

Original Research Article

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Promotion of Nutrient Uptake, Nutrient Use Efficiency and Apparent Nutrient Recovery of Wheat (*Triticum aestivum* L.) by Application of Phosphate and Potash Solubilizing Bacteria

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ABSTRACT

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A field experiment was conducted on calcareous clayey soil at Junagadh (Gujarat) during rabi season of 2014-15 to study the effect of phosphate and potash solubilizing bacterial inoculations on nutrient uptake, nutrient use efficiency and apparent nutrient recovery of Wheat (*Triticum aestivum* L.). The experimental results revealed that application of 45 kg P₂O₅/ha + phosphate solubilizing bacteria (PSB) seed inoculation + PSB soil application, being statistically at par with application of 45 kg P₂O₅ + PSB seed inoculation, significantly promoted phosphorus uptake by grain (17.98 kg/ha) and straw (5.72 kg/ha) as well as NUE of applied P (14.97 kg grain/kg P applied) and apparent nutrient recovery of P by 15.11%. While, Application of 45 kg K₂O/ha + KSB seed inoculation + KSB soil application (K₃) recorded significantly highest potassium uptake by grain (18.27 kg/ha) and straw (69.92 kg/ha). The treatment K₃ (45 kg K₂O/ha + KSB seed inoculation + KSB soil application) registered the highest potash use efficiency (15.73 kg grain/kg K applied) and apparent potash recovery (67.37%).

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important staple food crop cultivated in almost all the countries in the world. It's belonging to "Gramineae" family. Wheat is the second most important grain crop of India after rice and thus crucial for the food security of the country. It is the world's most cultivated food crop. It is eaten in various forms by more than one thousand million human beings in the

world. In India it is second important staple food crop, rice being the first.

Wheat provides about 20% of total food calories for the human race. Wheat grain contains about 12.2 per cent protein and the gluten in the grain provides the structural framework for the spongy, cellular texture of bread and bakery products. Wheat has a relatively high content of niacin and thiamine. Wheat straw is a good source of cattle feed,

used in paper industries and for making temporary huts and roofs. Wheat straw is also a good source of bedding material for livestock. Wheat can be grown on a variety of soils ranging from sandy to heavy clay, however, fertile and well-drained loam to clay loam soil is most suitable for higher production.

Wheat production in India is 93.50 million tonnes during 2015-16 which is higher by 6.97 million tonnes than the production of 86.53 million tonnes achieved during 2014-15. The major wheat growing states in India are Gujarat, Uttar Pradesh, Punjab, Haryana, Madhya Pradesh and Rajasthan. The average wheat productivity of India is 3093 kg/ha (Anonymous, 2017).

The fertilizer is essential as well as expensive input in agricultural production. Fertilizer plays a leading role in increasing crop production by almost 41%. The fertilizer recommendations need to be matched to genetic materials and agro-climatic situations to exploit potential yield of wheat.

Natural phosphate rocks have been recognized as a valuable alternative for P fertilizers. In India, it is estimated that there are almost 260 million tonnes of phosphate rock deposits and this material should provide a cheap source of phosphate fertilizer for crop production. Unfortunately, rock phosphate (RP) is not readily available to the plants in soils with a pH >5.5-6.0 (Illmer and Schinner, 1995). Several P-solubilizing microorganisms have the ability to convert insoluble low grade rock phosphates into soluble forms available for plant growth. Potassium (K) is an essential macronutrient and most abundantly absorbed cation that play an important role in the growth, metabolism and development of plants. Without adequate potassium, the plants will have poorly developed roots, grow slowly, produce small seeds and have lower

yields. Although, potassium constitutes about 2.5 per cent of the lithosphere but actual soil concentrations of this nutrient vary widely ranging from 0.04 to 3.0 per cent.

Certain bacteria are capable of decomposing minerals and releasing a portion of the phosphate and potassium contained therein (Basak and Biswas, 2009). In addition, phosphate and potash solubilizing bacteria are also known to produce amino acids, vitamins and growth promoting substances like indole-3-acetic acid (IAA) and gibberellic acid (GA3) which help in better growth of the plants (Ponmurugan and Gopi, 2006). Solubilization of phosphate and potassium from the potassium aluminium silicate and rock phosphate by the selected bacterial strains resulted to the action of different organic acids like citric, oxalic, malic, succinic and tartaric acid.

Thus, application of P and K solubilizing bacteria as biofertilizer for agriculture improvement can reduce the use of agrochemicals, improve nutrient use efficiency and support eco-friendly crop production. Considering the facts and to bridge the research gap highlighted above, the present experiment was undertaken during the *rabi* season of 2014-15.

Materials and Methods

The experimental soil was medium black calcareous clayey and slightly alkaline in reaction with pH 7.9 and EC 0.33 dS/m, medium in available nitrogen (254-269 kg/ha), available phosphorus (28.4-30.7 kg/ha) and available potash (183-185 kg/ha). The experiment comprise of 16 treatment combinations consisting of four levels of PSB (P₀: Control, P₁: 60 kg P₂O₅/ha, P₂: 45 kg P₂O₅/ha + PSB seed inoculation, P₃: 45 kg P₂O₅/ha + PSB seed inoculation + PSB soil application) and four levels of KSB (K₀:

Control, K₁: 60 kg K₂O/ha, K₂: 45 kg K₂O/ha + KSB seed inoculation, K₃: 45 kg K₂O/ha + KSB seed inoculation + KSB soil application). These treatments were replicated thrice in a randomized block design. Dose of nitrogen *i.e.* 120 kg N/ha in two equal splits at sowing and 25 DAS was applied uniformly to all the plots. Entire dose of phosphorus and potash as per treatments was applied in form of diammonium phosphate and muriate of potash, respectively at sowing. Liquid formulation of PSB (*Bacillus coagulans*) and KSB (*Frateruia aurantia*) were used for seed treatment as well as for soil application. For seed treatment, seeds were spreaded and PSB/KSB culture (108 viable cells/g) @ 30 mL/kg of seed was sprinkled on the seeds and then dried in shade. For soil application, PSB/KSB culture (108 viable cells/g) @ 3000 mL/ha was applied in furrows just after sowing before irrigation. The crop was raised as per the recommended package of practices.

Nutrient use efficiency

Nutrient use efficiency was calculated with the help of the following formula.

(Panda, 2012)

$$\text{Nutrient use efficiency (kg grain/kg fertilizer)} = \frac{Y_f - Y_c}{F_a}$$

Where; Y_f = Yield (grain or any other economic produce) under the fertilized plotin (kg/ha), Y_c = Yield (grain or any other economic produce) under the control (no fertilizer) plot (kg/ha), F_a = Fertilizer applied (kg/ha)

Apparent Nutrient Recovery (NR)

Apparent nutrient recovery was calculated with the help of the following formula (Panda, 2012)

$$\text{Apparent nutrient recovery (\%)} = \frac{U_f - U_c}{N_a} \times 100$$

Where; U_f = nutrient uptake by fertilized plot (kg/ha), U_c = nutrient uptake by control plot (kg/ha), N_a = nutrient applied (kg/ha)

Results and Discussion

Effect of PSB

Different levels of PSB exhibited significant impact on phosphorus uptake by grain and straw. Significantly the highest phosphorus uptake by grain and straw (17.98, 5.72 kg/ha, respectively) was recorded with application of 45 kg P₂O₅/ha + PSB seed inoculation + PSB soil application (P₃), nevertheless it remained statistically at par with application of 45 kg P₂O₅/ha + PSB seed inoculation (P₂). Total uptake of phosphorus also follows the same trend as in grain and straw. Application of 45 kg P₂O₅/ha + PSB seed inoculation + PSB soil application (P₃) registered 23.71 kg P ha⁻¹ uptake over control (16.90 kg/ha). Potassium uptake by grain and straw was also influenced by PSB. Among different levels of PSB, application of 45 kg P₂O₅/ha + PSB seed inoculation + PSB soil application (P₃) recorded significantly the highest potassium content by grain (17.14 kg/ha) and straw (66.76kg/ha) as well as total potassium uptake (83.89 kg/ha), which was statistically at par with application of 45 kg P₂O₅/ha + PSB seed inoculation (P₂) and 60 kg P₂O₅/ha (P₁). Application of 45 kg P₂O₅/ha + PSB seed inoculation + PSB soil application (P₃) recorded the highest phosphorus use efficiency (14.97 kg grain/kg P applied) and apparent nutrient recovery (15.11%), followed by application of 45 kg P₂O₅/ha + PSB seed inoculation (P₂) having phosphorus use efficiency of 11.44 kg grain/kg P applied and apparent phosphorus recovery of 11.67%.

Among different levels of PSB, application of 45 kg P₂O₅/ha + PSB seed inoculation + PSB soil application (P₃) recorded the highest potash use efficiency (9.13 kg grain/kg K

applied) and , followed by application of 45 kg P₂O₅/ha + PSB seed inoculation (P₂) having phosphorus use efficiency of 7.48 kg grain/kg K applied and apparent potash recovery (41.22%), followed by application of 45 kg P₂O₅/ha + PSB seed inoculation + PSB soil application (P₃) having apparent phosphorus recovery of 37.72%.

PSB solubilized the fixed soil phosphorus and readily hydrolysed the organophosphate and degraded them in the soil and increase the availability of fixed P and applied P to the plant owing to its favourable effects on division and multiplication of cells. Moreover, phosphorus is the important constituent of co-enzymes which are important for photosynthesis and protein synthesis. One of the main roles of the phosphorus in plant is in transfer of energy through ATP and also

involved in root development and in metabolic activities. The results are in conformity with those reported by Agrawal and Pathak (2011), Devi *et al.*, (2011), Jordan and Caldwell (2012), Saxena *et al.*, (2013), Kaur and Reddy (2014) and Yousefi and Berzegar (2014).

Effect of KSB

Application of 45 kg K₂O/ha + KSB seed inoculation + KSB soil application (K₃) recorded significantly the highest potassium uptake by grain (18.27 kg/ha) and straw (69.92 kg/ha). Significantly the highest total uptake of potassium (88.18 kg/ha) was noted with application of 45 kg K₂O/ha + KSB seed inoculation + KSB soil application (K₃), which maintained statistical equivalence with application of 45 kg K₂O/ha + KSB seed inoculation (K₂) (Table 1 and 2).

Table.1 Effect of different treatments on phosphorus and potassium uptake by grain and straw

Treatments	Phosphorus uptake (kg/ha)			Potassium uptake (kg/ha)		
	Grain	Straw	Total	Grain	Straw	Total
PSB						
P ₀ : Control	13.90	3.00	16.90	13.20	51.08	64.29
P ₁ : 60 kg P ₂ O ₅ /ha	15.67	4.61	20.29	14.71	62.11	76.82
P ₂ : 45 kg P ₂ O ₅ /ha + PSB seed inoculation	16.92	5.23	22.16	15.64	63.56	79.20
P ₃ : 45 kg P ₂ O ₅ /ha + PSB seed inoculation + PSB soil application	17.98	5.72	23.71	17.14	66.76	83.89
S.Em.±	0.64	0.18	0.68	0.51	2.60	2.59
C.D. at 5%	1.85	0.53	1.96	1.47	7.50	7.47
KSB						
K ₀ : Control	14.12	4.02	18.14	10.48	47.38	57.86
K ₁ : 60 kg K ₂ O/ha	15.30	4.59	19.89	15.25	60.95	76.20
K ₂ : 45 kg K ₂ O/ha + KSB seed inoculation	16.57	4.73	21.30	16.69	65.27	81.95
K ₃ : 45 kg K ₂ O/ha + KSB seed inoculation + KSB soil application	18.49	5.23	23.72	18.27	69.92	88.18
S.Em.±	0.64	0.18	0.68	0.51	2.60	2.59
C.D. at 5%	1.85	0.53	1.96	1.47	7.50	7.47

Table.2 Effect of different treatments on nutrient use efficiency and Apparent nutrient recovery (%)

Treatments	Nutrient use efficiency (kg grain/kg fertilizer applied)		Apparent nutrient recovery (%)	
	Phosphorus	Potash	Phosphorus	Potash
PSB				
P₀ : Control	0.00	6.65	0.00	35.14
P₁ : 60 kg P₂O₅/ha	5.30	5.64	5.64	37.39
P₂ : 45 kg P₂O₅/ha + PSB seed inoculation	11.44	7.48	11.67	41.22
P₃ : 45 kg P₂O₅/ha + PSB seed inoculation + PSB soil application	14.97	9.13	15.11	37.72
KSB				
K₀ : Control	7.24	0.00	7.68	0.00
K₁ : 60 kg K₂O/ha	8.09	3.36	8.30	30.57
K₂ : 45 kg K₂O/ha + KSB seed inoculation	10.01	9.80	7.66	53.53
K₃ : 45 kg K₂O/ha + KSB seed inoculation + KSB soil application	6.38	15.73	8.78	67.37

The potash use efficiency and apparent potash recovery (%) varied perceptibly under different treatments of potash. Wherein, the treatment K₃ (45 kg K₂O/ha + KSB seed inoculation + KSB soil application) registered the highest potash use efficiency (15.73 kg grain/kg K applied) and apparent potash recovery (67.37%), followed by the treatment K₂(application of 45 kg K₂O/ha + KSB seed inoculation) by recording potash use efficiency of 9.80 kg grain/kg K applied and apparent potash recovery of 53.53%.

Scrutiny of data revealed that different levels of KSB exercised their significant influence on phosphorus uptake by grain, straw and total uptake. Significantly the highest phosphorus uptake by grain (18.49 kg/ha), straw (5.23 kg/ha), was registered with application of 45 kg K₂O/ha + KSB seed inoculation + KSB soil application (K₃). The maximum total uptake of phosphorus (23.72 kg/ha) was found with application of 45 kg K₂O/ha + KSB seed inoculation + KSB soil

application (K₃). Application of 45 kg K₂O/ha + KSB seed inoculation (K₂) registered the highest phosphorus use efficiency (10.01 kg grain/kg P applied) and apparent phosphorus recovery (8.78%), followed by application of 60 kg K₂O/ha (K₁) having phosphorus use efficiency of 8.09 kg grain/kg P applied and apparent phosphorus recovery of 8.30 %. The response of KSB may be attributed to mobilization of K from soil because of secretion of organic acids by the bacterial strains, thereby enhanced plant growth and development, and finally greater acquisition of nutrients. The results are supported by other workers who have observed increase in plant assimilation of K by the use of potassium solubilizing microorganisms in soil. These results are in close conformity with the finding of Bagyalakshami *et al.*, (2012), Sangeeth *et al.*, (2012), Min *et al.*, (2013), Prajapati *et al.*, (2013), Zhanga and Konga (2014) and Padma and Sukumar (2015).

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