Indian Journal of Agronomy **53**(4): 279–284 (December 2008)

Effects of sources of phosphorus and biofertilizers on productivity and profitability of soybean (*Glycine max*)–wheat (*Triticum aestivum*) system

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Received: June, 2008

ABSTRACT

A field experiment was carried out during 2005-06 and 2006-07 at New Delhi to study the effect of different sources of phosphorus [single superphosphate (SP) and rock phosphate (RP)] and biofertilizers (phosphate-solubilizing bacteria and vesicular-arbuscular mycorrhiza) on productivity, nutrient uptake, P balance in the soil, phosphorus-use efficiency and economics of soybean [*Glycine max* (L.) Merr.]–wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping system. Application of 50% recommended dose of P as SP + PSB + VAM recorded the highest yield during the first year in soybean (2.0 t/ha) and during both the years in wheat (4.4 and 4.6 t/ha in the first and second years respectively), but that of 50% RD Pas RP + PSB + VAM registered the highest grain yield (2.2 t/ha) during the second year in soybean. P uptake and utilization efficiencies increased on application of both PSB and VAM under both the sources of P. In addition, the available P status of the soil improved by addition of both bio-fertilizers through both the sources. RP performed very poorly, but when inoculated with both the bio-fertilizers, it was comparable to SP. Although the highest net returns per rupee invested was observed in 0.5 RP+PSB+VAM, but 0.5 SP+PSB+VAM provided highest net returns of 34.4 and 41.3 thousand rupees in first and second years respectively, it gave benefit: cost ratio (B:C) very close to that of the previous treatment in the soybean-wheat cropping system. Thus half the dose of P could be saved through inoculation with both P-solubilizing and mobilizing micro-organisms to obtain higher productivity and profitability.

Key words *:* Cropping system, Phosphorus-use efficiency, Productivity, Soybean, Wheat

Soybean [*Glycine max* (L.) Merr.]–wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping system is being followed in 4.5 million ha, mainly in central India (Behera *et al.*, 2007). Both soybean and wheat being protein and energy-rich crops, have very high nutrient requirement and they deplete the soil of essential nutrients when grown in rotation. Soybean and wheat remove about 28 and 20 kg P/ha respectively from soil (Stauffer and Sulewski, 2001), and phosphorus is probably the most important nutrient for soybean as it helps in biological nitrogen fixation-process. The importance of diammonium phosphate (DAP) and single superphosphate (SP) as efficient P fertilizer is well established but these are very expensive and need to be imported. They also suffer from the problem of fixation in the long run. With the discovery of about 145.4 million tonnes reserves of rock phosphate (RP) in the country (FAI, 2007), interest in the use of this indigenous material as alternative phosphatic fertilizer has increased greatly. Although rock phosphate can effectively replace water-soluble phosphates in acid soils, its efficiency in alkaline and calcareous soils is extremely low. In this context, bio-fertilizers like phosphate-solublizing bacteria (PSB) and phosphate-mobilizing fungi, viz. vesicular arbuscular mycorrhiza (VAM) can prove very effective. Earlier much work has been done for the use of rock phosphate with either PSB or VAM, and the investigations were on soybean and wheat crop separately or with other than soybean-wheat cropping system. Very little work has been done on the use of rock phosphate along with both phosphorus-solublizing and mobilizing organisms, especially in soybean-wheat cropping system. Hence the present investigation was undertaken.

MATERIALS AND METHODS

A field experiment on soybean-wheat cropping system was carried out during 2005-06 and 2006-07 at Agronomy farm of Indian Agricultural Research Institute, New Delhi. The soil was sandy loam, having 0.58% organic C and pH 8.36. It was low in available N (149.4 kg/ha), medium in available P (13.8 kg/ha) and low in available K (140.2 kg/

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ha). There were 14 phosphorus-management practices, viz. 1.0 SP (recommended dose of P (RDP) in SSP), 1.0 RP (RDP in rock phosphate, RP), PSB, VAM, PSB+VAM, 0.5 SP (half the RDP in SSP), 0.5 SP+PSB, 0.5 SP+VAM, 0.5 SP+PSB+VAM, 0.5 RP (half the RDP in RP), 0.5 RP+PSB, 0.5 RP+VAM, 0.5 RP+PSB+VAM and the control. A fixed plot was used for study with 3 replications in randomized block design. The recommended doses of P for soybean and wheat are 34.9 and 26.2 kg P/ha respectively. The inoculum species used, PSB (*Pseudomonas striata*) and VAM (*Glomus fasciculatum*) were obtained from Division of Microbiology, IARI, New Delhi as pocket-containing carrier and inoculum. The PSB was inoculated at the rate of 500 g carrier/ha and the population count was 100,000,000 cells/g of the carrier. VAM was applied as 5 kg carrier (soil)/ha and the spore count was 30 spores/g carrier.

Bradyrhizobium japonicum inoculant was common for all the treatments in soybean. The recommended doses of N (30 kg N/ha for soybean and 120 kg N/ha for wheat) and K (33.2 kg/ha for both soybean and wheat) as urea and muriate of potash respectively were applied uniformly to all the plots at the time of sowing. Single superphosphate (6.99% water-soluble P) and Mussoorie rock phosphate (total 8.73% P) were also applied as per the requirement of treatment. Soybean ‘PK 1042’ and wheat cultivar ‘HD 2643’ were sown in sequence in 5.0 m x 4.5 m plots with a spacing of 45 cm and 22.5 cm between the rows for soybean and wheat respectively.

P content of grain and straw of both soybean and wheat was determined to work out the P removal. Available P of soil after the completion of 2 years of cropping system was estimated to find out the P balance in the soil.

The cost of cultivation was calculated. The costs of SP and rock phosphate/kg P were Rs 10.92 and Rs 2.75 respectively. PSB and VAM were purchased @ Rs 100 and Rs 20/kg carrier respectively. The prices of soybean grain were Rs 1,010 and Rs 1,020 in 2005 and 2006 respectively, and that of wheat were Rs 650 and Rs 750 in 2005-06 and 2006-07 respectively.

RESULTS AND DISCUSSION

Crop productivity

The grain yield of soybean and wheat increased with application of phosphorus through different sources and bio-fertilizers in both the years. The highest grain yield was obtained under 0.5 SP+PSB+VAM in the first year of soybean and in both the years of wheat, whereas 0.5 RP+PSB+VAM recorded the highest grain yield in the second year of soybean (Table 1). The sequence of grain yield in wheat was 0.5 SP+PSB+VAM, 0.5 SP+VAM, 1.0 SP and 0.5 RP+PSB+VAM in both the years, and these treatments are statistically on a par with each other. In soybean the sequence of grain yield differed in both the years. The sequence of grain yield for soybean was 0.5 SP+PSB+VAM, 1.0 SP, 0.5 RP+PSB+VAM, 0.5 SP+VAM and 0.5 SP+PSB in the first year, and 0.5 RP+PSB+VAM, 0.5 SP+PSB+VAM, 1.0 SP, 0.5 SP+VAM, 0.5 RP+PSB and 0.5 SP+PSB in the second year. All these treatments were significantly at par in the respective years. The change in sequence of grain yield was due to increase in available P (data not given) from rock phosphate-treated plots, especially when inoculated with PSB. All the treatments of rock phosphate with or without bio-fertilizers, full dose of SP and half the dose of SP inoculated with any of the bio-fertilizers gave higher grain yield in the second year than in the first year of both these crops. This increase in yield may be attributed to increase in available P or reduction of grain yield in other treatments, where P status of the soil declined by previous two crops without adding any phosphorus. Moreover, low P status might have also caused lower nitrogen fixation and lower N supply to soybean and the succeeding wheat, and reduced the overall growth and yield. The performance of rock phosphate with or without bio-fertilizers was better in soybean than in wheat. This might be due to the release of citric, malonic, malic and succinic acids through roots, which can solubilize P from RP as well as soil (Singh *et al.,* 2001) and provided higher soil-available P to the crop. Again, the dissolution of RP was reduced due to low soil temperature and lower activities of bio-fertilizers during the wheat-growing season. The performance of RP with or without bio-fertilizers was better in the second year of both crops than in the first year. This may be attributed to greater P availability from RP with the increase in time after application; unlike the case of soluble phosphate fertilizer, where the concentration of P in the soil solution rose initially and then decreased. The greater P availability might be due to the application of RP in the first year, which slowly transformed into available form by the action of PSB, decomposition of stubbles of the first year and greater dissolution due to activities of indigenous soil microbes for a longer duration. RP with or without bio-fertilizers produced less than the corresponding combination of SP during both the years in both these crops, except 0.5 RP+PSB and 0.5 RP+PSB+VAM in the second year of soybean. It was due to the undissolved RP left in the first year along with freshly applied in second year soybean dissolved to provide more available P by solubilizing effect of PSB and root exudates of soybean. The increases in grain yields due to highest producing treatments were 64% (in 0.5 SP+PSB+VAM) and 100% (in 0.5 RP+PSB+VAM) for soybean in the first year and second year respectively, and 36% and 45% in wheat compared with the control. It indicates the importance of P to soybean crop.

The combination of SP with VAM and of RP with PSB proved superior in both the crops. The addition of VAM along with PSB increased the effect beyond that observed from the addition of either organism alone in both the sources and in both the crops. PSB solubilize RP (insoluble P) by excreting organic acids, i.e. citric and gluconic acids (Kucey *et al.,* 1989), and chelating materials in the immediate vicinity of rhizosphere, which together improve the productivity when applied with RP. However, PSB inoculated with SP did not increase the yield significantly, perhaps because the presence of already available form of P might have decreased the performance of PSB. The compatibility of SP and VAM can be attributed to the fact that the vesicular arbuscular mycorrhiza might be instrumental in mobilizing soluble P in the form of SP and might have increased the surface area of absorption through hyphae, thus availability of nutrients from inaccessible areas. Besides, the acquisition of organically bound P is improved by acid phosphatase, and through hormones released from VAM, which might have exerted beneficial effect on productivity (Tarafdar and Marschener, 1994). The performance VAM with RP was poor because the fungi translocate the available nutrients but do not possess special mechanism to solubilize RP. Thus VAM plant roots could efficiently absorb solubilized form over a period of time, and this increase could be equivalent to that observed from the addition of phosphatic fertilizers (Kucey *et al.*, 1989; Zaidi *et al.*, 2003).

Application of phosphorus and bio-fertilizers significantly influenced the harvest index of both soybean and wheat. Application of 0.5 SP+PSB+VAM recorded the highest harvest index during the first year soybean and both years of wheat, but only during the second year in soybean. In soybean, both the levels of P in the form of SP with or without bio-fertilizers, and RP with PSB and PSB+VAM had statistically significant influence on harvest index in the first year. But in the second year and as well as pooled values, all the treatments were superior to the control. In wheat, 0.5 SP+PSB+VAM, 0.5 SP+VAM and 1.0 SP had superior harvest index than the control in the first year, whereas 0.5 SP+PSB, 0.5 RP+PSB+VAM and 0.5 RP+PSB along with the treatments of the first year were statistically higher in the second year. Harvest index responded directly to the P nutrition of crops, leading to significant increase in these treatments.

P uptake

All the treatments significantly increased the total P removal than the control by soybean in both the years, except application of 17.4 kg P/ha in the form of RP (0.5 RP) in the first year (Table 2). Similarly, RP alone (both levels) in first year and VAM and lower level of RP (0.5 RP) in the second year removed significantly more P than the control in wheat crop. Application of 0.5 SP+PSB+VAM during the first year in soybean and during both the years in wheat removed the highest amount of P, whereas 0.5 RP+PSB+VAM recorded the highest P removal during the second year in soybean. Full dose of SP and lower dose of SP inoculated with either or both the bio-fertilizers and lower dose of RP inoculated with both

Table 1. Effect of phosphorus treatment on grain yield and harvest index of soybean and wheat

Treatment	Grain yield (t/ha)						Harvest index					
	Soybean			Wheat			Soybean			Wheat		
	2005	2006	Pooled	2005-06	2006-07	Pooled	2005	2006	Pooled	2005-06	2006-07	Pooled
1.0 SP	1.98	2.03	2.00	4.27	4.34	4.30	0.34	0.36	0.35	0.42	0.43	0.43
1.0 RP	1.61	1.76	1.68	3.65	3.66	3.66	0.31	0.34	0.32	0.40	0.40	0.40
PSB	1.59	1.56	1.57	3.79	3.73	3.76	0.32	0.32	0.32	0.41	0.40	0.41
VAM	1.54	1.47	1.51	3.62	3.53	3.57	0.32	0.31	0.31	0.41	0.40	0.41
PSB+VAM	1.70	1.68	1.69	3.91	3.87	3.89	0.32	0.33	0.33	0.41	0.41	0.41
0.5 SP	1.80	1.76	1.78	4.00	3.94	3.97	0.33	0.33	0.33	0.41	0.41	0.41
0.5 SP+PSB	1.85	1.90	1.87	4.09	4.11	4.10	0.33	0.35	0.34	0.41	0.42	0.42
0.5 SP+VAM	1.93	1.98	1.95	4.33	4.39	4.36	0.34	0.35	0.35	0.42	0.43	0.43
0.5 SP+PSB+VAM	2.04	2.14	2.09	4.44	4.58	4.51	0.34	0.36	0.35	0.43	0.44	0.43
0.5 RP	1.52	1.62	1.57	3.50	3.53	3.51	0.31	0.32	0.31	0.39	0.39	0.39
0.5 RP+PSB	1.81	1.93	1.87	3.97	4.05	4.01	0.33	0.35	0.34	0.40	0.42	0.41
0.5 RP+VAM	1.71	1.86	1.79	3.67	3.72	3.69	0.32	0.35	0.34	0.40	0.41	0.40
0.5 RP+PSB+VAM	1.96	2.18	2.07	4.16	4.31	4.23	0.34	0.37	0.35	0.41	0.43	0.42
Control	1.24	1.09	1.17	3.26	3.17	3.21	0.29	0.27	0.28	0.38	0.38	0.38
SEm±	0.08	0.10	0.05	0.10	0.13	0.04	0.01	0.01	0.01	0.01	0.01	0.004
CD (P= 0.05)	0.23	0.29	0.15	0.30	0.39	0.12	0.03	0.03	0.02	0.03	0.03	0.01

SP = Supper phosphate; RP = rock phosphate the biofertilizers removed significantly equal P during both the years in soybean, except 0.5 SP+PSB in the second year. In wheat only 0.5 SP+VAM removed equal P with highest-removing treatment in both the years. When PSB was inoculated with lower dose of SP, there was no significant removal of P than with only lower dose of soluble P in both soybean and wheat during both the years. It might be attributed to reduction of performance of PSB in the presence of soluble P. Similarly, when VAM was inoculated lower dose of RP, there was also no significant increase in P removal by both soybean and wheat during both the years because it lacks solubilisation property and helps only in mobilization of available P. It clearly indicates that PSB with RP and VAM with SP increased the P removal than the corresponding phosphorus alone and inoculation with both the bio-fertilizers. P removal increased further by both the crops from both the sources. There was significant increase in P removal due to different sources of P application and bio-fertilizer inoculation in soybean-wheat cropping system. The highest P removal was obtained from 0.5 SP+PSB+VAM which was on a par with 0.5 SP+VAM and 1.0 SP in both the years and 0.5 RP+PSB+VAM in the second year only.

P balance

All the RP treatment except inoculation with bio-fertilizer, all bio-fertilizer treatments without any phosphorus application, 0.5 SP and the control reduced the available P compared with the initial status. Control and bio-fertilizer extracted P from the soil, and hence its balance was negative in the absence of application of fertilizer. Rock phosphate was not solubilized sufficiently to improve the status of soil- available P. In 0.5 SP treatment, the soluble amount of P might not be sufficient for the crop, and some amount might be adsorbed and fixed in the soil, leaving negative balance of available P. The highest available P was recorded after 2 years of cropping system in 0.5 SP+PSB+VAM, followed by 1.0 SP, 0.5 SP+PSB and 0.5 RP+PSB+VAM (Table 2). All these treatments provided positive available P balance due to inoculation of PSB. Application of 1.0 SP improved the soil-available P due to its higher level and soluble nature. Full dose of SP, half the dose of SP inoculated with either or both bio-fertilizers, and rock phosphate with PSB and PSB+VAM had marked influence on the residual available-P status after 2 years of the cropping system. The maximum positive and negative changes in the available P were obtained from 0.5 SP+PSB+VAM and VAM respectively. PSB helped in increasing the soil available P of both SP and RP whereas VAM did not improve the available P with RP. The highest positive and negative net P left in the soil were observed in 1.0 RP and PSB+VAM respectively, because P was not utilized by crop in 1.0 RP and more P was removed without any P application in PSB+VAM. Higher the P dose, higher the net P left in the soil, irrespective of the source of phosphorus. But it was much more in rock

Table 2. Effect of treatments on P uptake (kg/ha) by soybean and wheat crops and balance sheet of soil-available P (kg/ha) after 2 years of cropping system

Treatment	Soybean		Wheat		Soybean + wheat		P added	P removed	Available	Change	Net P
	2005	2006	2005-06	2006-07	2005-06	2006-07	(1)	by both crops in 2 years (2)	P at end of experiment (3)	in available P (3-*) (4)	left in soil (*+1–2)
1.0 SP	20.0	20.3	16.0	16.7	35.9	37.0	122.27	72.89	21.77	7.97	63.18
1.0 RP	15.7	16.6	10.6	11.0	26.3	27.6	122.27	53.87	13.74	-0.06	82.20
PSB	15.4	14.6	11.6	11.6	27.0	26.2	0.00	53.16	12.25	-1.55	-39.36
VAM	14.5	13.6	10.3	9.8	24.8	23.4	0.00	48.17	8.33	-5.47	-34.37
PSB+VAM	16.5	15.9	12.6	12.7	29.1	28.6	0.00	57.70	12.39	-1.41	-43.90
0.5 SP	17.5	17.1	13.4	13.2	31.0	30.3	61.14	61.24	13.63	-0.17	13.70
0.5 SP+PSB	18.3	18.5	14.0	15.3	32.3	33.8	61.14	66.14	21.67	7.87	8.80
0.5 SP+VAM	19.1	19.8	17.1	17.9	36.2	37.7	61.14	73.87	20.36	6.56	1.07
0.5 SP+PSB+VAM	20.8	21.2	18.3	19.1	39.1	40.3	61.14	79.42	22.01	8.21	-4.48
0.5 RP	14.1	15.3	9.5	9.8	23.6	25.1	61.14	48.67	13.22	-0.58	26.27
0.5 RP+PSB	17.8	19.0	13.2	14.4	31.0	33.4	61.14	64.40	20.50	6.70	10.54
0.5 RP+VAM	16.8	17.5	10.8	11.8	27.6	29.3	61.14	56.87	13.45	-0.35	18.07
0.5 RP+PSB+VAM	19.7	21.6	15.0	16.5	34.6	38.1	61.14	72.68	21.28	7.48	2.26
Control	11.4	10.4	8.4	8.0	19.8	18.4	0.00	38.22	8.71	-5.09	-24.42
SEm ±	0.9	0.9	0.8	0.7	1.2	1.1					
CD (P=0.05)	2.7	2.5	2.2	2.0	3.5	3.3					

* Initial available P: 13.80

phosphate with or without bio-fertilizers due to low P-utilization efficiency than in the corresponding treatments of SP. Bio-fertilizers reduced the residual soil P by utilizing it. The inoculation of VAM with SP and of PSB with rock phosphate led to utilization of more P and greater decrease in residual soil P compared with the reverse combination. The inoculation with both the bio-fertilizers decreased residual soil P more than inoculation with either bio-fertilizer through both the sources.

P-use efficiency

The highest agronomic efficiency and phosphorus-recovery efficiency were recorded in 0.5 SP+PSB+VAM during the first year in soybean and during both the years in wheat. 0.5 RP+PSB+VAM performed best during the second year in soybean, whereas 1.0 RP recorded their lowest values in both the crops in both the years.

Agronomic efficiency and phosphorus-recovery efficiency declined steadily with successive level of phosphorus from both the sources (Table 4). This was because the grain yield could not increase in tune with the rate of fertilizer P application following the law of diminishing return and low P-utilization efficiency, which resulted in lower agronomic efficiency (Panda, 2002). Further, in rock phosphate the solubilization of P was not directly proportional under higher doses. Rock phosphate performed very poorly than SP in both the crops. The decline in phosphorus-recovery efficiency under different sources may be due to the lack of luxury consumption of phosphorus on one hand and greater conversion of added soluble phosphorus into non-available form and higher retention of phosphorus in soil on the other (Ogoke *et al.*, 2006).

Contrary to P levels, biofertilizer treatments had a positive effect on agronomic efficiency and phosphorus recovery efficiency (Table 3). Inoculation with PSB might have increased the available P from both rock phosphate and SP and reconverted the unavailable fertilizer P to available form in the field through production of organic acids, which improved its availability and resulted in higher uptake of added P, finally leading to increased grain yield. But VAM inoculation efficiently utilized the available P and might have helped in exploration of greater volume of soil, and in turn increased the uptake of P and finally the grain yield.

In wheat, the highest phosphorus-harvest index (PHI) was obtained under 0.5 SP+PSB+VAM in both the years, closely followed by 0.5 SP+VAM, 1.0 SP and 0.5 RP+PSB+VAM. In soybean 0.5 SP+PSB+VAM and 0.5 RP+ PSB+VAM recorded the highest PHI in 2005 and 2006 respectively, followed by 1.0 SP and 0.5 SP+VAM. The lowest PHI was observed in the control plot in both soybean and wheat. PHI is the ratio of removal of P by grain to removal of P by the whole plant. Better P nutrition caused higher content of P in grain and straw, resulting ultimately in higher grain yield. Thus it almost followed the same trend as grain yield and the highest and lowest values corresponded to the highest and lowest grain yields respectively.

Economics

Total variable cost differed for different treatments due to variation in the inputs used (Table 4). There was increase in net returns when phosphorus from different sources and bio-fertilizers were applied. The highest net returns were obtained from 0.5 SP+PSB+VAM. However, during both the years, the benefit : cost (B:C) ratio was the

Table 3. Effect of different treatments on agronomic efficiency (kg grain/kg P applied), P-recovery efficiency (%) and P-harvest index (%) of soybean and wheat

Treatment	Agronomic efficiency				P-recovery efficiency				P-harvest index			
	Soybean		Wheat		Soybean		Wheat		Soybean		Wheat	
	2005	2006	2005-06	2006-07	2005	2006	2005-06	2006-07	2005	2006	2005-06	2006-07
1.0 SP	21	27	39	45	24	28	29	33	67	69	86	85
1.0 RP	11	19	15	19	12	18	08	11	65	66	83	83
PSB									65	66	85	83
VAM									66	65	84	83
PSB+VAM									66	67	84	83
0.5 SP	39	38	57	59	35	38	38	40	67	67	85	83
0.5 SP+PSB	35	46	63	72	39	46	43	56	67	68	85	84
0.5 SP+VAM	39	51	82	94	44	53	67	76	67	69	86	85
0. SP+PSB+VAM	46	60	91	108	54	62	76	85	68	70	87	86
0.5 RP	16	30	18	28	15	28	09	14	64	66	83	82
0.5 RP+PSB	33	48	54	68	37	49	37	49	66	68	84	85
0.5 RP+VAM	27	44	31	42	31	41	18	29	66	68	84	83
0.5 RP+PSB+VAM	41	62	68	87	47	64	50	65	67	70	85	85
Control									64	61	82	82

Table 5. Effect of treatments on economics of soybean-wheat cropping system

Treatment	Variable cost (Rs/ha)		Cost of cultivation (x 10^3 Rs/ha)		Net income (x 10^3 Rs/ha)		B:C ratio	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
1.0 SP	3,500	3,500	25.5	26.5	31.1	36.6	1.22	1.38
1.0 RP	882	882	22.9	23.9	25.5	30.9	1.11	1.30
PSB	100	100	22.1	23.1	26.8	30.1	1.21	1.30
VAM	200	200	22.2	23.2	24.7	27.3	1.11	1.18
PSB+VAM	300	300	22.3	23.3	28.8	32.3	1.29	1.38
0.5 SP	1,750	1,750	23.8	24.8	29.1	32.3	1.22	1.31
0.5 SP+PSB	1,850	1,850	23.9	24.9	30.2	35.0	1.26	1.41
0.5 SP+VAM	1,950	1,950	24.0	25.0	32.5	38.1	1.36	1.53
0.5 SP+PSB+VAM	2,050	2,050	24.1	25.1	34.4	41.3	1.43	1.65
0.5 RP	441	441	22.5	23.4	23.8	28.8	1.06	1.23
0.5 RP+PSB	541	541	22.6	23.5	30.3	36.3	1.34	1.54
0.5 RP+VAM	641	641	22.7	23.6	26.8	32.4	1.19	1.37
0.5 RP+PSB+VAM	741	741	22.8	23.7	33.0	40.7	1.45	1.72
Control	0	0	22.0	23.0	19.4	20.5	0.88	0.89

highest in 0.5 RP+PSB+VAM i.e. 1.45 and 1.72 respectively, because of involvement of all the three low input cost. But it was very closely followed by 0.5 SP+PSB+VAM, whose B:C ratios were 1.43 and 1.65 in the first and second years respectively. Inoculation of any biofertilizer increased the bernefit : cost ratio, and when both were inoculated this ratio improved further. The increases in net returns per Re invested in bio-fertilizer-treated plots were due to saving of phosphorus. The involvement of low-cost inputs like PSB and VAM, having greater compatibility among these, and complementary effect between them through solubilization and mobilization of P made the treatment 0.5 SP+PSB+VAM economically most viable in this soybean-wheat cropping system.

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