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

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DOI: https://doi.org/10.22271/chemi.2020.v8.i2o.8894

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\(_2\)O\(_5\) 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\(_2\)O\(_5\) 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 (Rajankanth 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 solubilize 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 solubilize 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 7.8 and EC 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 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 (N2-K2O: 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 P2O5 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 Dhone (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 photosynthesates 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 P2O5 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 P₂O₅ ha⁻¹)** | | | | | | | | |
| P₀ – 0     | 17.7             | 4.06                      | 69.4                            | 0.206                            | 19.9                        | 8.31                       | 4.34                       | 12.6             |
| P₁ – 12.5  | 18.5             | 4.11                      | 70.7                            | 0.216                            | 20.4                        | 8.41                       | 4.26                       | 12.7             |
| P₂ – 25    | 19.2             | 4.21                      | 73.1                            | 0.225                            | 20.6                        | 9.03                       | 4.03                       | 13.1             |
| P₃ – 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                             | 0.013                            | 1.5                         | 0.55                       | NS                         | 0.7              |
| **PSB levels (lit PSB ha⁻¹)** | | | | | | | | |
| PSB₀ – 0   | 17.7             | 3.97                      | 69.3                            | 0.208                            | 19.2                        | 8.35                       | 4.35                       | 12.7             |
| PSB₁ – 1   | 18.6             | 4.14                      | 70.9                            | 0.216                            | 20.5                        | 8.51                       | 4.21                       | 12.7             |
| PSB₂ – 2   | 19.2             | 4.28                      | 72.7                            | 0.226                            | 21.3                        | 9.07                       | 4.10                       | 13.2             |
| PSB₃ – 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 (%) |
|------------|-----------------------------|-------------------------------|---------------------|----------------|----------------|--------------------|
| P0 – 0     | 2201                        | 2675                          | 61.7                | 40.5           | 45.0           | 23.9               |
| P1 – 12.5  | 2227                        | 2690                          | 64.3                | 40.2           | 45.5           | 25.3               |
| P2 – 25    | 2393                        | 2877                          | 64.6                | 43.0           | 46.6           | 25.5               |
| P3 – 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\(^{-1}\)) |                      |                                |                     |                |                |                    |
| PSB0 – 0   | 2214                        | 2625                          | 62.1                | 40.0           | 45.3           | 24.0               |
| PSB1 – 1   | 2255                        | 2728                          | 63.3                | 41.3           | 45.9           | 25.0               |
| PSB2 – 2   | 2402                        | 2919                          | 64.8                | 42.4           | 46.1           | 25.5               |
| PSB3 – 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             | NS                 |
| PSB x PSB  | S. Em.±                     | 98                            | 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 |
|------------|-----------------------------|---------------------------------|
|            | PSB0 | PSB1 | PSB2 | PSB3 | Mean | PSB0 | PSB1 | PSB2 | PSB3 | Mean |
| P0         | 2167 | 2190 | 2215 | 2233 | 2201 | 8.18 | 8.27 | 8.36 | 8.43 | 8.31 |
| P1         | 2154 | 2197 | 2228 | 2330 | 2277 | 8.13 | 8.29 | 8.41 | 8.79 | 8.41 |
| P2         | 2237 | 2253 | 2310 | 2771 | 2392 | 8.44 | 8.50 | 8.72 | 10.46 | 9.03 |
| P3         | 2296 | 2378 | 2857 | 2848 | 2594 | 8.67 | 8.97 | 10.78 | 10.75 | 9.79 |
| Mean       | 2213 | 2254 | 2402 | 2545 | 2545 | 8.35 | 8.51 | 9.07 | 9.61 | 9.16 |
| 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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