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Yield attributes, yield and quality of summer groundnut as influenced by application of phosphorus and phosphorus solubilizing bacteria

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Abstract
In order to evaluate the effects of different combinations of phosphorus and phosphorus solubilizing bacteria on yield and yield attributes, quality of summer groundnut (var. GJG 31), a field experiment was conducted at Instructional farm, Junagadh Agricultural University, Junagadh, during summer seasons of 2018. The treatments comprising of different four levels of phosphorus viz., 0, 12.5, 25 and 50 kg ha^{-1} and four levels of phosphorus solubilizing bacteria (PSB) viz., 0, 1, 2 and 3 lit ha^{-1} in Factorial Randomized Block Design repeated thrice were tested in the experiment, in respect of growth parameters, yield attributes, yield and quality parameters. The application of 50 kg P_2O_5 ha^{-1} was significantly increased the plant height (15.26%), number of branches (10.12%), number of nodules (7.62%), nodule dry weight (13.82%), number of pegs (14.93%), number of mature pods (17.88%), number of total pods (8.72%), shelling percentage (6.10%), test weight (6.94%), oil percentage (3.56%), protein content (5.14%), pod yield (17.88%) and haulm yield (13.75%) over the control plot treatment. However, number of immature pods did not influenced by phosphorus application. The application 3 lit PSB ha^{-1} was produced significantly favorable effect on increased plant height (14.92%), number of branches (11.81%), number of nodules (8.19%), nodule dry weight (11.95%), number of pegs (18.75%), number of mature pods (14.99%), number of total pods (6.61%), shelling percentage (6.31%), test weight (8.38%), protein content (7.62%), pod yield (14.99%) and haulm yield (14.78%) over the control plot treatment. However, number of immature pods and oil percentage did not influenced by PSB application. The significant interaction effect of phosphorus and PSB application was observed only in case of number of mature pods per plant and pod yield. Significantly higher numbers of mature pods per plant and pod yield were recorded with combine application of 50 kg P_2O_5 ha^{-1} with 2 lit PSB ha^{-1}.

Keywords: Groundnut, phosphorus, PSB, yield and quality

Introduction
The groundnut (*Arachis hypogaea* L.) is one of the important food legume crop of tropical and subtropical parts of the world. China and India are the largest producers of groundnut sharing 42 and 20 per cent of the world groundnut production, respectively. India is one of the largest producers of oilseeds in the world and oilseeds occupy an important position in the Indian agricultural economy. In the recent years, the area under summer groundnut has increased due to assured and higher profit and productivity as it is grown in area where assured irrigation water is available and less incidence of a biotic and abiotic stresses on the crop as compared to rainy season (Rana *et al*., 2014) [1]. In Gujarat, It is grown on an area of 0.52 L ha with the production of 0.95 L tonnes and productivity of 1842 kg ha^{-1} during summer season (Anon., 2017) [2]. Phosphorus play beneficial role in the root development, nodulation and stimulation of the symbiotic nitrogen fixation. It enhances root development and nodulation, improves the supply of nutrients and water, increase in photosynthetic area resulting in more dry matter accumulation and yield (Rajanikanth *et al*., 2008) [3]. Phosphorus is an essential element for plant growth and development. Because of its sparingly soluble nature it is present in very less proportion in the soil for plant uptake. Major proportions of soil-P remain interlocked in various insoluble forms and not available for plant use. Some bacterial species have a natural potential to solublize the phosphorus. The use of phosphorus solubilizing bacteria (PSB) simultaneously enhances P availability to plants and crop yield. Present review emphasizes the role of phosphate solubilizing bacteria in sustainable management of soil by solubilization of

fixed-phosphorus in relation to crop responses. This review exhaustively explores the potential of PSB to solublize phosphate by highlighting the current practices and future prospects of their utility in soil management. Keeping all the above aspects in view and in order to test the combine effect of both factors with its various levels of application, investigation was carried out to study the "Effect of phosphorus and phosphorus solubilising bacteria on yield attributes, yield and quality of summer groundnut".

Materials and methods

A field experiment was conducted on summer groundnut (var. GJG 31) at Instructional farm, Junagadh Agricultural University, Junagadh, during summer seasons of 2018. The experimental soil was medium black calcareous, clayey in nature which was slightly alkaline in reaction, $pH_{2.5}$ (7.8) and $EC_{2.5}$ (0.33 dS m^{-1}), low in available nitrogen (237.0 kg ha^{-1}), medium in available phosphorus (36.2 kg ha^{-1}), sulphur (17.5 ppm), iron (5.35 ppm) and zinc (0.78 ppm) and high in available potassium (284.0 kg ha^{-1}), manganese (14.8 ppm) and copper (2.06 ppm). The treatments comprising all possible combination of different four levels of each phosphorus viz., 0, 12.5, 25 and 50 kg ha^{-1} and phosphorus solubilizing bacteria (PSB) viz., 0, 1, 2 and 3 lit ha^{-1} in Factorial Randomized Block Design repeated thrice were tested in the experiment, in respect of growth parameters *viz;* plant height and number of branches, yield attributes *viz;* number of nodules, nodule dry weight, number of pegs, number of mature pods, number of total pods quality parameters *viz;* shelling percentage, test weight, oil and protein content and pod and haulm yield. Nitrogen and Potash was applied as a basal as per recommended dose (N_2-K_2O: 25-50 kg ha^{-1}) to all the plots in form of Urea and MOP, respectively. While, Phosphorus was applied as per treatments in form of DAP. Phosphorus solubilizing bacteria (*Bacillus megaterium*) was applied as per treatments by drenching at the time of sowing. The experimental data recorded for growth parameters, yield attributes and yield were statistically analyzed for level of significance.

Results and Discussion

Effect of phosphorus on growth, yield attributes, yield and quality

The different levels of phosphorus was exerted their significant influence on growth parameters, yield attributes, yield and quality parameters of summer groundnut (Table-1 & 2). The application of 50 kg P_2O_5 ha^{-1} was significantly increased the plant height (20.4 cm), number of branches (4.47), number of nodules (74.7) at 30 DAS, nodule dry weight (0.233 g) at 30 DAS, number of pegs (22.8) at 60 DAS, number of mature pods (9.79), number of total pods (13.7), shelling percentage (65.5), test weight (43.3 g), oil percentage (46.6%), protein content (25.9%), pod yield (2595 kg ha^{-1}) and haulm yield (3043 kg ha^{-1}). However, number of immature pods did not influenced by phosphorus application. The favorable effect of phosphorus application was mainly due to its primary role in photosynthesis by way of rapid energy transfer and thereby increased photosynthetic efficiency and application of phosphorus increased P in root zone, which in turn resulted in better growth and development of roots as well as shoots and also helped in better nodulation. The higher photosynthesis and higher production of assimilates, resulted in higher yield. Kulkarni *et al.* (1986) [4] and Thorave and Dhonde (2008) [5] reported the favourable effect of P on growth, yield attributes and yield of groundnut. Similar results were also observed by Babaria *et al.* (2014) [6] in cotton. The increased in protein content with P application might be due to its role in protein synthesis. Increase in protein content by increasing phosphorus level was also reported by Patel and Patel (1994) [7], Kausale *et al*. (2009) [8] and Hadwani and Gundalia (2005) [9]. Phosphorus being a major constituent of fatty acid, higher accumulation of phosphorus at lower N/P fertilizer ratio must have resulted in higher seed oil content. Kausale *et al*. (2009) [8] also reported such favorable effect of phosphorus on increase oil percentage of groundnut.

Effect of phosphorus solubilizing bacteria on growth, yield attributes, yield and quality

The different levels of phosphorus solubilizing bacteria was executed their significant influence on growth parameters, yield attributes, yield and quality parameters of summer groundnut (Table-1 & 2). The application 3 lit PSB ha^{-1} was significantly increased the plant height (20.3 cm), number of branches (4.44), number of nodules (74.9) at 30 DAS, nodule dry weight (0.233 g) at 30 DAS, number of pegs (22.8) at 60 DAS, number of mature pods (9.61), number of total pods (13.5), shelling percentage (66.0), test weight (43.3 g), oil content (46.5%), pod yield (2545 kg ha^{-1}) and haulm yield (3013 kg ha^{-1}). However, number of immature pods, and oil percentage did not influenced by PSB application. The beneficial effect of phosphate solubilizing bacteria increased the availability of phosphorus, enhanced photosynthesis, production of photosynthates and their partitioning between vegetative and reproductive structure might have helped in improving the yield attributes and finally the pod and haulm yield. These results are in accordance with the findings of Kausale *et al.* (2009) [8], Singh *et al.* (2013) [10] and Chavan *et al.* (2014) [11].

Interaction effect of phosphorus and phosphorus solubilizing bacteria

The significant interaction effect of phosphorus and PSB application were observed only in case of number of mature pods per plant and pod yield. Significantly higher values of number of mature pods per plant (10.78) and pod yield (2875 kg ha^{-1}) were recorded with combined application of 50 kg P_2O_5 ha^{-1} with 2 lit PSB ha^{-1}(Table-3). The combined effect of phosphorus and PSB play a pivotal role due to their synergistic effect. Application of PSB solubilized unavailable phosphorus to available phosphorus nutrients. The overall development of plant in terms of root and shoot might have resulted in higher absorption of nutrients as well as moisture. The higher photosynthesis and higher production of assimilates, resulted in higher number of mature pods per plant. Kamble *et al.* (2006) [12] reported that combine application of phosphorus and PSB significantly increased mature pods of groundnut. These results are in conformity with those reported by Sawarkar and Thakur (2001) [13].

Table 1: Effect of phosphorus and phosphorus solubilizing bacteria on growth and yield attributes of summer groundnut

Treatments	Plant height (cm)	No. of branches per plant	No. of nodules/ plant at 30 DAS	Nodule dry wt./ plant at 30 DAS (g)	No. of pegs/ plant at 60 DAS	No. of mature pods/ plant	No. of immature pods/ plant	Total pods/ plant
P levels (kg P_2O_5 ha^{-1})								
P_0 – 0	17.7	4.06	69.4	0.206	19.9	8.31	4.34	12.6
P_1- 12.5	18.5	4.11	70.7	0.216	20.4	8.41	4.26	12.7
P_2 – 25	19.2	4.21	73.1	0.225	20.6	9.03	4.03	13.1
P_3 – 50	20.4	4.47	74.7	0.235	22.8	9.79	3.95	13.7
S.Em.±	0.4	0.09	1.2	0.005	0.5	0.19	0.12	0.2
C.D. at 5%	1.1	0.26	3.4	0.015	1.5	0.55	NS	0.7
PSB levels (lit PSB ha^{-1})								
PSB_0 – 0	17.7	3.97	69.3	0.208	19.2	8.35	4.35	12.7
PSB_1 – 1	18.6	4.14	70.9	0.216	20.5	8.51	4.21	12.7
PSB_2 – 2	19.2	4.28	72.7	0.226	21.3	9.07	4.10	13.2
PSB_3 – 3	20.3	4.44	74.9	0.233	22.8	9.61	3.93	13.5
S.Em.±	0.4	0.09	1.2	0.005	0.5	0.19	0.12	0.2
C.D. at 5%	1.1	0.26	3.4	0.015	1.5	0.55	NS	0.7
P x PSB								
S.Em.±	0.7	0.18	2.3	0.011	1.1	0.38	0.23	0.5
C.D. at 5%	NS	NS	NS	NS	NS	1.09	NS	NS
C.V. %	6.7	7.3	5.7	8.3	8.8	7.4	9.6	6.1

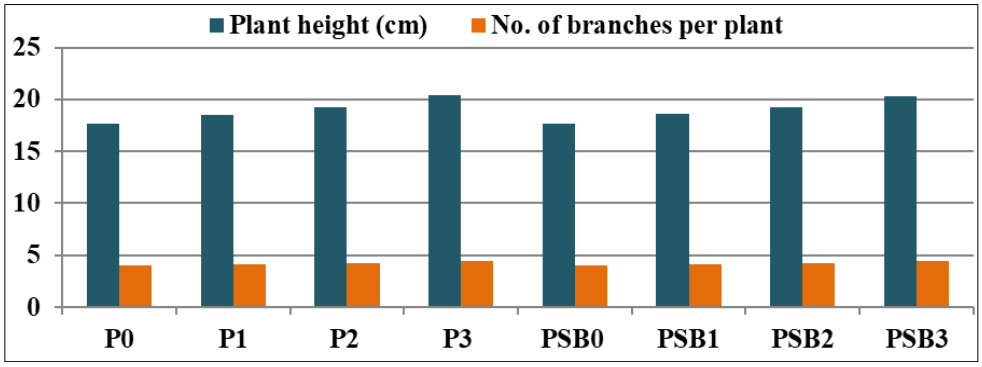

Fig 1: Effect of P and PSB on plant height (cm) and number of branches per plant

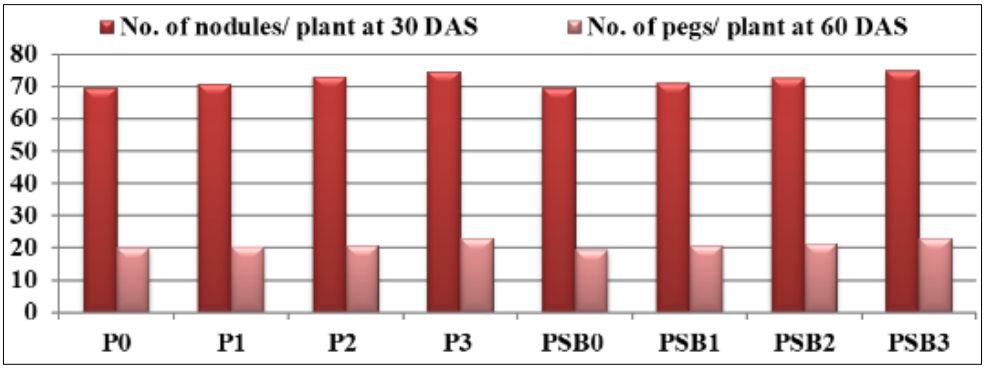

Fig 2: Effect of P and PSB on number of nodules and number of pegs per plant

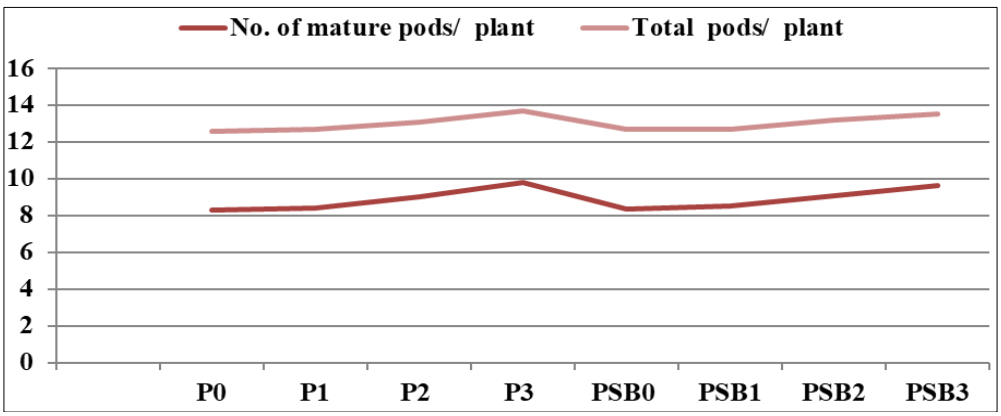

Fig 3: Effect of P and PSB on number of mature pods and total pods per plant

Table 2: Effect of phosphorus and phosphorus solubilizing bacteria on yield and quality parameters of summer groundnut

Treatments	Pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Shelling percentage	Test weight (g)	Oil content (%)	Protein content (%)
P levels (kg P_2O_5 ha^{-1})						
P_0 – 0	2201	2675	61.7	40.5	45.0	23.9
P_1- 12.5	2227	2690	64.3	40.2	45.5	25.3
P_2 – 25	2393	2877	64.6	43.0	46.6	25.5
P_3 – 50	2595	3043	65.5	43.3	46.6	25.9
S.Em.±	49	61	0.8	0.8	0.5	0.5
C.D. at 5%	141	177	2.3	2.3	1.4	1.4
PSB levels (lit PSB ha^{-1})						
PSB_0 – 0	2214	2625	62.1	40.0	45.3	24.0
PSB_1 – 1	2255	2728	63.3	41.3	45.9	25.0
PSB_2 – 2	2402	2919	64.8	42.4	46.1	25.5
PSB_3 – 3	2545	3013	66.0	43.3	46.5	26.1
S.Em.±	49	61	0.8	0.8	0.5	0.5
C.D. at 5%	141	177	2.3	2.3	NS	1.4
P x PSB						
S.Em.±	98	123	1.6	1.6	0.9	1.0
C.D. at 5%	282	NS	NS	NS	NS	NS
C.V. %	7.2	**7.5**	4.3	6.6	3.5	6.7

Table 3: Interaction effect of phosphorus and phosphorus solubilizing bacteria on pod yield and number of mature pods per plant

Treatments	Pod yield (kg ha^{-1})					Number of mature pods per plant				
	PSB_0	PSB_1	PSB_2	PSB_3	Mean	PSB_0	PSB_1	PSB_2	PSB_3	Mean
P_0	2167	2190	2215	2233	2201	8.18	8.27	8.36	8.43	8.31
P_1	2154	2197	2228	2330	2227	8.13	8.29	8.41	8.79	8.41
P_2	2237	2253	2310	2771	2392	8.44	8.50	8.72	10.46	9.03
P_3	2296	2378	2857	2848	2594	8.67	8.97	10.78	10.75	9.79
Mean	2213	2254	2402	2545		8.35	8.51	9.07	9.61	
S.Em.±	98					0.38				
C.D. at 5%	281					1.09				

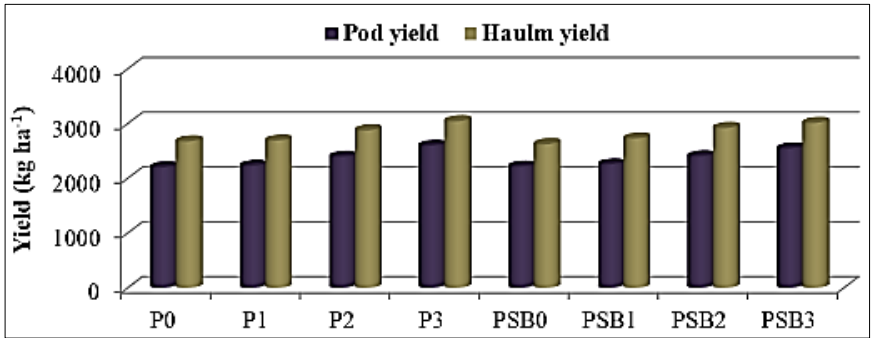

Fig 4: Effect of P and PSB on pod and haulm yield at harvest of groundnut

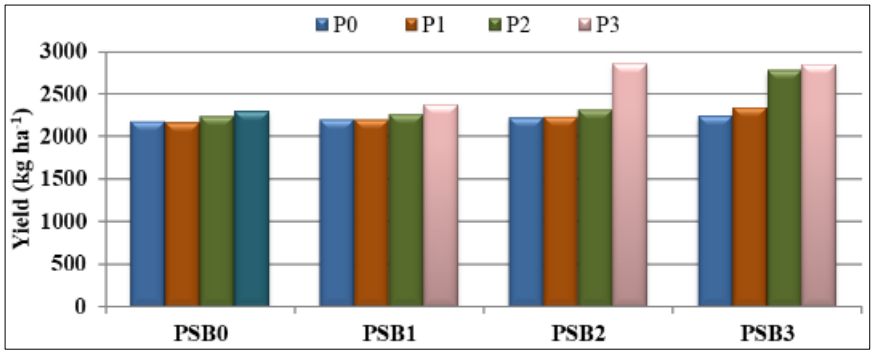

Fig 5: Interaction effect of P and PSB on pod yield of groundnut

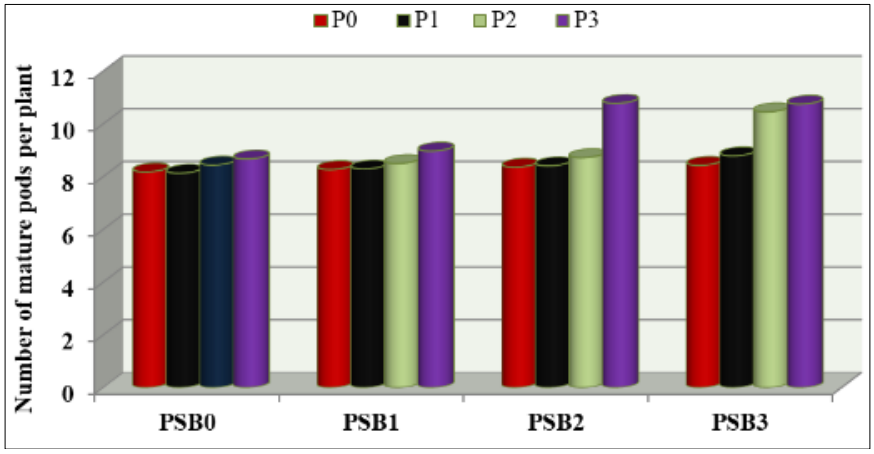

Fig 6: Interaction effect of p and PSB on mature pods per plant

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