

DISSOLUTION OF LOW GRADE UDAIPUR ROCK PHOSPHATE IN A RED NON-CALCAREOUS SOIL (TYPIC HAPLUSTALF)

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Abstract: The dissolution of low grade Udaipur rock phosphate (URP) in red non-calcareous soil (Typic Haplustalf) was examined through a closed incubation experiment. The rock phosphate (60 and 100 mesh size) at a rate equivalent to 0, 1000, 5000 and 10000 mg P_2O_5 kg^{-1} soil was mixed with soil (100g) and incubated for 120 days in plastic cups both in the presence and absence of *Phosphobacteria*. The dissolution was measured through a sequential P fractionation procedure. The per cent dissolution was calculated based on increase in the NaOH extractable P (inorganic plus organic P) as well as decrease in HCl-P (apatite or acid soluble P). Application of *Phosphobacteria* along with RP resulted in higher dissolution in 60 and 100 mesh size of RP.

Key words: Dissolution, Incubation, Phosphobacteria, Udaipur rock phosphate

INTRODUCTION

Phosphorus is one of the critical nutrient elements, which plays important role in increasing crop growth and yield. Phosphatic fertilizers are being used in maximizing agricultural production in developed countries in proper proportion with N and K, but many developing countries like India have low level of fertilizer P consumption due to cost escalation of P fertilizers. Thus, phosphate fertilization in such cases becomes a vital input. It is estimated that India has about 260 Mt. of rock phosphate (RP) deposits (FAO, 1994). Attempts are being made to utilize these indigenous RP as an alternate source of P fertilizers for direct application. However, direct application of RPs alone to non-acid soils is not considered beneficial. Under this soil condition, application of RP along with some bio-inoculant or organic manure may be beneficial since these are reported to increase the P availability to plants (Mishra *et al.*, 1980; Singh and Amberger, 1991). This study was aimed to examine the dissolution of a low grade RP and the effect of *Phosphobacteria* under neutral soil condition.

MATERIALS AND METHODS

A closed incubation experiment was carried out to measure the dissolution of RP in soil. The soil used for the experiment was sandy clay loam (Typic Haplustalf) with a pH of 7.7 and CEC of 12.9 $cmol(p^+) kg^{-1}$ soil. Different levels of low grade Udaipur rock phosphate (URP) at rates equivalent to 0, 1000, 5000 and 10000 mg P_2O_5 kg^{-1} with two different particle sizes (60 and 100 mesh) were thoroughly mixed with 100 g soil in 150 ml plastic cups. A bioinoculant, *Phosphobacteria* variety *megatherium* was added at a rate of 2 $kg ha^{-1}$. After thorough mixing, distilled water was added to bring the field capacity, which was maintained throughout the experi-

ment. The soil samples with different treatments in triplicate were incubated at $25 \pm 2^\circ C$ for 120 days. For each sampling triplicate samples were maintained separately. Soil samples were collected at the end of 15, 30, 60, 90 and 120 days and analyzed for various P fractions (Bolan and Hedley, 1989). The pH and exchangeable acidity (Blackmore *et al.*, 1987) were also measured.

RESULTS AND DISCUSSION

Compared to control, all the treatments showed a gradual reduction in pH from 15 to 120 days of incubation. The highest reduction was noticed in RP plus *Phosphobacteria* var *megatherium* treatment irrespective of the particle size of RP. During 120 days of incubation, RP (100 mesh) at 10000 mg P_2O_5 kg^{-1} level with *Phosphobacteria* recorded the lowest pH values 6.48 and the highest value was at control (7.65). The lowest value may be due to the acid produced by microorganisms.

Changes in concentration of P fractions

The concentration of solution P as extracted in 1M NaOH ranged from 91.3 to 666.7 and 88.0 to 716.7 mg kg^{-1} for 60 and 100 mesh particle sizes respectively, over a period of 15 to 120 days of incubation whereas in the presence of *Phosphobacteria* it ranged from 82.7 to 780 (60 mesh) and 85.3 to 806.7 mg kg^{-1} (100 mesh). Irrespective of treatments, the concentration of NaOH-Pi was found to increase during incubation indicating continuous dissolution (Mackay *et al.*, 1986 and Bolan and Hedley, 1989). Comparing the two size particles, the URP with 100 mesh generally recorded higher values of NaOH-Pi at all days of incubation, which may be due to higher reactive surface area. Finer the particle size, the greater the degree of contact between RP and soil and therefore greater the

Table 1. Dissolution of rock phosphate based on A NaOH-P₁ + P₀ (% added P₂O₅)

Treatments		Period of incubation, days						
		0	15	30	45	60	90	120
T ₁	Control	-	-	-	-	-	-	-
T ₂	URP @ 1000µg g ⁻¹ (60 mesh)	1.60	10.27	17.87	20.80	29.75	32.02	37.68
T ₃	URP @ 5000µg g ⁻¹ (60 mesh)	0.35	2.57	3.66	3.82	4.82	11.14	11.92
T ₄	URP @ 10000µg g ⁻¹ (60 mesh)	0.29	1.85	2.06	2.49	3.26	4.72	6.09
T ₅	Control	-	-	-	-	-	-	-
T ₆	URP @ 1000µg g ⁻¹ (100 mesh)	2.10	12.42	21.78	27.70	36.50	38.78	40.28
T ₇	URP @ 5000µg g ⁻¹ (100 mesh)	0.21	2.97	3.88	4.34	7.43	13.23	13.40
T ₈	URP @ 10000µg g ⁻¹ (100 mesh)	0.14	1.78	1.92	2.68	3.45	4.75	5.90
T ₉	Control	-	-	-	-	-	-	-
T ₁₀	T ₂ + PB	0.80	16.30	26.00	34.94	43.08	48.50	45.00
T ₁₁	T ₃ + PB	0.13	3.94	4.18	4.70	6.11	14.45	12.71
T ₁₂	T ₄ + PB	0.13	2.01	2.23	3.27	5.94	7.12	7.07
T ₁₃	Control	-	-	-	-	-	-	-
T ₁₄	T ₆ + PB	0.60	16.70	28.48	35.88	45.03	50.17	49.10
T ₁₅	T ₇ + PB	0.05	4.29	4.79	4.64	8.55	14.72	13.18
T ₁₆	T ₈ + PB	0.05	3.18	3.66	5.22	5.81	6.26	5.47

*PB = *Phosphobacteria*Table 2. Dissolution of rock phosphate based on A HCl-P (% added P₂O₅)

Treatments		Period of incubation, days						
		0	15	30	45	60	90	120
T ₁	Control	-	-	-	-	-	-	-
T ₂	URP @ 1000µg g ⁻¹ (60 mesh)	-	12.17	21.70	30.40	31.30	36.50	43.47
T ₃	URP @ 5000µg g ⁻¹ (60 mesh)	-	3.25	3.42	1.71	2.74	8.88	11.11
T ₄	URP @ 10000µg g ⁻¹ (60 mesh)	-	1.22	2.62	3.06	2.71	3.23	4.80
T ₅	Control	-	-	-	-	-	-	-
T ₆	URP @ 1000µg g ⁻¹ (100 mesh)	-	16.00	31.20	35.20	47.20	49.17	52.00
T ₇	URP @ 5000µg g ⁻¹ (100 mesh)	-	3.54	5.15	4.25	6.02	9.56	10.62
T ₈	URP @ 10000µg g ⁻¹ (100 mesh)	-	2.21	2.57	3.01	4.34	3.89	6.19
T ₉	Control	-	-	-	-	-	-	-
T ₁₀	T ₂ + PB	-	20.80	27.50	40.00	48.30	48.30	57.50
T ₁₁	T ₃ + PB	-	5.36	5.89	6.79	7.68	13.00	15.00
T ₁₂	T ₄ + PB	-	1.63	3.10	3.92	5.55	5.53	5.69
T ₁₃	Control	-	-	-	-	-	-	-
T ₁₄	T ₆ + PB	-	25.00	28.30	44.17	49.17	54.17	60.83
T ₁₅	T ₇ + PB	-	3.57	5.18	5.00	6.07	14.29	15.71
T ₁₆	T ₈ + PB	-	3.86	4.64	4.98	5.76	6.87	7.38

rate of RP dissolution. Similar reports were recorded by Hammond *et al* (1986) and Rajan and Ghani (1997). The concentration of organic phosphorus as extracted in 1M NaOH ranged from 41.7 and 109.2 mg kg⁻¹. Mostly higher levels of URP addition recorded the highest concentration of P₀ values. During the period of incubation, the dissolved P was immobilized microbially due to absorption and precipitation

reaction in soil. This precipitation will increase the concentration of organic P in soil. Approximately 2.6 to 3.5 per cent of added P was found transformed in to organic P during 120 days when URP was added at a rate of 1000 µg g⁻¹ (100 mesh size). Higher levels of URP addition (5000 µg g⁻¹) and relatively larger particle size (60 mesh) resulted lower concentration of NaOH-P₀. Thus larger the particle size, (60

mesh) the lesser the degree of contact between RP and soil due to lesser reactive surface area. This may be due to higher amounts of solution

Table 3. Exchangeable acidity, $\text{cmol}(\text{p}^+) \text{kg}^{-1}$

Treatments	Initial	Final
T ₁ Control	13.04	13.12
T ₂ URP @ 1000 $\mu\text{g g}^{-1}$ (60 mesh)	13.20	6.96
T ₃ URP @ 5000 $\mu\text{g g}^{-1}$ (60 mesh)	13.36	7.12
T ₄ URP @ 10000 $\mu\text{g g}^{-1}$ (60 mesh)	13.52	7.28
T ₅ Control	13.20	13.12
T ₆ URP @ 1000 $\mu\text{g g}^{-1}$ (100 mesh)	13.68	7.36
T ₇ URP @ 5000 $\mu\text{g g}^{-1}$ (100 mesh)	13.84	7.62
T ₈ URP @ 10000 $\mu\text{g g}^{-1}$ (100 mesh)	14.00	7.68
T ₉ Control	12.96	13.12
T ₁₀ T ₂ + PB	14.16	7.76
T ₁₁ T ₃ + PB	14.32	7.92
T ₁₂ T ₄ + PB	14.48	8.00
T ₁₃ Control	14.48	13.12
T ₁₄ T ₆ + PB	13.20	8.00
T ₁₅ T ₇ + PB	14.80	8.08
T ₁₆ T ₈ + PB	14.88	8.24
SE (d)	0.32	0.21
CD (0.05)	0.69	0.46

calcium, which might have been absorbed or co-precipitated and rendered insoluble (Bolan and Hedley, 1989).

The concentration of acid soluble inorganic P or apatite P as extracted in 1M HCl (HCl-Pi) varied between 91.7 and 9833.3 mg kg^{-1} without *Phosphobacteria*, whereas, it was between 500 and 10500 mg kg^{-1} with *Phosphobacteria* addition. In general, irrespective of levels of URP addition and particle sizes, the HCl-P concentration markedly decreased during 120 days incubation. The decrease in the concentration is mostly attributed to the dissolution of RP (Mahimairaja *et al.*, 1995).

Dissolution rate of Udaipur rock phosphate

Addition of URP as 60 mesh size resulted in dissolution based on A NaOH-P_j + P_o was ranged from 0.29 to 37.68 per cent. Application of *Phosphobacteria* markedly increased the dissolution of URP. Without bio-inoculant, the dissolution ranged between 1.60 and 37.68% for 60 mesh, whereas with *Phosphobacteria* it was from 0.80 to 48.50 % when URP was added at a rate equivalent to 1000 mg kg^{-1} (Table-1).

The dissolution based on A HCl-P showed relatively higher values than A NaOH-Pi method. For 60 mesh URP at lower levels (1000 mg kg^{-1}), dissolution ranged between 12.17 and 43.47 per cent. Due to bio-inoculant addition, it varied between 20.80 and 57.50 per cent (Table 2.). Application of *Phosphobacteria* markedly increased the dissolution of URP.

At all days irrespective of particle sizes, the dissolution percentage substantially decreased with the increase in levels of added P. With finer particles, the dissolution of RP values ranged between 16.0 and 52.0 and from 25.0 and 60.8 and from 3.5 and 10.6 per cent at 1000, 5000 and 10000 mg kg^{-1} level without *Phosphobacteria* treatment, respectively.

Initially only a small amount of URP (<2.1%) was recovered in the NaOH extract whereas 93.3 to 104 per cent was recovered in the HCl extract. The dissolution computed based on A HCl-P showed relatively higher values than the dissolution based on A NaOH P_i + P_o. However, a very close relationship ($r = 0.846^{**}$) was observed between these two methods. As immobilization (both microbial and/or chemical) and re-mineralization of P continuously occurring in soil, the method based on A NaOH P(P_i+P_o) is likely to underestimate, the dissolution of RP (Bolan and Hedley, 1989). The A HCl-P method appears to give a more accurate estimate of RP dissolution because it measures undissolved RP (apatite P) (Tambunan *et al.*, 1993). Irrespective of the treatments and method of computation, the dissolution of RP increased gradually and at 120 days after incubation the dissolution ranged between 43.47 and 60.83 per cent at 1000 mg kg^{-1} soil. Although the proportion of RP dissolved decreased with increasing rates of application, the absolute amounts dissolved increased. This might be due to the fact that at higher rates of application, diffusion of dissolution products away from the particle surface appears to be limiting. The finer particles of RP (100 mesh), in general, resulted in higher values of dissolution than relatively coarser particles. Similar results were reported by Khasawneh and Doll (1978), Bolan *et al.*, (1990) and Chien (1995).

Phosphobacteria enhanced dissolution to the extent of 8.8 to 14.1 per cent. The microbial synthesis of organic acid and increase in P sink size as it got microbially immobilized in micro-

bial cells of *Phosphobacteria* might be the reason for the enhanced dissolution of URP (Bangar *et al.*, 1985 and Mahimairaja *et al.*, 1995). Relatively lower values of soil pH observed after 120 days provide evidence for the organic acid production in soil due to *Phosphobacteria*, which could have enhanced the RP dissolution. This suggests that such higher dissolution was possible in soils with high sorption capacity. The experimental soil showed a sorption capacity of 82 per cent.

Changes in the exchangeable acidity indicated that approximately 6.72 - 6.20 cmol (p+) kg⁻¹ was reduced in soil during 120 days incubation. With this magnitude of reduction, theoretically one could expect about 2965 mg of P to be released (2 moles of H needed for one mole of PO₄ to be released) from RP. However, the measured dissolution showed only 43.5 to 52.0 per cent when RP was added at a rate of 1000 mg kg⁻¹ suggesting that only a fraction of exchangeable acidity was involved in the dissolution of RP and remaining might have involved in neutralization buffering reaction of soil (Table 3).

In conclusion, the finer panicles of RP (100 mesh) in general resulted in higher value of dissolution than relatively coarser particles. The dissolution computed from A HCl-P appeared to give more precise estimate of net amount of RP dissolved (60.8 per cent) than A NaOH-P method (50.1 per cent). Addition of RP at rates higher than 1000 mg kg⁻¹ resulted in decline in the rate of dissolution.

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