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Effects of Phosphorus Levels Alone or in Combination with Phosphate-solubilizing Bacteria and Farmyard Manure on Growth, Yield and Nutrient Up-take of Wheat (*Triticum aestivum*)

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ABSTRACT

An experiment was conducted during 2003 and 2004 at agricultural farm Mungeli- Bilaspur, Chhattisgarh to study the effect of phosphorus levels with and without farmyard manure and phosphate-solubilizing bacteria(*Pseudomonas striata*) on growth, yield and nutrient up-take of wheat (*Triticum aestivum* L. emend Fiori & Paol). The experiment was laid out in randomized block design with 13 treatments using wheat variety 'HI 8498'. Commercial grade single superphosphate as P source [@ 12.7, 19.5, 26.7 & 34.9 kg/ha] was applied in respective plots at the time of sowing. The data revealed that phosphorus application significantly increased the plant height (69.9 cm), total number of tillers/m^2 (1257), leaf number/m^2 (698), leaf weight (180 g/m^2), leaf area index (1.69), dry matter accumulation (13.98 tonnes/ha), number of grains per spike (36.2), 1000 grain-weight (35.8 g), seed yield (3.98 tonnes/ha), straw yield (4.73 tonnes/ha) and N, P and K uptake (34.8, 4.8 & 31.9 kg/ha) over control. However, integrated use of P and organic source (farmyard manure) proved significantly superior to alone application of P level (12.7, 19.5, 26.7 & 34.9 kg/ha). The analysis for respective years of experimentation further revealed that the maximum plant height (91.9 cm), total number of tillers/m^2 (1798), leaf number/m^2 (1070), leaf weight (275 g/m^2), leaf area index (2.48), dry matter accumulation (18.34 tonnes/ha), number of grains per spike (47.5), 1000 grain-weight (45.2 g), seed yield (5.05 tonnes/ha), straw yield (7.0 tonnes/ha) and N, P and K uptake (49.3, 7.2 & 50.1 kg/ha), were recorded in the plots receiving phosphorus in combination with phosphate-solubilizing bacteria (*Pseudomonas striata*) and farmyard manure indicating that the combined application of phosphorus and farmyard manure with phosphorus-solubilizing bacteria had highest degree of influence on growth, yield and nutrients up-take of wheat thus emphasizing the need for P application in conjunction with solubilizer and organic source (farmyard manure) to wheat and other crops.

Key Words: Crop; Fertilizer; Grain; Nutrient up-take; Phosphorus; Yield

INTRODUCTION

In India wheat is the major grain crop and the species under cultivation is mainly *Triticum aestivum.* Wheat like other commonly grown field crops requires 16 essential elements to complete the metabolic processes necessary for growth and reproduction (Andrew *et al*., 1968; Graham *et al*., 1977).

Fertilizers constitute an essential input in modern agriculture and they help in realizing high crop yields. Phosphorus is being considered second major element whose deficiency has become widespread in Indian soils (hasan, 1994).

Phosphorus fertilizer is an expensive input and its use efficiency by crops may range from 10 - 25% (Bahl & Singh, 1986). Several workers (Andrew *et al*., 1968; Graham *et al*., 1977; Grant *et al*., 1989) have obtained significant increase in seed yield of wheat due to phosphorus application. In normal conditions, the quantity of fertilizers to be applied depends on crop, inherent soil fertility status, yield goal and other considerations like irrigated or rainfed conditions. Farmers mostly use single superphosphate as P source, which contains 16% P_2O_5 and 12% S (Jaggi *et al*., 2003).

Role of phosphorus in increasing tillering and growth is well recognized. Phosphorus is an essential element and is involved in energy transfer through ATP. It is also involved in root development and in metabolic activities specially in synthesis of protein (Tanwar & Shaktawat, 2003). An adequate supply of phosphorus to the crop plants during their early growth period is very important for the initiation of leaves and florets primordial (Richards *et al*., 1985). Application of phosphorus improves various growth parameters like, plant height, fertile tillers/m^2 and yield parameters like seed yield. Application of farmyard manure along with chemical fertilizers improves the yields further and maintains the soil fertility as revealed by the long-term fertilizer experiments. The major part of the water-soluble phosphorus in fertilizers soon becomes insoluble and un-available to the growing crops within short period due to its chemical fixation in soils. Hence solubilization of fixed soil P through the use of micro-organisms coupled with organics (i.e. farmyard manure) is available option to augment the availability of P in easily assimilable form by the crops (Poonamgautam *et al*., 2003).

Optimal production requires suitable cultural practices including proper fertility management. Hence, a field experiment was conducted to investigate the effect of phosphorus rate with and without phosphate-solubilizing bacteria (*Pseudomonas striata*) and farmyard manure on various growth and yield parameters of wheat.

MATERIALS AND METHODS

The field experiment was conducted at Agricultural Farm Mungeli - Bilaspur, Chhattisgarh, India during 2003 and 2004. Physico-chemical properties of the soil were measured by the standard methods of soil chemical analysis (NIAST, 1988). The analysis for respective years of experimentation revealed that the soil had o.52, 0.58% organic carbon, 200.50, 214.4 kg/ha available nitrogen, 19.4, 20.9 kg/ha available phosphorus, 203.4, 207.2 kg/ha available potassium, 9.1 and 9.3 mg/kg available sulphate-sulphur, and Cd 0.20, 0.22 mg/kg soil with pH 7.30 and 7.39. The experiment was laid out in randomized block design with 13 treatments and replicated thrice. Treatment details were as follows: T_1 = Control (no P+ PSB+ FYM); T_2 = 12.7 kg P/ha; T_3 = 19.5 kg P/ha; T_4 = 26.7 kg P/ha; T_5 = 34.9 kg P/ha; T_6 = FYM @ 10 tonnes/ha + 12.7 kg P/ha; T_7 = FYM @ 10 tonnes/ha + 19.5 kg P/ha; T_8 = FYM @ 10 tonnes/ha + 26.7 kg P/ha; T_9 = FYM @ 10 tonnes/ha + 34.9 kg P/ha; T_{10} = PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha + 12.7 kg P/ha; T_{11} = PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha + 19.5 kg P/ha; T_{12} = PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha + 26.7 kg P/ha; T_{13} = PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha + 34.9 kg P/ha

(Abbreviations: P, phosphorus; FYM, farmyard manure; PSB phosphate-solubilizing bacteria)

The culture *Pseudomonas striata* was obtained from the Division of Microbiology, Indian Agricultural Research Institute, New Delhi.

Commercial grade single superphosphate as P source, which contains 16% P2O5 and 12% S was applied in respective plots at the time of sowing. As per the treatments, farmyard manure was incorporated at the time of field preparation and phosphate-solubilizing bacteria (*Pseudomonas striata*) was applied as seed treatment. A uniform application of 125 kg/ha N as urea and 100 kg/ha K as K_2O were given to all the plots. Wheat variety 'HI 8498' was sown at a row spacing of 25 cm x 10 cm in the first week of November. Crop was raised following the recommended package of practices.

Five hills in each plot were randomly selected and tagged for recording the plant height, tillers/m^2, green leaves/m^2, leaf weight (g/m^2) and leaf-area index 110 days after transplanting. The observations on dry-matter accumulation were recorded up to 110 days after transplanting (at 30-days interval). The net plots area were harvested and sun-dried for 5 days in the field and the total biomass yield was recorded. After threshing, cleaning and drying the grain and straw, yields were recorded and yield-attributes viz grains/spike and 1000-grain weight was recorded from plant samples. The up-take of nutrients (N, P, K) was calculated as nutrient uptake (kg/ha) = concentration (%) of the given nutrient × yield on dry weight basis (kg/ha). The data were analyzed statistically on pooled basis for both years, as per procedure suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Pooled data for 2003 and 2004 showed the maximum plant height, number of tillers/m^2, leaf number/m^2, leaf weight (g/m^2), leaf area index, grains/spike and 1000-grain weight (g) were associated with PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha + 26.7 kg P/ha (Table I).

Plant height reveals the overall vegetative growth of the crop in response to various management practices. Combined application of phosphorus fertilizer and solubilizer with farmyard manure influenced the plant height of wheat significantly over control (Table I). Maximum plant height (91.9 cm) was recorded in treatment T_{12} (PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha+ 26.7 kg P/ha). P levels below or beyond this exhibited reduced plant height. An increase in plant height has been reported due to inoculation of phosphate-solubilizing micro-

Table I. Influence of different treatments on growth and yield components of wheat

	Treatment	Plant height (cm)	No of tillers/ m^2	Green leaves/ m^2	Leaf weight (g/ m^2)	Leaf area index	No of grains/ spike	100- grains weight (g)
T_1	Control (no P+ PSB+ FYM)	55.3d‡	987d	607d	155d	1.49d	26.7d	30.1d
T_2	12.7 kg P / ha	67.3c	1205c	684c	174c	1.62c	33.8c	34.1c
T_3	19.5 kg P / ha	67.8c	1227c	697c	178c	1.65c	34.9c	34.4c
T_4	26.7 kg P / ha	69.9c	1257c	687c	175c	1.69b	35.7c	35.1c
T_5	34.9 kg P / ha	69.5c	1230c	698c	180c	1.69b	36.2c	35.8c
T_6	FYM* +12.7 kg P / ha	77.2b	1367b	825b	209b	1.78b	39.5b	37.1c
T_7	FYM + 19.5 kg P / ha	78.2b	1347b	899b	231b	1.76b	39.9b	38.4b
T_8	FYM + 26.7 kg P / ha	82.3b	1378b	842b	213b	1.84b	40.8b	39.2b
T_9	FYM + 34.9 kg P / ha	81.9b	1353b	874b	225b	1.85b	40.1b	38.2b
T_{10}	PSB + FYM +12.7 kg P / ha	88.1a	1536b	1024a	263ab	2.01a	42.9b	42.9a
T_{11}	PSB + FYM + 19.5 kg P / ha	89.3 a	1602a	1048a	268a	2.12a	43.6a	44.9a
T_{12}	PSB + FYM + 26.7 kg P / ha	91.9 a	1798 a	1070a	275a	2.13a	47.5a	45.2a
T_{13}	PSB + FYM + 34.9 kg P / ha	90.1a	1791a	1052a	268a	2.48a	45.7a	43.9a
	LSD (P = 0.05%)	2.3	14.5	10.6	5.2	0.12	1.7	1.9

LSD: minimum significant difference; ***** @ 10 mg / kg; **‡** All results are the means of three replicates. Values followed by the same letter in a column are not significantly different (p < 0.05) organism (Dubey, 1997), application of farmyard manure (Sharma & Mishra, 1997) and Phosphorus (Dubey, 1997). Increase in plant height due to application of phosphorus may be attributed to better vegetative growth. It might be due to more availability of nutrients due to increased levels of P, which exerted beneficial effect on vegetative growth of plant. These results are in close conformity with the findings of Grant *et al*. (1989) and Mandal *et al.* (1992).

The treatment T_{12} [PSB (*Pseudomonas striata*) + FYM @ 10 tonnes /ha+ 26.7 kg P/ha] resulted in highest (1798) number of tillers/m^2 (Table I). It was statistically at par with that of treatment T_{13} [PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha+ 34.9 kg P/ha]. Under the treatments, the control plots produced lowest productive tillers (987/m^2). The increase in number of fertile tillers with the increase in phosphorus levels can be attributed to the reduction in mortality of tillers and enabling the production of more tillers from the main stem. It might be due to role of P in metabolic activities, high root growth and increased up-take of nutrients. These results are quite in line with Singh *et al*. (1972) and Stewart *et al*. (1981). Zhang *et al*. (1996) also reported that the application of P fertilizer with PSB (*Pseudomonas striata*) + FYM increased tillering, root development and plant dry weight.

The data on the leaf number and leaf weight are presented in Table I. The treatments T_{12} and T_{13} [PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha+ 26.7 kg P/ha & PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha+ 34.9 kg P/ha] significantly increased the number of green leaves by 76.2% and 73.3%, respectively over control and were statistically identical. A similar pattern was also registered with respect to leaf weight of crop. The increase in leaf count as well as leaf weight due to adequate fertilizer nutrition is explainable in terms of possible increase in nutrient mining capacity of plant as a result of better root development and increased translocation of carbohydrates from source to growing points in well-fertilized plots (Singh & Agrawal, 2001).

The data regarding leaf area index is presented in Table I. Data reveals that treatment T_{13} [PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha + 34.9 kg P/ha] produced maximum leaf area index (2.48) and the minimum leaf area index (1.49) was produced with the treatment T_1 Control (no P + PSB + FYM) at 110 days after transplanting. It might be due to improved nutrients availability and enhanced growth of plant. These results are in line with the findings of Martin *et al.* (1988). It seems that fertilizer P possibly facilitated root proliferation and ultimately resulted higher nutrient and water up-take to the growing cells, and manifested greater leaf area of the crop.

Dry matter accumulation increased significantly with integrated use of P-fertilizer and solubilizer with farmyard manure in wheat at all the growth stages of the crop. The data presented in Table II revealed a statistically significant increase due to application of PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha+ 26.7 kg P/ha throughout the measurement period. Significantly highest dry-matter accumulation (18.34 tonnes/ha) was obtained during 2003 when PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha + 26.7 kg P/ha was applied at harvest. These results were statistically at par with that of treatment T_{10}, where PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha + 12.7 kg P/ha was applied. In general, dry-matter accumulation increased at slow rate up to 30 days after transplanting and thereafter increased at faster rate up to harvest. It might be due to decreased crop-growth rate and net assimilation rate at latter growth periods and consequently the rate of dry-matter accumulation. These findings are in close conformity with those of Shrivastava and Tripathi (1999).

There is highly significant difference among different treatments for number of grains per spike (Table I). Treatment T_{12} [PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha + 26.7 kg P/ha] resulted the highest number of grains per spike (47.5) during respective years of experimentation. Significantly lowest number of grains per spike (26.7) was obtained from treatment T_1 [control (no P+ PSB+ FYM)]. This trend might be due to role of phosphorus and organic source in crop maturation, flowering and fruiting including seed formation. These results are in accordance with those of Thakur *et al.* (1981). Grains per spike is an important trait to see the spike sterility or failure of setting grains in developed florets. However, visual sterility is an indication of lower grain yield of plants caused by spike sterility (Samad *et al*., 2002).

Data reveals that 1000-seed weight was significantly affected by phosphorus levels, manure and solubilizer (Table I). Application of PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha + 26.7 kg P/ha resulted in the highest 1000–grain weight of 45.2 g, followed by T_{11} PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha + 19.5 kg P/ha treatment that resulted in 44.9 g of 1000-seeds weight. While control resulted in lowest 1000-seed weight (30.1 g). Gupta *et al*. (1977) also reported increase in 1000-grain weight with the application of P + PSB + FYM. It might be due to role of phosphorus in the presence of organic manure and solubilizer in metabolism specially in synthesis of protein, which increased the grain weight. Similar results were also reported by Nelson *et al*. (1989).

Data regarding grain yield/ha is presented in Table III. The data show that all the treatments produced significantly higher grain yield over control. The values ranged from 2.07 to 5.05 tonnes/ha. It reveals that the highest yield of grain on the basis of two years combined average was 5.05 tonnes/ha from the crop receiving dose of PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha + 26.7 kg P/ha and was statistically similar to treatments T_{11} and T_{13} [PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha + 19.5 kg P/ha (4.96 tonnes/ha) and PSB (*Pseudomonas striata*) + FYM 10 tonnes/ha + 34.9 kg P/ha(4.97 tonnes /ha)]. An increase in seed yield has been reported due to inoculation of phosphate-solubilizing micro-organism (Dubey, 1997) application of farmyard manure (Sharma & Mishra, 1997)

Table II. Effect of different treatments on dry-matter accumulation of wheat at different growth stages

	Treatment	Dry-matter accumulation (tonnes/ha) 2003				Dry-matter accumulation (tonnes/ha) 2004			
		30 DAT**	60 DAT	90 DAT	At harvest	30 DAT	60 DAT	90 DAT	At harvest
T_1	Control (no P+ PSB+ FYM)	2.13d‡	6.14d	8.21d	10.23d	2.23d	6.17d	8.21d	10.41d
T_2	12.7 kg P / ha	3.31cd	7.84cd	10.51cd	12.91c	3.21cd	7.91 d	10.61c	12.93c
T_3	19.5 kg P / ha	3.39cd	7.99cd	10.91cd	13.11c	3.56c	7.98d	11.02c	13.21b
T_4	26.7 kg P / ha	3.67c	8.21c	11.48c	13.65c	3.78c	8.36c	11.78c	13.89b
T_5	34.9 kg P / ha	3.89c	8.32c	11.78c	13.96c	3.99c	9.37c	12.72b	13.98b
T_6	FYM* +12.7 kg P / ha	4.89b	10.98b	12.87bc	14.75b	4.79c	10.99b	12.88b	14.95b
T_7	FYM + 19.5 kg P / ha	5.02a	11.32b	12.98bc	14.98b	5.12b	11.46a	12.96b	14.99b
T_8	FYM + 26.7 kg P / ha	5.01a	11.04 b	13.37b	15.45 a	5.91b	11.14 a	13.22b	15.44 a
T_9	FYM + 34.9 kg P / ha	5.77 a	11.27b	13.19b	15.87a	5.85b	9.50 c	13.28b	15.98a
T_{10}	PSB + FYM +12.7 kg P / ha	6.24a	12.64a	15.32a	18.21a	6.39a	12.77a	15.36a	18.11a
T_{11}	PSB + FYM + 19.5 kg P / ha	6.28a	12.34a	15.69a	17.66a	6.31a	12.33a	15.98a	17.87a
T_{12}	PSB + FYM + 26.7 kg P / ha	6.62a	12.87a	16.32a	18.34a	6.71a	12.97a	16.38a	18.33a
T_{13}	PSB + FYM + 34.9 kg P / ha	6.19a	11.99a	14.68a	16.94a	6.39a	10.25a	14.98b	17.01a
	LSD (*P* = 0.05%)	0.75	0.79	0.81	0.89	0.31	0.73	0.94	0.97

LSD: minimum significant difference; * @ 10 mg / kg; **DAT, Days after transplanting; ‡ All results are the means of three replicates. Values followed by the same letter in a column are not significantly different ($p < 0.05$)

Table III. Effect of different treatments on yield and N, P and K uptake of wheat

	Treatment	Seed yield (tonnes/ha)			Straw yield (tonnes/ha)			Nutrient uptake (kg/ha)		
		2003	2004	Pooled	2003	2004	Pooled	N	P	K
T_1	Control (no P+ PSB+ FYM)	2.01d	2.14d	2.07d	3.29d	3.31d	3.30d	24.8d	3.11d	22.7d
T_2	12.7 kg P / ha	3.57c	3.59c	3.58c	4.32c	4.31c	4.31c	30.7c	4.12c	28.5c
T_3	19.5 kg P / ha	3.82c	3.87c	3.84c	4.35c	4.41c	4.38c	33.2c	4.78c	29.2c
T_4	26.7 kg P / ha	3.98c	3.98c	3.98c	4.72c	4.74c	4.73bc	34.8c	4.80c	31.9b
T_5	34.9 kg P / ha	3.96c	3.99c	3.97c	4.26c	4.29c	4.27c	36.7c	4.64c	33.3b
T_6	FYM* +12.7 kg P / ha	4.52b	4.53b	4.52b	5.12bc	5.15b	5.13b	37.3c	5.11b	34.9b
T_7	FYM + 19.5 kg P / ha	4.56b	4.55b	4.55b	5.23bc	5.27b	5.25b	40.7b	5.53b	34.7b
T_8	FYM + 26.7 kg P / ha	4.62ab	4.56b	4.59b	5.71b	5.74b	5.72b	41.1b	5.65b	37.4b
T_9	FYM + 34.9 kg P / ha	4.61ab	4.63b	4.62b	5.71b	5.78b	5.74b	43.7b	5.14b	38.2b
T_{10}	PSB + FYM +12.7 kg P / ha	4.92a	4.95a	4.93a	6.87a	6.88a	6.87a	46.1a	6.11a	47.8b
T_{11}	PSB + FYM + 19.5 kg P / ha	4.96a	4.97a	4.96a	6.57a	6.59a	6.58a	46.3a	6.71a	48.9a
T_{12}	PSB + FYM + 26.7 kg P / ha	4.99a	5.12a	5.05a	7.02a	6.99a	7.00a	49.3a	7.20a	50.1a
T_{13}	PSB + FYM + 34.9 kg P / ha	4.97a	4.97a	4.97a	6.54a	6.57a	6.55a	48.2a	6.91a	48.2a
	LSD (*P* = 0.05%)	0.27	0.24	0.26	0.61	0.67	0.71	6.5	0.9	5.9

LSD: minimum significant difference; * @ 10 mg / kg; ‡ All results are the means of three replicates. Values followed by the same letter in a column are not significantly different ($p < 0.05$).

and Phosphorus (Grant *et al*., 1989). There is a very close relation between the yield and its components, especially with number of filled grains per ear.

The highest straw yield (7.00 tonnes/ha) was observed in response to application of PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha + 26.7 kg P/ha, followed by treatment T_{13} [PSB (*Pseudomonas striata*) + FYM 10 tonnes/ha + 34.9 kg P/ha] giving 6.55 tonnes/ha straw yield. The control treatment produced significantly the lowest straw yield of 3.30 tonnes/ha (Table III). This might be owing to the continuous supply of P to the crop during crop-growth period, which is more beneficial and increased total number of tillers, dry matter accumulation, number and weight of filled grains and fertilizer-use efficiency and resulted in higher yields of the wheat. Mittal *et al.* (1978) had also reported similar findings. The integrated use of phosphatic fertilizer + phosphorus-solubilizing bacteria with organic source proved significantly superior to control. This might be due to modified soil environment resulting in gradual increase of nutrients and manifested in higher yield and nutrient up-take.

Application of phosphorus with solubilizer and farmyard manure significantly increased the N, P and K up-takes of wheat (Table III). Application of PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha + 26.7 kg P/ha significantly increased total N, P and K uptake over the control by 98.7%, 131.5% and 120.7%, respectively. The better availability of phosphorus through a readily available source (single superphosphate) caused better root development resulting in higher up-take of phosphorus and other nutrients. Combined application of phosphorus fertilizer and solubilizers had pronounced effect on up-take of wheat. This might be due to dissolution of P in the presence of farmyard manure along with phosphorus-solubilizing bacteria. Tanwar and Shaktawat (2003) also reported similar results.

The results indicate a pivotal role of phosphorus nutrition in improving growth, productivity, and nutrient up-take of wheat (Tables I, II & III). As reported by Andrew *et al*. (1968) and Wilson *et al*. (1978), phosphorus is critical in the metabolism of plants, playing a role in cellular energy transfer, respiration and photosynthesis therefore all the growth and yield parameters and up-take of nutrients increased significantly with an increase in P level at all the growth stages of the crop.

Integrated use of P and organic source (farmyard manure) proved significantly superior to alone application of P level (12.7, 19.5, 26.7 & 34.9 kg/ha). This beneficial effect of organic manure on growth, yield and its attributes might be because of additional supply of plant nutrients as well as improvement in physical and biological properties of the soil (Majumdar *et al*., 2002). It has been well documented that organic matters not only produce acids, which dissolve the fixed phosphorus and release essential nutrients during decomposition but also provide substrate for microbial growth (Hannapel *et al*., 1964; Sinha *et al*., 1981). The introduction of efficient P solubilizers (*Pseudomonas striata*, *Bacillus polymaxa* etc) in the rhizosphere of crops and soils increases the availability of P from insoluble sources and a variety of mechanisms such as production of aliphatic and aromatic acids, phytases and phospholipases etc are responsible for this (Chhonkar & Tilak, 1997). Thus the combined application of phosphorus and farmyard manure with phosphorus-solubilizing bacteria had highest degree of influence on growth, yield and nutrients up-take of wheat.

Based on the findings of the present investigation, application of PSB (*Pseudomonas striata*) + FYM @ 10 tonnes/ha + 26.7 kg P/ha was found to be optimum for wheat ('HI 8498') production. Thus, it may be concluded that the use of P in conjunction with microbe and farmyard manure was found beneficial to increase the growth, productivity and up-take of crop plants as observed in present experiment. Phosphorus nutrition should be part of the management strategy that considers the importance of other nutrients.

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