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Agin George
Department of Soil Science & Agricultural Chemistry, SKN College of Agriculture, Jobner, Jaipur, Rajasthan, India

Dr. KK Sharma
Department of Soil Science & Agricultural Chemistry, SKN Agriculture University, Jobner, Rajasthan, India

Corresponding Author:
Agin George
Department of Soil Science & Agricultural Chemistry, SKN College of Agriculture, Jobner, Jaipur, Rajasthan, India

Impact of phosphorus levels and bio-inoculants on yield and nutrient uptake of wheat (*Triticum aestivum* L.)

Agin George and Dr. KK Sharma

Abstract
The experiment consisted of 16 treatment combinations comprising four levels of phosphorus (0, 30, 60 and 90 kg P_2O_5 ha^{-1} in integration with four treatments of phosphatic bio-inoculants (Uninoculated, PSF, VAM and PSB). This experiment was laid out in a factorial randomised block design with three replications. The results of the experiment indicated that application of 60 kg P_2O_5 ha^{-1} significantly increased the grain and straw yield. N, P, and K uptake in plants were significantly higher at 60 kg P_2O_5 ha^{-1}. Use of PSF, VAM and PSB inoculants significantly increased the grain and straw yield. The grain yield, straw yield, N, P, and K uptake in plants were significantly higher under PSB inoculation. Results further showed that application of 60 kg P_2O_5 ha^{-1} followed by inoculation of PSB gave maximum grain and straw yield, N, P and K uptake in grain and straw.

Keywords: Impact, phosphorus, bio-inoculants, wheat, *Triticum aestivum* L.

Introduction

Wheat is the second most important food crop of our country. It is mostly consumed in the north and north-west parts of the country. Wheat is a good supplement for nutritional requirement of human body as it contains 9-10% protein and 60-80% carbohydrates. Being rich in protein, vitamin and carbohydrates, it provides a balanced food to millions of people each day. India has the largest area of wheat cultivation (29.14 million hectares), but ranks second in production (102.19 million tonnes) after China with the average productivity of 3154 kg/ha (GOI, 2019) [9]. It is cultivated mainly in Uttar Pradesh, Punjab, Rajasthan, Haryana, Bihar, Madhya Pradesh, Gujarat and Maharashtra. About 14% of the total cropped area in the country is under wheat cultivation. India accounts for about 12% of the total wheat production in the world. The total area under the wheat crop is about 29 million hectare in the country.

Phosphorus (P) has a vital role in plant growth and is the major plant growth-limiting nutrient despite its abundance in soils in both inorganic and organic forms (Gyaneshwar *et al.*, 1999) [11]. It is absorbed by plants in orthophosphate forms (Hinsinger, 2001) [13]. Phosphorus is a structural component of many co-enzymes, phosphoproteins, phospholipids (Ozanne, 1980) [19] and a part of the DNA genetic memory of all living things. It is involved in the transfer and storage of energy which is used for growth and reproduction (Griffith, 1999) [10]. Phosphorus has an important role in several physiological processes of plants, especially in photosynthesis, carbon metabolism and membrane formation (Wu *et al*., 2005) [30].

Microorganisms are integral in the natural phosphorus cycle. The use of phosphate solubilizing microorganisms (PSMs) as bio-inoculants for agriculture enhancement has been a subject of study for years. PSM induce plant growth and their possible role as biofertilizer in crop production. PSM enable P to become available for plant uptake after solubilization. Several soil bacteria and fungi possess the ability to bring insoluble phosphates in soil into soluble forms by secreting organic acids such as acetic acid, propionic acid, formic acid, lactic acid, glycolic, fumaric and succinic acids. These acids reduce the pH and bring about the dissolution of bound forms of phosphates. Some of the hydroxyl acids may chelate with calcium and iron resulting in effective solubilization and utilization of phosphates. A considerable portion of P fertilizer can be reduced by inoculation of soil with some suitable PSB isolates. Increasing cost of P fertilizers in developing countries like India and high fixation of P in soil leads to the search for sustainable way of phosphorus nutrition of crops. In this regards phosphate-solubilizing microorganisms (PSM) have been seen as the best eco-friendly means for P nutrition of crops. Vesicular Arbuscular Mycorrhiza (VAM) is a complex structure in plant roots which is formed by mutual interactions of soil fungi and roots tissues. The main role of

VAM is to mobilize the soil P and hence P uptake by macrosymbiont (Toljander, 2006) [29]. The increment ability in absorbing P by plant that infected by VAM is predicted to be caused by enzyme phosphatase activities (George *et al*., 1992) [8].

Material and Methods
Experimental site
This experiment was conducted at Agronomy Farm, S.K.N. College of Agriculture, Jobner (Rajasthan) on field No. 10 during *rabi season*, 2020-2021. The Jobner is situated 45 km west of Jaipur at 26°05′ N-latitude and 75°28′ E-longitude and at an altitude of 427 metres above mean sea level. The region falls under Agro-climatic zone III A (Semi-Arid Eastern Plains) of Rajasthan.

Climate and weather conditions
The climate of this region is a typically semi-arid, characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 48°C, while in winters, it may fall as low as -1.0°C. Frost is not uncommon during winter. The average annual rainfall of this tract ranges between 400-500 mm, most of which is contributed by the S-W monsoon during the months of July and August. There is hardly any rain during winter and summers. As the climate affects the growth, yield and quality of agricultural product, it is necessary to present climatic variables.

Soil of the experimental field
In order to evaluate the physico-chemical properties of the experimental field, soil samples from 0-15 cm depth were taken from different random spots of the experimental area prior to layout and a homogeneous and representative composite soil sample was prepared by mixing and processing of all the soil samples together. The composite soil sample was subjected to mechanical, physical and chemical analyses to ascertain its physico-chemical properties. Results showed that the experimental field was loamy sand in texture, alkaline in reaction, poor in organic carbon with low in available nitrogen and medium in available phosphorus and potassium content.

Field preparation
The experimental field was irrigated and after two days ploughed with tractor drawn disc plough followed by cross ploughing and planking to obtain fine tilth. Prior to cross ploughing a uniform dose of nitrogen and potassium was applied in the field and incorporated well while ploughing. After field preparation, seed beds of 2.0 m × 1.80 m size were prepared as per the plan of layout.

Treatment application
The whole quantity of phosphorus was applied through SSP (Contain 16% P_2O_5) as per treatment details prior to sowing and incorporated manually in top 15cm of the soil.
The bio-inoculants used in this experiment are PSB, VAM and PSF. PSB applied as seed inoculation while VAM and PSF applied as soil inoculation. In seed inoculation wheat seed was inoculated with liquid PSB culture @ 4 ml/kg seed as per routine procedure 2-3 hours before sowing as per treatments. In soil inoculation soil was inoculated with VAM and mixed it thoroughly with equal amount of sterilized soil. This mixture was spread before sowing of seed in root zone. The same way PSF (*Aspergillus awamori*) also inoculated in soil.

Observations and Analysis
After threshing and winnowing grain yield plot^{-1} was weighted and expressed in term of kg ha^{-1}. Straw yield was obtained by subtracting the grain yield per plot from the respectively biological yield per plot and finally expressed in terms of kg ha^{-1}. The representative samples of seed and straw drawn at the time of threshing that were first oven dried and then ground to fine powder by electrical grinder stainless steel Willey mill, were analysed for their N, P and K concentrations. Estimation of nitrogen was done by colorimetric method using Nessler's reagent to develop colour (Snell and Snell, 1949) [25]. Phosphorus concentration in seed and straw was determined by 'Vanadomolybdo phosphoric acid' yellow colour method. Digestion of samples was done by tri-acid mixture and the intensity of colour was measured by Spectophotometer (Jackson, 1973) [14]. Potassium concentration in the samples used earlier was determined by digesting them in tri-acid mixture of HNO_3:H_2SO_4:$HClO_4$ and was estimated by 'flame photometric method' (Richards, 1954) [22].

$$\text{Total nutrient uptake (kg/ha)} = \frac{\text{Nutrient conc. in seed (\%) X Seed yield (kg/ha)} + \text{Nutrient conc. in straw (\%) X Straw yield (kg/ha)}}{100}$$

Statistical analysis
In order to test the significance of variation in experimental data obtained for various treatment effects, the data were statistically analysed as described by Fisher (1950) [6]. The critical differences were calculated to assess the significance of treatment mean wherever the F test was found significant at 5 per cent level of probability.

Results
Grain and straw yield
Data showed in table 2 illustrated the significant effect of application of phosphorus to the soil in increasing the grain yield. Although, the highest grain yield was obtained at 90 kg P_2O_5 ha^{-1} (39.21 q/ha), which was at par with that of 60 kg P_2O_5 ha^{-1} (36.46 q/ha). The extent of rise recorded over control was of the order of 18.81 and 33.70 per cent, with the application of 30 and 60 kg P_2O_5 ha^{-1}, respectively. Table 2 shows that the phosphatic bio-inoculants considerably enhanced grain yield when compared to the control. The increase in grain production with PSF, VAM, and PSB inoculation was on the order of 11.58, 12.66, and 15.48 percent, respectively, as compared to no inoculation. However, the grain yield of PSF (34.09 q/ha), VAM (34.42 q/ha) and PSB (35.28 q/ha) were found at par. The maximum grain yield was recorded with the application of PSB.
Table 2 showed that applying phosphorus levels up to 60 kg P_2O_5 ha^{-1} considerably boosted the straw production. When compared to control, the increase attributable to the application of 30 and 60 kg P_2O_5 ha^{-1} was on the order of 22.47 and 38.11 percent, respectively. Despite the fact that the largest straw yield was obtained at 90 kg P_2O_5 ha^{-1} (50.72 q/ha), it was comparable to that obtained at 60 kg P_2O_5 ha^{-1} (47.08 q/ha). The statistics in table 2 clearly showed that the phosphorus-solubilizing microorganisms greatly boosted straw yield as compared to no inoculation. PSF, VAM, and PSB inoculation improved straw yield by 9.66, 13.33, and

16.1 percent, respectively, as compared to control. The inoculation of PSB resulted in the highest straw yield (47.08 q/ha). Even though, straw yield with PSF, VAM, and PSB was found to be comparable.

Nutrients Uptake by Wheat

Table 3 showed that increasing the amount of phosphorus application boosted grain nitrogen uptake by upto 60 kg P_2O_5 ha^{-1}. The significantly highest nitrogen uptake (57.517 kg ha^{-1}) at harvest of the crop was recorded under the treatment P_3, while minimum nitrogen uptake (36.531 kg ha^{-1}) was recorded under P_0 treatment. The application of 60 kg P_2O_5 ha^{-1} being at par with 90 kg P_2O_5 ha^{-1}, significantly increased the nitrogen uptake to the extent 44.27 and 16.03 percent as compared to control and 30 kg P_2O_5 ha^{-1}, respectively. The data presented in table 3 revealed the importance of the micro-organisms inoculation with PSF, VAM and PSB significantly increased the uptake of nitrogen in grain. The inoculation with PSF, VAM and PSB respectively increased N uptake by 18.42, 20.62 and 24.9 per cent, compared with non-inoculation. The three strains were found at par in influencing the N uptake by wheat grain. The maximum nitrogen uptake by grain was caused when inoculated with PSB (51.377 kg ha^{-1}).

The data mentioned in table 3 indicated that increasing the amount of phosphorus application enhanced the nitrogen uptake by straw by up to 60 kg P_2O_5 ha^{-1}. The nitrogen uptake by straw was greatly increased with 60 kg P_20_5 ha^{-1} by 59.2 and 21.75 percent over control and 30 kg P_2O_5 ha^{-1}, respectively, but was comparable to 90 kg P_2O_5 ha^{-1}. However, straw's maximum nitrogen uptake was measured at 90 kg P_2O_5 ha^{-1} (20.1 kg ha^{-1}). The data presented in table 3 revealed that the inoculation with different combinations of phosphorus solubilizing microorganisms significantly increased nitrogen uptake by straw of wheat. The inoculation with PSF, VAM and PSB respectively increased N uptake by 14.6, 19.6 and 22.1 per cent, compared with non-inoculation of wheat seed. The maximum nitrogen uptake by straw was found with PSB (17.081 kg ha^{-1}). However, a further study of the data revealed that the three strains were found at par in influencing the N uptake by wheat straw.

Table 4 showed that increasing the amount of phosphorus application boosted grain phosphorus uptake by upto 60 kg P_2O_5 ha^{-1}. The significantly highest phosphorus uptake (8.348 kg ha^{-1}) at harvest of the crop was recorded under the treatment P_3, while minimum phosphorus uptake (5.216 kg ha^{-1}) was recorded under P_0 treatment. The application of 60 kg P_2O_5 ha^{-1} being at par with 90 kg P_2O_5 ha^{-1}, significantly increased the phosphorus uptake to the extent 46.1 and 20.1 per cent as compared to control and 30 kg P_2O_5 ha^{-1}, respectively. The data presented in table 4 revealed the importance of the micro-organisms inoculation with PSF, VAM and PSB significantly increased the uptake of phosphorus in grain. The inoculation with PSF, VAM and PSB respectively increased P uptake by 17.94, 21.21 and 25.47 per cent, compared with non-inoculation. The three strains were found at par in influencing the P uptake by wheat grain. The maximum phosphorus uptake by grain was caused when inoculated with PSB (7.434 kg ha^{-1}).

The data mentioned in table 4 indicated that increasing the amount of phosphorus application enhanced the phosphorus uptake by straw by up to 60 kg P_2O_5 ha^{-1}. The phosphorus uptake by straw was greatly increased by 60 kg P_2O_5 ha^{-1} over control and 30 kg P_2O_5 ha^{-1} by 48.91 and 20.34 per cent, respectively, but was comparable to 90 kg P_2O_5 ha^{-1}. However, straw's maximum phosphorus uptake was measured at 90 kg P_2O_5 ha^{-1} (4.982 kg ha^{-1}). The data in table 4 revealed that the inoculation with different combinations of phosphorus solubilizing micro-organisms significantly increased the phosphorus uptake by straw of wheat. The inoculation with PSF, VAM and PSB respectively increased P uptake by 14.78, 21.14 and 26.56 per cent, respectively as compared with non-inoculation of wheat seed (control). The maximum phosphorus uptake by straw was found with PSB (4.50 kg ha^{-1}).

Analysis of data (Table 5) revealed that phosphorus application with increasing levels significantly increased the K uptake by grain upto 60 kg P_2O_5 ha^{-1}. Potassium uptake was increased by 54.32 and 18.67 percent, respectively, when 60 kg P_2O_5 ha^{-1} was applied over control and 30 kg P_2O_5 ha^{-1} respectively. A critical examination of data in table 5 revealed that inoculation with phosphatic bio-inoculants significantly increased the potassium uptake by wheat in grain. As a result of the treatment getting inoculation with PSF, VAM, and PSB, K uptake increased by 18.81, 22.71, and 28.41 percent, respectively, over the control. Individually, the bio-inoculants had similar effects on potassium uptake by wheat grains.

Data given in same table 5 further revealed that the application of increasing levels of phosphorus significantly increased the K uptake by wheat straw upto 60 kg P_2O_5 ha^{-1}. Application of 60 kg P_2O_5 ha^{-1} significantly increased the K uptake by straw which was 52.8 and 17.81 per cent, higher over control and 30 kg P_2O_5 ha^{-1} respectively. The data on the response of different phosphatic bio-inoculants on the uptake of K is presented in table 5, which reveals that inoculation with PSF, VAM and PSB significantly increased the K uptake by wheat straw. As a result of the treatment getting inoculated with PSF, VAM, and PSB, the amount of the increase reported in straw over control was of the order of 16.62, 23.72, and 29.5 percent. The phosphatic bio-inoculants remains at par in their influence on K uptake by the straw of wheat.

Discussion

Grain and straw yield

The results of phosphorus level performance demonstrated a substantial positive relationship between grain and straw yield with increased phosphorus application (Table 2). These results are consistent with Singh and Rai's findings (2003) [23]. The stimulating effect of phosphorus on plant processes such as cell division and root elongation in meristematic tissues, which is a constituent of ADP and ATP in plants, could explain the improvement in growth and yield parameters. The Results showed that inoculation with PSF, VAM and PSB significantly improved the grain and straw yield of wheat over un-inoculated (control), but were at par to each other. However, the inoculation of PSB recorded maximum increase in grain and straw yield of wheat over control (Table 2). Increased P availability through solubilization of insoluble inorganic phosphate by organic acid, decomposition of phosphate-rich organic compounds and production of plant growth promoting substances could explain the increase in grain and straw yield of wheat after inoculation with P solubilizing microorganisms (Gaur and Sunita 1999) [7].

Nutrients Uptake by Wheat

With increasing quantities of phosphorus up to 60 kg P_20_5 ha^{-1}, significant increases in nitrogen uptake by wheat grain and straw were seen (Table 3). It was because of the potential for phosphorus to have a beneficial influence on nitrogen. Phosphorus fertilization may have resulted in higher nitrogen buildup as a result of the increased production. Tanwar (2002), Chaturvedi *et al.* (2006) and Suri *et al.* (2006) [27, 2, 26] were also reported similar findings. Results shown in the table 3 showed that the uptake of nitrogen in grain and straw increased with inoculation of phosphatic bio-inoculant strains. Inoculation with phosphate solubilizing microorganisms also boosted nitrogen uptake, which could be owing to increased phosphorus availability and uptake, which is known to be positively connected to nitrogen intake. Increased plant N content could indicate increased N availability owing to organic N mineralization (Reddy and Reddy, 1998) [21]. The enhancement in symbiotic N_2 fixation resulted in a significant rise in N concentration and total nitrogen absorption. Furthermore, it is well recognized that improving plant P nutrition, whether through fertilizer or biological means, improves symbiotic N_2-fixation and plant N content. These findings back up previous research by Han and Lee (2006) and Yadav *et al.* (2009) [12, 31].

With increasing amounts of phosphorus up to 60 P_20_5 ha^{-1}, a considerable increase in phosphorus uptake by grain and straw was seen (Table 4). This could be attributed to an increase in phosphorus concentration in the soil solution as phosphorus treatment increases. Larger P content, as well as grain and straw yields with higher P doses, could explain the increase in P uptake. The findings are consistent with those of Choudhary *et al.* (1997) [3]. Plant P content increased considerably when P was applied to the test soil. Unlike dry matter production, P concentration tended to decrease as soil fertility increased, which could be attributed to dry matter accumulation rates being higher than P absorption rates. The native P and graded levels of applied P had a considerable impact on total P uptake by wheat plants, just as they had on dry matter production. Singh *et al.* (2004) [24] and Bhunia *et al.* (2006) [1] were also reported similar findings. It is obvious from the data presented in the table 4 that inoculation with different phosphatic bio-inoculants significantly increased the P uptake of wheat crop. Due to microbial activity that could have resulted in quantitative and qualitative changes in root exudates composition due to the degradation of exudate compounds and the release of microbial metabolites, inoculation with phosphate-solubilizing micro-organisms increased phosphorus uptake to a significant level compared to uninoculated plots (Neumann and Romheld, 2000) [18]. Microbial activity affects inorganic P conversions and is a key element in the soil organic P cycle (Kucey *et al.*, 1989) [15]. The effect of P status on uptake efficiency could be linked to changes in the plant's root characteristics. Increased enzyme activity in soils revealed that soil has the capacity to influence the biochemical transformations required for soil fertility maintenance (Rao *et al.*, 1990) [20]. The findings show that phosphate-solubilizing microbes have a favourable impact on wheat yield, owing to enhanced phosphatase and phytase release. Increased phosphatase activity has been linked to plants acquiring more P. (Dodd *et al.*, 1987; Tarafdar & jungk, 1987) [5, 28]. Phosphate-solubilizing microorganism strains differed in their ability to enhance wheat plant growth and nutrient uptake. Sole inoculation of PSF, VAM and PSB dramatically increased P uptake by wheat grain and straw compared to controls, which found as comparable. This could be owing to the enormous amount of infected root, sporocarp, and VAM spores left in the soil. Increased root growth and more absorptive surface available for P use could be the result of VAM fungus exploring a larger volume of soil.

Increased potassium uptake in grain and straw could be attributed to a synergistic impact between phosphorus and potassium, resulting in improved root growth. Potassium concentration in grain and straw may have increased as a result of enhanced uptake of this nutrient. With the application of 60 kg P_20_5 ha^{-1} in grain and straw, the potassium absorption was dramatically increased (Table 5). Because nutrient uptake is influenced by grain and straw content as well as crop yield. The intake of this nutrient increases as these parameters rise as a result of phosphorus treatment. Kumar (2000), Dhadeech (2001) and Suri *et al.* (2006) [16, 4, 26] were also reported similar findings. Inoculation with phosphate-solubilizing microorganisms considerably boosted the uptake of potassium in wheat crops, according to the results (Table 5). The capacity of these microorganisms to react with K-minerals is demonstrated by a considerable increase in K concentration after inoculation with these bio-inoculants. Raised soil K availability might be attributed to direct soil K supply as well as the solubilization of K from K-bearing minerals via organic acids produced, which could have increased K content in plants. The enhanced impacts on nitrogen uptake could also be attributed to the improved physical qualities of the soil (Nambiar and Abrol, 1989) [17].

Conclusion

Based on the results of present investigation it is clear that phosphorus when applied @ 60 kg P_2O_5 ha^{-1} along with inoculation of PSB played a vital role for overall improvement in crop growth as judged by increased growth and yield attributes, nutrient content and uptake in wheat crop. Thus application of 60 kg P_2O_5 ha^{-1} and PSB to wheat crop is recommended.

Table 1: Initial physico - chemical properties of soil of the experimental field

Soil properties	Content
Mechanical properties	
Coarse sand (%)	25.0
Fine sand (%)	57.5
Silt (%)	9.8
Clay (%)	7.5
Textural class	Loamy sand
Chemical properties	
Organic carbon (%)	0.15
Available nitrogen (kg/ha)	132.6
Available phosphorus (kg/ha)	16.63
Available potash (kg/ha)	134.1
EC of saturation extract at 25 °C (dS/m)	1.41
pH (1:2 soil water suspension)	8.2

Table 2: Effect of phosphorus levels and bio-inoculants on grain and straw yield of wheat

Treatments	Grain yield (q/ha)	Straw yield (q/ha)
Phosphorus level		
P_0 (control)	27.27	34.09
P_1 (30 kg/ha P_2O_5)	32.40	41.75
P_2 (60 kg/ha P_2O_5)	36.46	47.08
P_3 (90 kg/ha P_2O_5)	39.21	50.72
S.Em+	1.13	1.37
CD (P=0.05)	3.25	3.96
Bio-inoculant		
B_0 (ControI)	30.55	38.59
B_1 (PSF)	34.09	43.48
B_2 (VAM)	34.42	44.74
B_3 (PSB)	35.28	45.82
S.Em+	1.13	1.37
CD (P=0.05)	3.25	3.96

Table 3: Effect of phosphorus levels and bio-inoculants on nitrogen uptake (kg ha^{-1}) by grain and straw of wheat

Treatments	Nitrogen uptake	
	Grain	Straw
Phosphorus level		
P_0 (control)	36.531	11.211
P_1 (30 kg/ha P_2O_5)	45.422	14.946
P_2 (60 kg/ha P_2O_5)	52.705	18.198
P_3 (90 kg/ha P_2O_5)	57.517	20.077
S.Em+	1.74	0.685
CD (P=0.05)	5.02	1.98
Bio-inoculants		
B_0 (control)	41.143	14.015
B_1 (PSF)	48.723	16.060
B_2 (VAM)	49.632	16.769
B_3 (PSB)	51.377	17.081
S.Em+	1.74	0.685
CD (P=0.05)	5.02	1.98

Table 4: Effect of phosphorus levels and bio-inoculants on phosphorus uptake (kg ha^{-1}) by grain and straw of wheat

Treatments	Phosphorus uptake	
	Grain	Straw
Phosphorus level		
P_0 (control)	5.216	3.079
P_1 (30 kg/ha P_2O_5)	6.345	3.810
P_2 (60 kg/ha P_2O_5)	7.620	4.585
P_3 (90 kg/ha P_2O_5)	8.348	4.982
S.Em+	0.265	0.154
CD (P=0.05)	0.765	0.444
Bio-inoculants		
B_0 (control)	5.925	3.558
B_1 (PSF)	6.988	4.084
B_2 (VAM)	7.182	4.310
B_3 (PSB)	7.434	4.503
S.Em+	0.265	0.154
CD (P=0.05)	0.765	0.444

Table 5: Effect of phosphorus levels and bio-inoculants on potassium uptake (kg ha^{-1}) by grain and straw of wheat

Treatments	Potassium uptake	
	Grain	Straw
Phosphorus level		
P_0 (control)	11.133	43.251
P_1 (30 kg/ha P_2O_5)	14.569	56.155
P_2 (60 kg/ha P_2O_5)	17.181	66.084
P_3 (90 kg/ha P_2O_5)	18.927	72.102
S.Em+	0.64	2.19
CD (P=0.05)	1.86	6.33
Bio-inoculants		
B_0 (control)	13.070	50.316
B_1 (PSF)	15.528	58.680
B_2 (VAM)	16.038	62.252
B_3 (PSB)	16.782	65.143
S.Em+	0.64	2.19
CD (P=0.05)	1.86	6.33

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Reference

1. Bhunia SR, Chauhan RPS, Yadav BS, Bhati AS. Effect of phosphorus, irrigation and Rhizobium on productivity, water use and nutrient uptake in fenugreek (*Trigonella foenum-graecum*). Indian Journal of Agronomy 2006;49:53-56.
2. Chaturvedi I. Effects of phosphorus levels alone or in combination with phosphate-solubilizing bacteria (*Pseudomonas striata*) and farmyard manure on growth, yield and nutrient uptake of wheat (*Triticum aestivum*). Journal of Agriculture and Social Science 2006;2:96-100.
3. Choudhary NR, Vyas AK, Singh AK. Growth and nutrient uptake in wheat as influenced by nitrogen, phosphorus and zinc fertilization. Annals of Agricultural Research 1997;18:365-366.
4. Dhadheech RC. Influence of graded doses of phosphorus and indigenous plant growth regulators on N and P uptake of black gram. 66th Annual Convention, National Seminar on Development in Soil Science. 139. Held at Rajasthan College of Agriculture, Udaipur, Rajasthan 2001.
5. Dodd JC, Burton CC, Bums RG, Jeffries P. Phosphatase activity associated with the roots and the rhizosphere of plants infected with vesicular arbuscular mycorrhizal fungi. The New Phytologist 1987;107:163-172.
6. Fisher RA. Statistical methods for research workers. Oliver and Boyd, Edinburg, Landon 1950,57-63p.
7. Gaur AC, Sunita G. Phosphate solubilizing microorganisms in - An overview. Current Trends in Life Science 1999;23:459-464.
8. George E. Contribution of mycorrhizal hyphal to nutrient and water uptake of plants. Mycorrhizas in Ecosystems 1992,42-47.
9. GOI. Agricultural statistics at a glance. Directorate of Economics and Statistics. Department of Agriculture and Cooperation, Ministry of Agriculture 2019. http//dacnet.nic.in.
10. Griffith B. Phosphorus Efficient Fertilizer Use Manual, fourth ed. IMC Global http://www.imc-agro.com/fertilize/education/ efu manual 1999. (Accessed 5 January 2018).
11. Gyaneshwar P, Parekh LJ, Archana G, Podle PS, Collins MD, Hutson RA *et al*. Involvement of a phosphate starvation inducible glucose dehydrogenase in soil phosphate solubilization by *Enterobacter asburiae*. FEMS Microbiol. Lett 1999;171:223-229.
12. Han HS, Supanjani, Lee KD. Effect of co-inoculation with phosphate and potassium solubilizing bacteria on mineral uptake and growth of pepper and cucumber. Plant and Soil Environment 2006;52:130-136.
13. Hinsinger P. Bioavailability of soil inorganic P in the rhizosphere as affected by root-induced chemical change: a review. Plant Soil 2001;237:173-195.
14. Jackson ML. Soil chemical analysis. Prentice Hall of India Pvt., Ltd., New Delhi 1973,498p.
15. Kucey RMN, Janzen HH, Legget ME. Microbially mediated increases in plant-available phosphorus. Advances in Agronomy 1989;42:199-222.
16. Kumar J. Response of chickpea to phosphorus and molybdenum in loamy sand. M.Sc. (Ag.) Thesis, Rajasthan Agricultural University, Bikaner, Rajasthan 2000.
17. Nambiar KK, Abrol IP. Long term fertilizer experiments in India-A overview. Fertilizer News 1989;34:11-20.
18. Neumann G, Romheld V. The release of root exudates as affected by plant's physiological status. The Rhizosphere Biochemistry and Organic Substances at the Soil-Plant Interface, in R. Pinton, Z. Varanini and P. Nannipieri 2000,41-93p.
19. Ozanne PG. Phosphate nutrition of plants general treatise. In: The Role of Phosphorus in Agriculture. American Society of Agronomy and Science Society of America, Madison, WI, USA 1980,559-589p.
20. Rao AV, Bala K, Tarafdar JC. Dehydrogenase and phosphatase activities in soil as influenced by the growth of arid-land crops. Journal of Agriculture Science Cambridge 1990;115:221-225.
21. Reddy GB, Reddy S. Effect of organic manures and nitrogen levels in soil available nutrients status in maize-soybean cropping systems. Journal of the Indian Society of Soil Science 1998;51:78-80
22. Richards LA. Diagnosis and improvement of saline-alkali soils. USDA Handbook No. 60, U.S. Department of Agriculture, Washington D.C. (USA) 1954.
23. Singh T, Rai RK. Growth parameters, nutrient uptake and soil fertility under wheat (*Triticum aestivum* L.) as

influenced by levels of phosphorus and phosphate-solubilizing micro-organisms. Indian Journal of Agronomy 2003;48:182-185.
24. Singh V, Paudia RS, Totawat KL. Effect of phosphorus and zinc nutrition on wheat *(Triticum aestivum)* in soils of sub- humid southern plains of Rajasthan. Indian Journal of Agronomy 2004;49:46-48.
25. Snell FD, Snell CT. Colorimetric method and analysis. Third edition. Van. Nostt and Co. Inc. New York 1949,11b.
26. Suri VK, Girish Chander, Choudhary AK, Verma TS. Co-inoculation of VA-mycorrhizae (VAM) and phosphate solubilizing bacteria (PSB) in enhancing phosphorus supply to wheat in a typic Hapludalf. Crop Research Hisar 2006;31:357-361.
27. Tanwar SPS. Effect of phosphorus sources under the influence of FYM and phosphorus solubilizing bacteria on productivity of soybean-wheat cropping system. Ph.D. Thesis. Department of Agronomy, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan 2002.
28. Tarafdar JC, Jungk A. Phosphate activity in rhizosphere and its relation to the Depletion of soil organic phosphorus. Biology and Fertility of Soils 1987;3:199-204.
29. Toljander JF. Interaction between soil bacteria and arbuscular mycorrhizal fungi. Swedish University of Agricultural Sciences, Uppsala. Final Ph.D. Thesis 2006.
30. Wu SC, Cao ZH, Li ZG, Cheung KC, Wong MH. Effect of biofertilizer containing N-fixer, P and K solubilizers and AM fungi on maize growth: a greenhouse trial. Geoderma 2005;125:155-166.
31. Yadav BK, Niwas R, Yadav RS, Tarafdar JC. Effect of *Chaetomium globosum* inoculation and organic matter on phosphorus mobilization in soil and yield of cluster bean. Annals of Arid Zone 2009;48:41-44.