> )	533.32	Bremner [10]
Available nitrogen (mg kg <sup>-1</sup> )	87.91	Bremner and Keeney [11]
Available phosphorus (mg kg <sup>-1</sup> )	36.90	Bray and Kurtz [12]
Available potassium (mg kg <sup>-1</sup> )	9.20	Jackson [8]
Inorganic P fractions (mg kg <sup>-1</sup> )	Al-P (34.72) Fe-P (74.20) S-P (4.95) Ca-P (17.30) O-P (91.60)	Jackson [8]

different fractions of inorganic P in an acid soil subjected to wetting and drying cycles in presence and absence of Mussoorie rock phosphate.

### Materials and Methods

Composite soil sample (0–15 cm depth) was collected from Regional Research Farm (BCKV) (22°27'47'' N 87°0'45'' E), Jhargram, Paschim Medinipur (West Bengal) during the year 2014. The soil was air dried, powdered, passed through a 2 mm sieve. The physical and chemical properties of the initial soil were presented in Table 1. The experiment was conducted in controlled laboratory condition. Two kg air dried soils were taken in each plastic pot. As treatment material, Mussoorie rock phosphate (17.4% P<sub>2</sub>O<sub>5</sub>, supplied by West Bengal Mineral Development Corporation) at 180 kg ha<sup>-1</sup> was mixed thoroughly with the soil of respective pots where the effect of drying phase(s) was studied in presence of rock phosphate [5–7]. Altogether 8 sets of treatments with 3 replications were adopted for the experiment. The treatments adopted for the experiment are as follows:

T<sub>1</sub> = Soils were maintained at 60% Moisture holding capacity (60% MHC) throughout the experimen-

tion period up to 90<sup>th</sup> days of incubation. T<sub>2</sub> = T<sub>1</sub> + Mussoorie rock phosphate at 180 kg ha<sup>-1</sup>. T<sub>3</sub> = Soils were maintained at 60% MHC up to 30<sup>th</sup> day where a drying phase was given and then the soils were re-moistened to its pre-dried 60% MHC on 45<sup>th</sup> day and maintained up to 90<sup>th</sup> day of incubation. T<sub>4</sub> = T<sub>3</sub> + Mussoorie rock phosphate at 180 kg ha<sup>-1</sup>. T<sub>5</sub> = Soils were maintained at 60% MHC up to 60<sup>th</sup> day where a drying phase was given and then the soils were re-moistened to its pre-dried 60% MHC on 75<sup>th</sup> day and maintained up to 90<sup>th</sup> day of incubation. T<sub>6</sub> = T<sub>5</sub> + Mussoorie rock phosphate at 180 kg ha<sup>-1</sup>. T<sub>7</sub> = Two drying phases, one at 30<sup>th</sup> day and another at 60<sup>th</sup> day of experiment, were given and after each drying phase soils were re-moistened to its pre-dried 60% MHC on 45<sup>th</sup> day and 75<sup>th</sup> day respectively and maintained up to 90<sup>th</sup> day of incubation. T<sub>8</sub> = T<sub>7</sub> + Mussoorie rock phosphate at 180 kg ha<sup>-1</sup>.

Soils were sampled on 0<sup>th</sup>, 30<sup>th</sup>, 45<sup>th</sup>, 60<sup>th</sup>, 75<sup>th</sup> and 90<sup>th</sup> day of incubation and analyzed for inorganic P fractions (Available-P, Fe-P, Al-P, Ca-P, Saloid-P, Occluded P, Reductant-Soluble P) following standard [8–12].

All the data were statistically analyzed following methods meant for randomized block design

**Table 2.** Changes in the amount ( $\text{mg kg}^{-1}$ ) of available P in soil treated with or without Mussoorie rock phosphate and maintained at 60% of MHC as well as subjected to one and / or two cycle(s) of wetting and drying. Where,  $T_1$  = Soils were maintained at waterlogged condition throughout the experimentation period up to 90<sup>th</sup> days of incubation,  $T_2 = T_1 +$  Mussoorie Rock Phosphate at  $180 \text{ kg ha}^{-1}$ ,  $T_3$  = Soils were maintained at waterlogged condition up to 30<sup>th</sup> day where a drying phase was given and then the soils were remoistened to its pre-dried waterlogged stage on 45<sup>th</sup> day and maintained up to 90<sup>th</sup> day of incubation,  $T_4 = T_3 +$  Mussoorie Rock Phosphate at  $180 \text{ kg ha}^{-1}$ ,  $T_5$  = Soils were maintained at waterlogged condition up to 60<sup>th</sup> day where a drying phase was given and then the soils were remoistened to its pre-dried waterlogged stage on 75<sup>th</sup> day and maintained up to 90<sup>th</sup> day of incubation,  $T_6 = T_5 +$  Mussoorie Rock Phosphate at  $180 \text{ kg ha}^{-1}$ ,  $T_7$  = Two drying phases, one at 30<sup>th</sup> day and another at 60<sup>th</sup> day of experiment, were given and after each drying phase soils were remoistened to its pre-dried waterlogged stage on 45<sup>th</sup> day and 75<sup>th</sup> day respectively and maintained up to 90<sup>th</sup> day of incubation,  $T_8 = T_7 +$  Mussoorie Rock Phosphate.

Treatments	Incubation period (days)						Mean
	0	30	45	60	75	90	
$T_1$	15.0	17.0	18.3	19.6	21.5	22.3	18.95
$T_2$	15.2	17.8	19.9	21.7	23.7	24.9	20.54
$T_3$	15.2	17.2	15.7	21.3	24.0	25.1	19.77
$T_4$	15.4	18.1	16.3	25.4	27.4	28.5	21.84
$T_5$	14.9	16.8	18.6	19.9	17.5	26.1	18.97
$T_6$	15.1	17.6	20.3	22.0	19.7	28.7	20.58
$T_7$	15.1	17.1	15.6	21.1	18.2	28.0	19.17
$T_8$	15.4	18.1	16.2	23.3	20.6	31.1	20.76
Mean	15.15	17.46	17.63	21.78	21.56	26.84	
SEm ( $\pm$ )	0.01	0.01	0.02	0.01	0.02	0.01	
CD (5%)	0.02	0.02	0.06	0.02	0.05	0.04	

(RBD). Their mean effects were further subjected to Post-Hoc test to identify homogeneous means. The means were compared with value of Critical Difference (CD) at 5% level of significance.

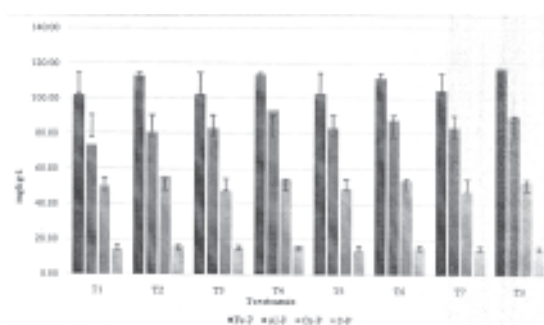
## Results and Discussion

Irrespective of treatments, available P increased with increase in the period of incubation (Table 2). This increase in available P is due to mineralization of organic P present in soil [13]. Addition of Mussoorie rock phosphate as P source increased available P content in soil [14]. Data further revealed that maintenance of one or two drying and rewetting phase did not remarkably change the available P content in soil. The observed change in the available P is due to reaction with other soil constituents (like Fe, Al) which are the most active phosphate fixers in soils and thus get retained [15]. Mean value of the results in Table 2 also showed little effect under different treatments on changes in available P. However, statistical interpretation of the results showed that adopted treatments are significantly effective in changing available P at different stages of the experiment.

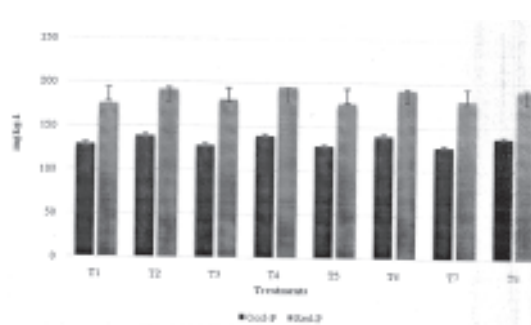
Results presented in Figure 1 showed that addi-

tion of rock phosphate increased the Fe-P content in soil. Soils subjected to a drying phase either at 30<sup>th</sup> or at 60<sup>th</sup> day of the experiment decreased Fe-P content in soil which leads to release of fixed Fe-P under oxidized (drying phase) situation [4]. Results further revealed that maintenance of a drying phase at early stage increases the availability of Fe-P than of soil subjected to a drying phase at the later stage of crop growth. The reason is release of Fe-P in the early stage and subsequent formation of hydrated oxides of Fe-P at the later stage of the experiment. However, the increment in Fe-P is more prominent in soils which received two cycles of wetting and drying phases.

More or less similar trend of results were observed in Al-P as was found for Fe-P in soils (Figure 1). A significant increase in Al-P is observed from 45<sup>th</sup> to 60<sup>th</sup> day of study. Soils subjected to two cycles of wetting and drying did not show drastic variation in release of Al-P. The results find support of earlier investigations carried out by Kerr et al. [16]. Furthermore, the amount of Ca-P present in the soil is of lower order than that of Fe and Al-P (Figure 1). Irrespective of addition of P fertilizer, Ca-P is increased where 60% MHC was maintained throughout the in-



**Fig. 1.** Amount ( $\text{mg kg}^{-1}$ ) of different fractions of active phosphorus [Fe-P, Al-P, Ca-P and saloid bound P (S-P)] in soil maintained at 60% of MHC without considering the period of incubation.



**Fig. 2.** Changes in the amount ( $\text{mg kg}^{-1}$ ) of two inorganic P fractions [occluded P (occl-P) and reductant soluble P (Red-P)] in soil maintained at 60% of MHC without considering the period of incubation.

cubation period owing to formation of di-calcium or tricalcium phosphate in soil.

Saloid bound P also followed similar trend of results as in case of other active P fractions in soil (Figure 1). Comparatively very lesser amount of inorganic P is present in saloid bound form. This form does not play any significant role in P transformation process in soil [17]. No drastic variation in saloid bound P is observed when the soils are subjected to one or two cycles of wetting and drying phases (validated by the mean value of saloid bound P).

It is note worthy to maintain that active P fractions (Fe-P + Al-P + Ca-P + saloid bound P) are more susceptible to release P in soil in absence of added P fertilizer. Aging of phosphate helps to retain more amount of inorganic P in active P form. Results also

pointed out that maintenance of a drying phase at 60<sup>th</sup> day released comparatively higher amount of active P over that of the soil subjected to a drying phase at 30<sup>th</sup> day of the incubation.

The amount of occluded P is more than Fe-P and Al-P (Figure 2). The reason lies in nature of the soil (dominated by Fe-oxides) with which the experiment was conducted. Maintenance of a single drying and rewetting phase at the early stage releases more P from occluded form, which can be taken up by the growing crops. The release of occluded-P is due to oxidation of iron compounds which binds available P in soils [18]. Mean value of the occluded P also showed little effect of treatments particularly over the whole experimentation period. The effect of Mussoorie rock phosphate is well marked at the last stage of the experiment as the rock phosphate is

**Table 3.** Correlation co-efficient among different inorganic fractions of P in soil maintained at 60% of MHC. \*\*Correlation is significant at the 0.01 level, \*Correlation is significant at the 0.05 level. S-P = Saloid bound P, Al-P = Aluminium P, Fe-P = Iron P, Red-P = Reductant soluble P, Occl-P = Occluded P, Ca-P = Calcium P, Av-P = Available P and Active P = (Al-P + Fe-P + Ca-P + S-P).

	S-P	Al-P	Fe-P	Red-P	Occl-P	Ca-P	Av-P	Active-P
S-P	1							
Al-P	0.649	1						
Fe-P	0.924**	0.689	1					
Red-P	0.959**	0.743*	0.939**	1				
Occl-P	0.906**	0.586	0.915**	0.956**	1			
Ca-P	0.810*	0.353	0.830*	0.841**	0.937**	1		
Av-P	0.938**	0.774*	0.844**	0.944**	0.875**	0.769*	1	
Active-P	0.921**	0.835**	0.964**	0.970**	0.910**	0.782*	0.924**	1

slowly dissolved with time [14]. Figure 2 revealed that reductant soluble P is of higher order in comparison to other inorganic P fractions in the present soil. The striking observation is that highest amount of reductant P is released when the soil received two cycles of wetting and drying phases. The release of P from reductant P is more prominent in soils, subjected to 2<sup>nd</sup> drying phase on 60<sup>th</sup> day of incubation and treated with rock phosphate. The reason behind this is slow dissolution of rock phosphate and release of available P in the soil system [14].

Results of correlation study (Table 3) revealed that saloid bound P is highly correlated with available P and active P fractions of the soil. Results also showed that Al-P is highly correlated with active P fractions of the soil. Again, Fe-P is highly correlated with reductant soluble P, occluded P, available P and active P pools of the soil. Maintenance of drying and rewetting phases changed the microenvironment in soil through oxidation-reduction states which influence fixation and release of Fe-P in soil. Thus, it is clear from the correlation data (Table 3) that wetting and drying cycles has a good impact on retention and release of available P which is dependent on active P components in the soil system. The results corroborate the earlier studies carried out by Han et al. [19] and Zin et al. [20].

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