

Efficacy of Rock Phosphate and Super Phosphate with Phosphate Solubilizer (*Bacillus megatherium* var. *phosphaticum*) on Cowpea in a Rainfed Entisol

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Abstract: Field experiments were conducted for two years during 1998 and 1999 in an Entisol (Typic Ustorthent) with two phosphatic fertilizers, viz., Single Super Phosphate (SSP) and Rock Phosphate (RP) at two levels each viz., 25 kg ha⁻¹ (100%) and 18.75 kg ha⁻¹ (75%), with and without seed soaking and phosphobacterium (*Bacillus megatherium* var. *phosphaticum*) on cowpea under rainfed condition. The results indicated that the yield, uptake and economics were improved by the sources of P. Application of 18.75 kg P₂O₅ ha⁻¹ as RP, coupled with phosphobacterium and seed soaking resulted in maximum yield (537 kg ha⁻¹) with higher net return (Rs. 4544 ha⁻¹) and B/C ratio (3.39). The recovery of applied P and the residual soil P were also improved by the P solubilizer and seed soaking. A positive P balance could be noticed under the P-treated plots, while it was negative in the untreated control.

Key words: Cowpea, phosphorus, yield, uptake, efficiency.

The importance of phosphorus in the maintenance of soil fertility and improving crop productivity is recognized now as 2/3rd of Indian soils are known to give universal response to P application. It is the most critical element in highly weathered tropical and sub-tropical soils and per cent utilization of applied P by the crops is very low. Recovery rate rarely exceeds 20% and rest is rendered unavailable due to chemical fixation in the soil (Singh and Sharma, 1994). Among the different sources of P, the superiority of DAP and SSP has been studied (Singaram and Kothandarman, 1993). The P nutrition in many crops grown in low fertility soils has been improved through the use of P solubilizers (Gaur, 1990). The utilization of low grade rock phosphate as a source of P has been explored to develop an alternate cheaper source

of P fertilization (Marwaha *et al.*, 1981). The usefulness of seed fortification with nutrients for improving the yield of pulses has been studied (Ponnuswamy and Vijaya, 1997). In the north-western zone of Tamil Nadu, more than 70% of the cultivable area is red loamy sand with low P status due to high fixation. Cowpea is one of the major pulse crops grown for food and fodder in this zone, which requires proper P nutrition management. Therefore, the present study was designed to investigate the efficacy of SSP and RP with and without P solubilizing microorganisms and seed soaking on cowpea under rainfed conditions.

Materials and Methods

Field experiments were conducted for two years during 1998 and 1999 at Regional Research Station, Paiyur, Tamil Nadu

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Agricultural University. The soils of the experimental sites were red loamy sand, with pH 8.29 and EC 0.16 dS m⁻¹ belonging to the soil group Typic Ustorthent. The available N, P and K status were 154 and 196, 9.6 and 10.64, 370 and 390 kg ha⁻¹ in the two years, respectively. The nine treatments included T₁: Control; T₂: 25 kg P₂O₅ ha⁻¹ as SSP; T₃: 25 kg P₂O₅ ha⁻¹ as RP (Mussoorie); T₄: 18.75 kg P₂O₅ ha⁻¹ as SSP + seed soaking; T₅: 18.75 kg P₂O₅ ha⁻¹ as RP + seed soaking; T₆: 18.75 kg P₂O₅ ha⁻¹ as SSP + phosphobacterium; T₇: 18 to 75 kg P₂O₅ ha⁻¹ as RP + phosphobacterium; T₈: T₆ + seed soaking in a randomized block design with three replications. Cowpea Paiyur - 1 was sown as test crop, adopting a spacing of 30 x 10 cm with seed rate of 20 kg ha⁻¹. The seed soaking was done @ 10 g of fertilizer per kg seed for one hour. Phosphobacterium (*Bacillus megatherium* var. phosphaticum) @ 2 kg ha⁻¹ with population of 10⁸ cells g⁻¹ of lignite-based carrier was applied to the soil by mixing with 50 kg FYM. The RP (Mussoorie) used in the experiments was powdery in nature with particle size of 60 mesh, non-hygroscopic and black in color. The material was having 20.2% total P₂O₅, 32.2% CaO, 4.50% MgO and 0.34% Fe₂O₃. The P fertilizers, as per treatment schedule, were also applied basally. A common dose of 12.5 kg N ha⁻¹ in the form of pilled urea was given to all the treatment plots. Data were recorded on yield attributes and yield of grain and haulms. The grain and haulms samples were collected and analyzed for total N (Humphries, 1956), P and K (Jackson, 1973) and uptake calculated. The P-use efficiency and P recovery were also worked out. The

soil samples collected from 0 to 15 cm depth were analyzed for available N (Subbiah and Asija, 1956), P (Watenabe and Olsen, 1965) and K (Hanway and Heidal, 1952). The balance sheet for available P was calculated as per More and Agale (1993). The data were subjected to statistical analysis (Snedecor and Cochran, 1968).

Results and Discussion

Yield attributes

The number of seeds pod⁻¹, grain test weight and number of nodules plant⁻¹ were significantly improved by the sources and levels of P (Table 1). Higher number of seeds (6.96 pod⁻¹) was recorded by the treatment of 18.75 kg P₂O₅ ha⁻¹ as SSP with phosphobacterium and seed soaking (T₈). However, 1000-grain weight (91.6 g) and nodules plant⁻¹ (20.7) were higher in the treatment T₉ (18.75 kg P₂O₅ ha⁻¹ as RP coupled with phosphobacterium + seed soaking) and lower values (76.6 g and 12.7 nodules, respectively) were observed in control. The pod length, though varied among the treatments from 11.8 to 13.5 cm, did not attain any level of significance.

Yield and P-use efficiency

The yield of cowpea improved significantly due to P fertilization (Table 1). The highest grain yield of 539 kg ha⁻¹ was recorded at 18.75 kg P₂O₅ (75%) ha⁻¹ as RP coupled with phosphobacterium + seed soaking (T₉) and was significantly superior over other treatments and control (299 kg ha⁻¹). The yield increase in this treatment was 79.6% over control and might be due to better yield attributing factors and availability of P (Ramamoorthy and

Table 1. Effect of treatments on yield and yield attributes and economics in cowpea cultivation (average of two years)

Treatment	Yield attributes			Nodules plant ⁻¹	Yield (kg ha ⁻¹)		PUE (kg grain kg P ₂ O ₅ ⁻¹)	Economics		
	Pod length (cm)	Seeds pod ⁻¹	1000 grain wt. (g)		Grain	Haulms		Gross income (Rs. ha ⁻¹)	Net income (Rs. ha ⁻¹)	Benefit/ cost ratio
T ₁	12.5	4.93	76.6	12.7	299	1493	—	3588	1972	2.22
T ₂	12.9	5.64	90.0	16.9	388	1815	3.56	4656	2572	2.23
T ₃	11.8	5.01	83.9	16.1	356	1897	2.28	4272	2356	2.23
T ₄	13.2	6.58	84.0	19.3	381	2032	4.37	4572	2591	2.31
T ₅	12.9	4.47	86.0	13.6	406	2032	5.71	4872	3022	2.63
T ₆	13.5	6.83	92.0	19.8	440	2599	7.52	5280	3263	2.62
T ₇	12.2	6.50	86.6	15.4	410	2817	5.92	4920	3029	2.60
T ₈	13.3	6.96	87.3	15.2	484	2692	9.87	5808	3777	2.86
T ₉	12.8	5.48	91.3	20.7	539	2775	12.69	6444	4544	3.39
CD (5%)	NS	0.22	7.01	3.89	42.9	391.0	—	—	—	—

Arokiaraj, 1997). Regarding the haulms yield, however, the treatment of 18.75 kg P₂O₅ ha⁻¹ as RP combined with phosphobacterim (T₇) recorded 2817 kg ha⁻¹ and was at par with T₉ and T₈, with values of 2775 and 2692 kg ha⁻¹, respectively. Roy *et al.* (1999) also reported increased yield in green gram due to phosphatic fertilizers with P solubilizing micro-organisms. The P-use efficiency was again higher in T₉ (12.68 kg grain kg⁻¹ P₂O₅), followed by T₈ with 9.87 kg grain kg⁻¹ P₂O₅ as compared to 2.28 and 3.56 kg grain kg⁻¹ P₂O₅ recorded by the application of 25 kg P₂O₅ ha⁻¹ as RP and SSP, respectively, without P solubilizer, indicating the positive influence of P solubilizing micro-organisms in improving the yield of cowpea. Further, the P-use efficiency was higher under lower doses, as compared to higher levels of P, and this might be due to greater capacity

of plants for nutrient absorption at lower doses of phosphorus (Gaur, 1990).

Economics

Application of 18.75 kg P₂O₅ ha⁻¹ as RP conjoint with phosphobacterium and seed soaking (T₉) accounted for the highest gross and net returns of Rs. 6444 and Rs. 4544 ha⁻¹, respectively (Table 1), while the lowest gross return (Rs. 3588 ha⁻¹) and net income (Rs. 1972 ha⁻¹) was shown by control. The B/C ratio also followed the same trend as that of net income, the highest value being accounted for by T₉ (3.39), followed by T₈ (2.86), whereas the lowest value of 2.22 was registered in control.

Nutrients uptake and P recovery

The uptake of N, P and K by grain and haulms improved significantly over control (T₁) due to different levels and

Table 2. Effect of sources and levels of P on nutrient uptake and soil fertility status (average of two years)

Treatment	N uptake (kg ha ⁻¹)		P uptake (kg ha ⁻¹)		K uptake (kg ha ⁻¹)		P recovery (%)	Soil fertility (kg ha ⁻¹)		
	Grain	Haulms	Grain	Haulms	Grain	Haulms		N	P	K
T ₁	7.84	37.93	0.97	3.76	3.83	20.61	–	167.4	7.06	342.5
T ₂	10.96	47.24	1.39	4.91	5.14	25.93	6.28	185.0	14.90	408.6
T ₃	10.36	47.02	1.14	5.86	4.83	26.24	9.08	189.0	10.56	382.6
T ₄	12.52	52.28	1.27	6.29	5.25	30.05	15.09	195.5	15.00	384.3
T ₅	13.74	54.55	1.52	6.72	6.46	28.58	18.72	191.4	13.78	357.2
T ₆	12.07	69.79	1.48	7.33	5.61	35.18	21.76	185.2	15.50	376.7
T ₇	11.94	66.73	1.47	5.70	5.57	25.26	13.01	184.6	14.60	383.3
T ₈	13.59	69.82	1.64	8.84	6.28	37.73	30.67	178.6	14.88	361.9
T ₉	15.36	66.20	1.69	5.79	6.96	30.84	17.87	179.1	15.95	377.0
CD (5%)	2.15	12.9	0.259	1.36	0.75	5.95	–	NS	3.54	NS

sources of fertilizers (Table 2). The increase in N, P and K uptake in grain ranged from 31.1 to 95.1, 17.5 to 74.2 and 26.1 to 81.7%, respectively, over control and the highest being under the treatment of 18.75 kg P₂O₅ ha⁻¹ as RP with phosphobacterium and seed soaking (T₉). However, in the haulms, the highest N, P and K uptake of 69.82, 8.84 and 37.73 kg ha⁻¹, respectively, were registered under T₈ (18.75 kg P₂O₅ ha⁻¹ as SSP + phosphobacterium + seed soaking) whereas the lowest was under control (37.93, 3.76 and 20.61 kg NPK ha⁻¹, respectively). Similar findings of increase in nutrient uptake by pulses due to SSP and RP with phosphate solubilizers was reported by Das *et al.* (1999) and Dubey (2000). The recovery of P ranged from 6.28 to 30.67%. The effectiveness of SSP and RP was improved through the seed soaking and addition of P solubilizers to the tune of

24.39 and 9.64%, respectively. The improvement in P recovery might be due to the more solubilization of P in RP by phosphate solubilizer. The findings of Das *et al.* (1999) lend support to the present results.

Residual nutrient status

No significant differences were observed in the available N (167.4 to 195.5 kg ha⁻¹) and K (342.5 to 408.6 kg ha⁻¹) status of soil after harvest of the cowpea crop (Table 2). However, the treatments were able to alter the availability of P to a significant extent. The treatment T₉ (18.75 kg P₂O₅ ha⁻¹ as RP with phosphobacterium and seed soaking) registered higher availability of 15.95 kg P ha⁻¹, however, at par with other P-treated plots, but was superior over control (7.06 kg ha⁻¹), which was at par with T₃ (RP alone) with a P status of 10.56 kg ha⁻¹.

Table 3. Balance sheet of available P (kg ha⁻¹) at crop harvest

Treatment	1998		1999		Mean gain (+) or loss (-) over two years
	P status at the end	Net gain (+) or loss (-)	P status at the end	Net gain (+) or loss (-)	
T ₁	6.83	-2.77	7.28	-3.36	-3.07
T ₂	12.13	+2.53	17.67	+7.03	+4.87
T ₃	7.28	+2.32	13.83	+3.19	+0.44
T ₄	11.12	+1.52	18.88	+8.24	+4.88
T ₅	11.09	+1.49	16.47	+5.83	+3.66
T ₆	12.43	+2.83	18.57	+7.93	+5.38
T ₇	10.01	+0.41	19.20	+8.56	+4.49
T ₈	14.74	+5.14	15.02	+4.38	+4.76
T ₉	13.96	+4.36	17.93	+7.29	+5.83

Phosphorus balance

The balance sheet of available P after cowpea for the two years of experimentation (Table 3) showed a negative balance in control. Application of P₂O₅ (18.75 kg ha⁻¹) through SSP with phosphobacterium + seed soaking (T₈) during the first year (14.74 kg ha⁻¹) and RP coupled with phosphobacterium (T₇) during the second year (19.20 kg ha⁻¹) resulted in higher residual available P with net gain of 5.14 and 8.56 kg ha⁻¹, respectively. The mean gain or loss over the two years showed a higher positive balance of 5.83 kg ha⁻¹ under RP conjoint with P solubilizer and seed soaking (T₉). Mishra and Nanda (1993) and Roy *et al.* (1999) also observed dissolution of low grade indigenous rock phosphate in neutral to slightly alkaline soils and release of P through P solubilizers. In both the years, the control recorded a negative balance (-2.77 and -3.36 kg ha⁻¹, respectively) with a mean loss of -3.07 kg ha⁻¹.

The present study suggests that rock phosphate with P solubilizer and seed soaking could be used as a cheaper phosphatic fertilizer in place of SSP for obtaining higher yield and monetary return under cowpea, coupled with improvement in soil residual P status and net positive P balance in the slightly alkaline red loamy sand soils.

References

- Das, P.K., Sethi, A.K., Jena, M.K. and Patra, R.K. 1999. Effect of P sources and dual inoculation of VA-Mycorrhiza and *Rhizobium* on dry matter yield and nutrient uptake by greengram. *Journal of Indian Society of Soil Science* 47: 466-470.
- Dubey, S.K. 2000. Effectiveness of rock phosphate and super phosphate amended with phosphate solubilizing microorganisms in soybean grown on Vertisols. *Journal of Indian Society of Soil Science* 48: 71-75.
- Gaur, A.C. 1990. *Phosphate Solubilizing Microorganisms as Biofertilizers*. Omega Scientific Publishers, New Delhi.
- Hanway, J.J. and Heidal, H. 1952. Soil analysis methods as used in the Iowa state college soil

- testing laboratory. *Iowa State College Agriculture Bulletin* 57: 1-13.
- Humphries, E.C. 1956. Mineral components and ash analysis. *Modern Methods of Plant Analysis*. Springer-Verlag, Berlin. Vol. 1, pp. 468-502.
- Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Private Ltd., New Delhi.
- Marwaha, B.C., Kanwar, B.S. and Tripathi, B.R. 1981. Direct and residual effectiveness of Mussoorie rock phosphate in wheat-maize rotation. *Indian Journal of Agricultural Sciences* 51: 870-874.
- Mishra, U.K. and Nanda, B. 1993. Dissolution of rock phosphate as affected by soil properties: A laboratory incubation study. *National Seminar on Development of Soil Science*. Abstract. Indian Society of Soil Science. P. 93.
- More, S.D. and Agale, B.N. 1993. Phosphate balance studies in irrigated cotton. *Journal of Indian Society of Soil Science* 41: 498-500.
- Ponnuswamy, A.S. and Vijaya, J. 1997. Effect of seed fortification and pelleting on crop growth and yield in cowpea. *Madras Agricultural Journal* 84: 393-395.
- Ramamoorthy, K. and Arokiaraj, A. 1997. Agronomic effectiveness of organic sources and Mussoorie rock phosphate to phosphorus economy in rainfed greengram. *Madras Agricultural Journal* 84: 593-595.
- Roy, P., Tarafdar, J.C. and Singh, A.P. 1999. Enhancing phosphorus release from Mussoorie rock phosphate by blending with organic materials and phosphate solubilizers. *Journal of Indian Society of Soil Science* 47: 591-593.
- Singaram, P. and Kothandaraman, G.V. 1993. Effect of different source of P on available soil P, yield and nutrient uptake by maize. *Journal of Indian Society of Soil Science* 41: 591-593.
- Singh, K.D. and Sharma, B.M. 1994. In *Phosphorus Researches in India* (Ed. G. Dev), p. 47. PPIC-India programme. Dundahera. Gurgaon.
- Snedecor, G.W. and Cochran, W.G. 1968. *Statistical Methods*. Oxford and IBH Publishing Company, New Delhi.
- Subbiah, B.V. and Asjija, G.L. 1956. A rapid procedure for estimation of available nitrogen in soils. *Current Science* 25: 259-260.
- Watanable, F.S. and Olsen, S.R. 1965. Test of an ascorbic acid method for determination of phosphorus in water and NaHCO_3 extracts from soil. *Soil Science Society American Proceedings* 29: 677-679.