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Agronomic efficacy of indigenous and exotic rock phosphates in soybean (*Glycine max*) in an acid soil

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ABSTRACT

A field experiment was conducted during 1995 and 1996 to study agronomic efficacy of rock phosphates, North Carolina rock phosphate (NCRP), Udaipur rock phosphate (URP), and Mussoorie rock phosphate (MRP) as phosphorus source in an acidic silty clay loam soil at Palampur, with 'Bragg' soybean [*Glycine max* (L.) Merr.] as test crop and single superphosphate as standard. Direct application of rock phosphate @ 60 kg P_2O_5/ha resulted significant increase in growth and yield attributes of soybean over the control. Combination of rock phosphate with FYM or single superphosphate (50:50) further enhanced the growth and yield and seed yield. The uptake of P and Ca as affected by different treatments followed the trend, similar to seed yield. Application of 60 kg P_2O_5/ha through NCRP, URP and MRP along with 5 tonnes FYM/ha recorded substantial increase in agronomic efficiency of rock phosphate. Comparing the relative agronomic effectiveness (RAE) of different sources, the exotic source NCRP was superior.

Key words : Agronomic efficacy, Rock phosphates, P source, Soybean, Acidic soil

Phosphorus is one of the major limiting plant nutrient in most of the Indian soils, particularly in acid soils. In addition to the escalation in the prices of water-soluble phosphorus sources such as single superphosphate and diammonium phosphate, their use efficiency is also low in acid soils due to high P-fixing capacity. Hence there has been renewal of interest in the use of rock phosphate as P source in different parts of the world including India. The agronomic efficacy of low-priced P-source such as rock phosphate gets increased when applied in conjunction with organics and in proportion with single superphosphate. Legumes use the sparingly soluble-P from rock phosphate in several ways which partly explains their importance in P-deficient soils. Soybean is a prominent and promising oil legume crop of Himachal Pradesh having high P requirement like other legumes. For harnessing full production potential of soybean, balanced nutrition is essential. Hence, the present experiment was conducted to study the effect of rock phosphates alone and in combination with FYM and single superphosphate on yield attributes, yield and nutrients uptake in soybean.

MATERIALS AND METHODS

The field experiment was conducted during the rainy seasons of 1995 and 1996 at the University farm, Palampur, representing a Typic Hapludalf soil. The silty clay loam soil had pH 5.9 and organic carbon 1.3 %. The surface soil analysis depicted available N 295 kg, P 17 kg and K 185 kg/ha and 350 mg P/kg soil as P-fixing capacity.

The treatments comprised recommended level of phosphorus @ 25 kg P/ha through single superphosphate (SSP), North Carolina rock phosphate (NCRP), Udaipur rock phosphate (URP) and Mussoorie rock phosphate (MRP), and 9 combinations of rock phosphate sources with FYM and SSP. The combinations included the application of 25 kg P/ha through 3 rock phosphates sources in conjunction with 5 tonnes FYM/ha and in mixture with SSP in ratio of 50:50 and 75:25 as per detail in Table 2. A total of 15 treatments including the control with respect to P (N and K only) and FYM @ 5 tonnes/ha were tried in randomized block design with 3 replications. Composition of rock phoshate sources is given in Table 1. Basal application of N and K was made @ 20 kg N and 33 kg K/ha through urea and mariate of potash, respectively, in all the treatments except in FYM @ 5 tonnes/ha. 'Bragg' soybean was taken as the test crop. For recording growth and yield attributes, 6 plants were randomly selected. Plant height, branches and leaves/plant and leaf-area index were recorded at flowering stage. Number of pods/plant and root length were recorded at maturity. Root length was computed using the modified method of Newman (1966). Soil and plant analyses were done as per standard procedures. The relative agronomic effectiveness (RAE) was calculated as:

$$RAE = \frac{Yt-Yc}{Ys-Yc} \times 100$$

where Yt, yield of treatments; Yc, yield of control; Ys, yield of standard.

RESULTS AND DISCUSSION

Growth and yield-attributing characters

Direct application of NCRP, URP and MRP resulted in significant increase in yield attributes, viz. plant height, branches/plant and leaves/plant, at flowering stage over the control (Table 2). The exotic source NCRP was at par with water-soluble source SSP. Application of rock phosphates along with FYM @ 5 tonnes/ha further resulted in significant increase in plant height, branches/plant and leaves/plant. However, the treatment NCRP + FYM excelled other treatments and maintained its superiority to SSP source. The physical mixing of rock phosphate and single superphosphate in 50:50 and 75:25 ratio significantly affected the yield-parameters and 50:50 mixture was found to be superior. Since phosphorus is a constituent of ADP and ATP, the beneficial effects of P in affecting the yield parameters may be attributed to the efficient supply of these constituents. Also P has specific role to play in root development which results in increase in shoot biomass and hence the yield attributes, ultimately affecting the crop growth and yield. The results are in confirmity with the findings of Abbas *et al.* (1994). Significant and positive correlation between plant height vs seed yield (r=0.936), number of branches vs seed yield (r=0.867) and leaves/plant vs seed yield (r=0.839) further substantiated results.

Significant effect of treatments was recorded on leaf-area index (LAI), pods/plant and root length. Leaf-area index varied between 5.3 and 10.05 and North Carolina rock phosphate recorded the values at par with single superphosphate. This parameter has direct bearing on accumulation of photosynthates which is related with increase in biomass production (Ramamurthy and Shrivashankar, 1996) and consequently the yield. The results were further supported by significant and positive correlation between LAI and seed yield (r=0.941). Corollary to LAI, the results relating to the effect of different phosphorus sources on pods/plant indicated the significant effect of P applica-

Table 1. Composition of rock phosphates

Parameter	Source		
	URP	MRP	NCRP
Physical composition (mesh size)	100	100	100
Chemical composition [constituent (%) total-P]	6.9	8.7	12.8
AOAC citrate-soluble - P (per cent of P in rock)	2.9	5.4	13.6
Ca	26.7	24.4	39.7
Mg	0.12	0.15	0.33
$Co_3 : PO_4$ ratio	0.028	0.062	0.178

The standard source SSP was in powdered form containing 16% P_2O_5 (water soluble) and 10% Ca

Table 2. Effect of rock phosphates alone and in combination with FYM and single superphosphate on growth and yield attributes of soybean (pooled over 2 years)

Treatment	Plant height (cm)	Branches/ plant	Trifoliate leaves/ plant	Leaf-area index at flowering stage	Pods/ plant	Root length/ plant (m) at flowering stage
T_1, Control (N, K only)	59.3	5.3	18.6	5.30	51.2	9.554
T_2, FYM @ 5 tonnes/ha	61.0	5.6	19.6	5.70	53.8	10.91
T_3, SSP @ 60 kg P_2O_5/ha	70.3	7.0	24.3	8.90	59.3	12.67
T_4, NCRP @ 60 kg P_2O_5/ha	70.0	6.5	24.6	8.90	59.6	12.67
T_5, URP @ 60 kg P_2O_5/ha	63.0	5.5	19.6	5.95	53.3	10.51
T_6, MRP @ 60 kg P_2O_5/ha	62.0	5.3	19.3	5.75	51.0	10.44
T_7, NCRP + FYM @ 5 tonnes/ha	72.0	6.8	25.6	9.40	61.0	13.19
T_8, URP + FYM @ 5 tonnes/ha	66.3	6.3	22.3	7.25	56.6	11.39
T_9, MRP + FYM @ 5 tonnes/ha	66.6	6.3	22.0	7.45	56.6	11.90
T_{10}, NCRP + SSP (50 : 50)	73.3	7.3	26.6	10.05	63.0	13.23
T_{11}, URP + SSP (50 : 50)	68.3	6.6	22.6	8.00	58.0	12.30
T_{12}, MRP + SSP (50 : 50)	69.6	6.6	24.0	8.55	58.0	12.30
T_{13}, NCRP + SSP (75 : 25)	71.6	6.6	25.3	9.35	60.5	12.79
T_{14}, URP + SSP (75 : 25)	65.0	6.0	20.3	6.30	55.3	11.45
T_{15}, MRP + SSP (75 : 25)	64.3	6.0	19.6	6.15	55.3	11.25
CD (P = 0.05)	1.06	0.2	0.3	2.80	1.2	0.16

tion on pod development. The results corroborate the findings of Tuteja *et al.* (1995). The total root length of soybean plants varied from 9.54 to 13.23 m plant. The role of P may be explained on the basis that better root development results in increased shoot biomass and hence the other yield attributes which consequently result in better crop growth and high yield. This is further substantiated with correlation between root length and soybean seed yield (r=0.854).

Soybean seed yield

Seed yield varied between 17.8 and 31.4 q/ha during rainy season 1995 and 13.0 and 22.9 q/ha during rainy season 1996. The lower yield levels during 1996 were on account of erratic rainfall. During both the years, the maximum seed yield was recorded when recommended dose of P was applied @ 60 kg P_2O_5/ha through North Carolina Rock phosphate along with 5 tonnes FYM/ha and remained at par with standard source (SSP). Further, direct application of recommended dose of P through NCRP, URP and MRP also recorded significant increase in soybean seed yield over the control treatment.

Application of rock phosphates (T_7, T_8, T_9) along with 5 tonnes FYM further enhanced the soybean seed yield significantly over the control and the treatment where only FYM was applied (T_2) during both the seasons. The beneficial effects of FYM may be attributed to the release of organic acids during the decomposition, which helps in dissolving the rock phosphate and release P for plant uptake and additive effect of organics.

Mixing of insoluble rock phosphates with water-soluble source (SSP) in the ratio of 50 : 50 (T_{10}, T_{11}, T_{12}) also recorded significant increase in soybean seed yield over the control. The advantage of applying rock phosphate in combination with single superphosphate lies in the fact that adequate supply of readily available phosphorus in early stage of plant growth helps in establishment of roots (Waggaman and Hofman, 1967) and in later stage these roots can utilize the P from rock phosphate more effectively. These findings support those of Gopal Krishan and Palaniappan (1992).

The significant response of soybean to P applied through different sources may be attributed to low available P content and high P-fixing capacity of acidic soils. Marwaha (1986) and Sharma and Bhardwaj (1993) also reported the beneficial effects of P application through rock phosphates in affecting soybean seed yield in acid soils. The foregoing observations revealed that among rock phosphates, exotic source (NCRP) had an edge over the indigenous rock phosphates (URP and MRP), which were almost at par in their effectiveness.

Relative agronomic effectiveness

The relative agronomic effectiveness in soybean varied between 42-101 and 51-110 during 1995 and 1996 respectively (Table 3). Corollary to seed yield, exotic rock phosphate source NCRP had an edge over the indigenous sources. The variation in agronomic effectiveness, whether applied alone or in combination with FYM or SSP may be attributed to the differences in the dissolution rate of rock phosphates which is further affected by citrate solubility in rock phosphate and CO_3/PO_4 ratio in the crystal lattice.

Table 3. Effect of rock phosphates alone and in combination with FYM and single superphosphate on soybean seed yield and relative agronomic effectiveness (RAE)

Treatment	Seed yield (q/ha)		RAE	
	1995	1996	1995	1996
T_1, Control (N, K only)	17.8	13.0		
T_2, FYM @ 5 tonnes/ha	20.0	15.8		
T_3, SSP @ 60 kg P_2O_5/ha	31.2	22.1	100	100
T_4, NCRP @ 60 kg P_2O_5/ha	30.0	21.0	91	89
T_5, URP @ 60 kg P_2O_5/ha	25.0	18.0	54	55
T_6, MRP @ 60 kg P_2O_5/ha	23.4	17.6	42	51
T_7, NCRP + FYM @ 5 tonnes/ha	31.4	22.9	101	110
T_8, URP + FYM @ 5 tonnes/ha	27.3	21.0	71	88
T_9, MRP + FYM @ 5 tonnes/ha	26.9	21.0	67	88
T_{10}, NCRP + SSP (50 : 50)	31.1	22.2	99	102
T_{11}, URP + SSP (50 : 50)	28.3	21.7	78	96
T_{12}, MRP + SSP (50 : 50)	28.1	21.7	77	95
T_{13}, NCRP + SSP (75 : 25)	29.3	21.0	86	88
T_{14}, URP + SSP (75 : 25)	26.3	19.7	63	74
T_{15}, MRP + SSP (75 : 25)	25.2	19.0	55	70
CD (P=0.05)	1.9	1.1		

Table 4. Effect of rock phosphates alone and in combination with FYM and single superphosphate on nutrient uptake by soybean seeds during 1995 and 1996

	P uptake (kg P/ha)		Ca uptake (kg Ca/ha)	
	1995	1996	1995	1996
T_1, Control (N, K only)	4.45	6.77	3.92	3.12
T_2, FYM @ 5 tonnes/ha	8.51	9.43	5.98	4.60
T_3, SSP @ 60 kg P_2O_5/ha	15.29	13.73	7.80	6.52
T_4, NCRP @ 60 kg P_2O_5/ha	13.50	14.20	9.00	6.79
T_5, URP @ 60 kg P_2O_5/ha	9.00	9.83	6.75	5.22
T_6, MRP @ 60 kg P_2O_5/ha	8.66	11.13	6.55	5.24
T_7, NCRP + FYM @ 5 tonnes/ha	15.39	15.50	10.36	7.68
T_8, URP + FYM @ 5 tonnes/ha	10.65	12.73	7.92	6.37
T_9, MRP + FYM @ 5 tonnes/ha	10.99	13.57	8.04	6.44
T_{10}, NCRP + SSP (50 : 50)	14.62	14.23	10.57	7.68
T_{11}, URP + SSP (50 : 50)	13.02	14.00	8.59	6.71
T_{12}, MRP + SSP (50 : 50)	12.62	14.02	8.71	6.93
T_{13}, NCRP + SSP (75 : 25)	13.47	13.33	9.37	6.96
T_{14}, URP + SSP (75 : 25)	11.29	12.17	7.35	5.70
T_{15}, MRP + SSP (75 : 25)	10.20	11.33	7.39	5.38
CD (P=0.05)	1.50	1.10	1.08	0.40

Nutrient uptake

During 1995, seed P uptake was 4.45-15.39 kg P/ha and during 1996 it was 6.77–15.50 kg P/ha (Table 4). Maximum P uptake was recorded in the treatment where recommended dose of P was added through exotic source (NCRP) along with 5 tonnes FYM/ha. Incorporation of FYM with NCRP, URP and MRP recorded significant increase in P uptake over the treatments T_4, T_5 and T_6 where direct application of rock phosphate was made at the recommended level. The beneficial effects of farmyard manure may be attributed to the dissolution of rock phosphates by the organic acid released during decomposition. The P thus released in taken up by the growing plants. The results also revealed that application of rock phosphate and water-soluble source SSP in the ratio of 50:50 recorded substantial increase in P uptake of soybean seeds during both the years.

The NCRP had an edge over the indigenous rock phosphates as URP and MRP in effecting Ca uptake. Higher rate of Ca uptake in NCRP-treated plots may be attributed to the higher value of CO_3:PO_4 ratio in the crystal lattice, resulting in higher rate of rock phosphate disintegration. Consequent to this, there is release of Ca which is taken up by the plants.

The results emanating from the field study conclude that exotic source NCRP was superior to indigenous sources in improving the yield attributes, nutrient (P, Ca) concentration and their uptake and seed yield of soybean. The agronomic efficacy of indigenous sources, URP and MRP could be increased by their application along with farmyard manure @ 5 tonnes/ha or by physical mixing with SSP in the ratio of 50 : 50.

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