Influence of nutrients accumulation by various levels of phosphorus and phosphorus solubilizing bacteria in summer groundnut

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Abstract
A field experiment was conducted on summer groundnut (var. GJG 31) at Junagadh Agricultural University, Junagadh during summer, 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 content and uptake of nutrients like N, K, S, Fe, Mn, Zn and Cu at harvest and P at 30, 60 DAS and at harvest in pod & haulm and their total uptake by groundnut crop. Application of 50 kg P₂O₅ ha⁻¹ significantly increased only the phosphorus content in pod and haulm at harvest and in plant at 30 and 60 DAS. Whereas, phosphorus application did not exert any significant effect on N, K, S, Fe, Mn, Zn and Cu content in pod and haulm. Application of 50 kg P₂O₅ ha⁻¹ significantly increased the uptake of all the nutrients (N, P, K, S, Fe, Mn and Cu) by pod, haulm and its total uptake by the groundnut crop, except Zn uptake by pod and haulm. Application of PSB produced significantly favorable effect on phosphorus content in pod and haulm at harvest and in plant at 30 & 60 DAS of groundnut. While, PSB application did not exert any significant effect on N, K, S, Fe, Mn, Zn and Cu content in pod and haulm. Significantly higher values of all these parameters were observed with application of 3 lit PSB ha⁻¹. Application of 3 lit PSB ha⁻¹ also significantly increased the uptake of all the nutrients (N, P, K, S, Fe, Mn and Cu) by pod, haulm and its total uptake by the groundnut crop, except Zn uptake by pod and haulm.

Keywords: Groundnut, phosphorus, PSB, nutrients content and uptake

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 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 “Influence of nutrients accumulation by various levels of phosphorus and phosphorus solubilizing bacteria in summer groundnut”.

Materials and Methods
A field experiment was conducted on summer groundnut (var. GIG 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 (3.55 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 content and uptake of nutrients like N, K, S, Fe, Mn and Cu at harvest and P at 30, 60 DAS in plant and at harvest in pod & haulm and their total uptake by groundnut. All the nutrients content and uptake in plant were determined by adopting standard processors.

Results and Discussion
Effect of phosphorus on nutrients content
An assessment of data indicated that different levels of phosphorus exerted their significant influence on only phosphorus content (Table 1) in summer groundnut. The concentration of phosphorus recorded significantly higher in pod and haulm with the values of 0.527% and 0.490% at harvest and at 30 and 60 DAS in groundnut plant with value 0.531% and 0.287% under application of 50 kg P₂O₅ ha⁻¹, respectively. The concentration of nitrogen, potassium, sulphur and micro-nutrient (Fe, Mn, Zn and Cu) in pod and haulm at harvest did not influenced by phosphorus application. Application of phosphorus significantly increased the P content in haulm at 30 and 60 DAS and in pod and haulm at harvest. This may be due to phosphorus increases root growth of the crop which ultimately helped in increasing the p absorption by groundnut and also may enhance the availability of the soil phosphorus for plant nutrition. The results of present investigation were in close agreements with the finding of Choudhary and Yadav (2017) [4], Vaghasia and Bhalu (2016) [5], and Agrawal (1997) [6].

Nutrients uptake
An assessment of data (Table 2) indicated that different levels of phosphorus exerted their significant influence on nutrients uptake by summer groundnut. The uptake of nitrogen, phosphorus, potassium, sulphur and micro-nutrient (Fe, Mn, and Cu) by pod and haulm were significantly increased with phosphorus application. The application of 50 kg P₂O₅ ha⁻¹ showed significantly higher value of nitrogen (98.7 & 55.9 kg ha⁻¹), phosphorus (13.7 & 13.4 kg ha⁻¹), potassium (16.9 & 23.9 kg ha⁻¹), sulphur (8.13 & 9.75 kg ha⁻¹) and micro-nutrient like iron (1215 & 1881 g ha⁻¹), manganese (116 & 332 g ha⁻¹) and copper (81 & 107 g ha⁻¹) by pod and haulm, respectively. However, the zinc uptake by pod and haulm did not influenced significantly by phosphorus application. Similarly, the application of 50 kg P₂O₅ ha⁻¹ showed significantly higher value of total uptake nitrogen (155 kg ha⁻¹), phosphorus (27.4 kg ha⁻¹), potassium (40.8 kg ha⁻¹), sulphur (17.88 kg ha⁻¹), iron (3122 g ha⁻¹), manganese (448 g ha⁻¹), zinc (312 g ha⁻¹) and copper (188 g ha⁻¹) by groundnut crop. The reason behind increases in uptake of nutrients may be due to phosphorus increases the root growth of the crop which ultimately helped in increasing the uptake of nutrients. This result is in accordance with Jana et al. (1990) [7]. The crop could better take up the said nutrients only when the suitable dose of phosphorus was applied (Deka et al., 2001) [8]. The nutrient uptake is a function of yield and nutrient concentration in plant. Thus, improvement in uptake of N, P, K, S, Fe, Mn and Cu might be attributed to their respective higher concentration in pod and haulm and associated with higher pod and haulm yields. The results of present investigation are in close agreements with the findings of Hadwani and Gundalia (2005) [9], Thorave and Dhonde (2008) [10], Kumar et al. (2008) [11] and Vaghasia and Bhalu (2016) [5] in groundnut and Babaria et al. (2014) [12] in cotton.

Effect of phosphorus solubilizing bacteria nutrients content
An assessment of data (Table 1) indicated that different levels of phosphorus solubilizing bacteria exerted their significant influence only on phosphorus content in summer groundnut. The concentration of phosphorus recorded significantly higher in pod and haulm with the values of 0.530% and 0.530% at harvest and at 30 and 60 DAS in groundnut plant with value 0.522% and 0.275% under treatment of 3 lit PSB ha⁻¹ (PSB), respectively. The concentration of nitrogen, potassium, sulphur and micro-nutrient (Fe, Mn, Zn and Cu) in haulm at harvest did not influenced by PSB application. Application of PSB significantly increased the P content in pod and haulm at 30 and 60 DAS and at harvest, which might be due to releasing P from native as well as protecting fixation of applied phosphorus which rendered more available P for the plant leading to increased nutrient content. Sharma et al. (2014) [13] showed that application of PSB significantly increase P content in pod and haulm of groundnut.

Nutrients uptake
An examination of data (Table 2) showed that different levels of phosphorus solubilizing bacteria executed their significant influence on nutrients uptake by summer groundnut. The uptake of nitrogen, phosphorus, potassium, sulphur and micro-nutrient (Fe, Mn, and Cu) by pod and haulm were significantly increased with PSB application. The application of 3 lit PSB ha⁻¹ showed significantly higher value of nitrogen (98.4 & 55.9 kg ha⁻¹), phosphorus (13.6 & 13.3 kg ha⁻¹), potassium (17.2 &23.7 kg ha⁻¹), sulphur (7.93 & 9.78 kg ha⁻¹) and micro-nutrient like iron (1196 & 1873 g ha⁻¹), manganese (114 & 331g ha⁻¹) and copper (78 & 106 g ha⁻¹) by pod and haulm, respectively. However, zinc uptake by pod and haulm did not influenced by PSB application. The application of 3 lit PSB ha⁻¹ showed significantly higher value of total uptake of nitrogen (168 kg ha⁻¹), phosphorus (27.2 kg ha⁻¹), potassium (40.8 kg ha⁻¹), sulphur (17.71 kg ha⁻¹), iron (3102 g ha⁻¹), manganese (445 g ha⁻¹), zinc (312 g ha⁻¹) and copper (185 g ha⁻¹) by groundnut crop. Phosphate solubilizing bacteria had shown positive response with respect to uptake of all the nutrients under study (N, P, K, S, Fe, Mn, Zn and Cu) by pod and haulm and its total uptake by groundnut crop at harvest, except Zn uptake by pod and haulm. Phosphate solubilizing bacteria (PSB) solubilize unavailable phosphorus by secretion.
of organic acids and phosphatase enzyme. These all might have contributed towards increased available phosphorus status of the soil (Kachot et al., 2001) [14]. Thus, increased yield of pod and haulm ultimately, improvement in uptake of N, P, K, S, Fe, Mn, Zn and Cu by groundnut. The observations recorded were found similar with Manisha et al. (2006) [15], Zalate and Padman (2010) [16], Choudhary et al. (2011) [17] and Singh et al. (2013) [18].

Table 1: Effect of phosphorus and phosphorus solubilizing bacteria on N, P, K and S content in groundnut

| Treatments | At 30 DAS | At 60 DAS | At harvest Pod | Hauml | N (%) | K (%) | S (%) |
|------------|-----------|-----------|----------------|--------|-------|-------|-------|
| P₀ – 0     | 0.467     | 0.237     | 0.487          | 0.404  | 3.62  | 1.81  | 0.650 |
| P₀ – 25    | 0.531     | 0.270     | 0.511          | 0.431  | 3.78  | 1.82  | 0.659 |
| P₀ – 50    | 0.351     | 0.287     | 0.527          | 0.490  | 3.80  | 1.83  | 0.651 |
| S. Em.±    | 0.009     | 0.006     | 0.010          | 0.009  | 0.10  | 0.05  | 0.014 |
| C.D. at 5% | 0.027     | 0.017     | 0.028          | 0.026  | NS    | NS    | NS    |

PSB levels (lit PSB ha⁻¹)

| Treatments | At 30 DAS | At 60 DAS | At harvest Pod | Hauml | N (%) | K (%) | S (%) |
|------------|-----------|-----------|----------------|--------|-------|-------|-------|
| P₀ – 0     | 0.481     | 0.250     | 0.481          | 0.401  | 3.59  | 1.80  | 0.635 |
| P₀ – 25    | 0.509     | 0.264     | 0.512          | 0.510  | 3.79  | 1.83  | 0.663 |
| P₀ – 50    | 0.522     | 0.275     | 0.530          | 0.530  | 3.86  | 1.86  | 0.673 |
| S. Em.±    | 0.009     | 0.006     | 0.010          | 0.009  | 0.10  | 0.05  | 0.014 |
| C.D. at 5% | 0.027     | 0.017     | 0.028          | 0.026  | NS    | NS    | NS    |

Table 1.1: Effect of phosphorus and phosphorus solubilizing bacteria on micronutrients (Fe, Mn, Zn and Cu) content in groundnut

| Treatments | Fe (ppm) | Mn (ppm) | Zn (ppm) | Cu (ppm) |
|------------|----------|----------|----------|----------|
| Pod        | Hauml    | Pod      | Hauml    | Pod      | Hauml    |
| P₀ – 0     | 457      | 598      | 43.6     | 102      | 64.1     | 54.0     | 29.7    | 34.6    |
| P₀ – 25    | 462      | 606      | 44.1     | 106      | 63.5     | 53.7     | 30.1    | 34.8    |
| P₀ – 50    | 468      | 621      | 44.3     | 108      | 62.8     | 52.3     | 30.5    | 35.0    |
| S. Em.±    | 9        | 13       | 1.0      | 2        | 1.7      | 1.1      | 0.6     | 0.8     |
| C.D. at 5% | NS       | NS       | NS       | NS       | NS       | NS       | NS      | NS      |

PSB levels (lit PSB ha⁻¹)

| Treatments | Fe (ppm) | Mn (ppm) | Zn (ppm) | Cu (ppm) |
|------------|----------|----------|----------|----------|
| Pod        | Hauml    | Pod      | Hauml    | Pod      | Hauml    |
| P₀ – 0     | 458      | 598      | 43.6     | 102      | 63.9     | 53.8     | 29.8    | 34.7    |
| P₀ – 25    | 462      | 607      | 44.0     | 105      | 63.2     | 53.1     | 30.1    | 34.9    |
| P₀ – 50    | 469      | 618      | 44.4     | 108      | 62.6     | 52.3     | 30.4    | 35.0    |
| S. Em.±    | 9        | 13       | 1.0      | 2        | 1.7      | 1.1      | 0.6     | 0.8     |
| C.D. at 5% | NS       | NS       | NS       | NS       | NS       | NS       | NS      | NS      |

Table 2: Effect of phosphorus and phosphorus solubilizing bacteria on nutrients uptake by summer groundnut

| Treatments | N uptake (kg ha⁻¹) | P uptake (kg ha⁻¹) | K uptake (kg ha⁻¹) |
|------------|------------------|--------------------|--------------------|
| Pod        | Hauml            | Total              | Pod                | Hauml            | Total              | Pod                | Hauml            | Total              |
| P₀ – 0     | 79.7             | 48.7               | 128                | 10.7             | 10.8              | 21.7              | 14.3             | 19.9              | 34.2              |
| P₀ – 12.5  | 83.5             | 48.8               | 132                | 11.1             | 11.1              | 22.4              | 14.7             | 20.4              | 35.0              |
| P₀ – 25    | 90.5             | 52.2               | 143                | 12.3             | 12.4              | 25.0              | 15.8             | 22.3              | 38.2              |
| P₀ – 50    | 98.7             | 55.8               | 155                | 13.7             | 13.4              | 27.4              | 16.9             | 23.9              | 40.8              |
| S. Em.±    | 2.7              | 1.7                | 3                  | 0.4              | 0.3               | 0.5               | 0.5              | 0.7               | 0.8               |
| C.D. at 5% | 7.9              | 5.0                | 11                 | 1.1              | 1.0               | 1.5               | 1.5              | 1.9               | 2.3               |

PSB levels (lit PSB ha⁻¹)

| Treatments | N uptake (kg ha⁻¹) | P uptake (kg ha⁻¹) | K uptake (kg ha⁻¹) |
|------------|------------------|--------------------|--------------------|
| Pod        | Hauml            | Total              | Pod                | Hauml            | Total              | Pod                | Hauml            | Total              |
| P₀ – 0     | 79.4             | 47.0               | 135                | 10.6             | 10.5              | 21.2              | 14.0             | 19.3              | 33.4              |
| P₀ – 12.5  | 83.6             | 49.0               | 143                | 11.3             | 11.4              | 22.9              | 14.6             | 20.7              | 35.3              |
| P₀ – 25    | 91.0             | 53.5               | 158                | 12.3             | 12.5              | 25.2              | 15.9             | 22.8              | 38.7              |
| P₀ – 50    | 98.4             | 55.9               | 168                | 13.6             | 13.3              | 27.2              | 17.2             | 23.7              | 40.8              |
| S. Em.±    | 2.7              | 1.7                | 4                  | 0.4              | 0.3               | 0.5               | 0.5              | 0.7               | 0.8               |
| C.D. at 5% | 7.9              | 5.0                | 11                 | 1.1              | 1.0               | 1.5               | 1.5              | 1.9               | 2.3               |
Table 2.1: Effect of phosphorus and phosphorus solubilizing bacteria on nutrients uptake by summer groundnut

| Treatments | S uptake (kg ha\(^{-1}\)) | Fe uptake (g ha\(^{-1}\)) | Mn uptake (g ha\(^{-1}\)) |
|------------|-----------------------------|-----------------------------|-----------------------------|
|            | Pod Haulm Total             | Pod Haulm Total             | Pod Haulm Total             |
| P levels (kg P\(_2\)O\(_5\) ha\(^{-1}\)) | | | |
| P\(_0\) – 0 | 6.46 7.95 14.41 | 1007 1596 2621 | 96 274 370 |
| P\(_1\) – 12.5 | 6.70 8.38 15.07 | 1030 1630 2670 | 98 285 383 |
| P\(_2\) – 25 | 7.43 9.13 16.56 | 1120 1791 2937 | 106 312 418 |
| P\(_3\) – 50 | 8.13 9.75 17.88 | 1215 1881 3122 | 116 332 448 |
| S.Em.± | 0.22 0.31 0.33 | 30 48 60 | 3 10 10 |
| C. D. at 5% | 0.63 0.91 0.97 | 88 139 175 | 8 29 30 |
| PSB levels (lit PSB ha\(^{-1}\)) | | | |
| PSB\(_0\) – 0 | 6.60 7.80 14.41 | 1012 1572 2583 | 97 267 364 |
| PSB\(_1\) – 1 | 6.80 8.38 15.18 | 1044 1655 2709 | 99 287 386 |
| PSB\(_2\) – 2 | 7.38 9.25 16.63 | 1120 1798 2956 | 107 316 423 |
| PSB\(_3\) – 3 | 7.93 9.78 17.71 | 1196 1873 3102 | 114 331 445 |
| S.Em.± | 0.22 0.31 0.33 | 30 48 60 | 3 10 10 |
| C. D. at 5% | 0.63 0.91 0.97 | 88 139 175 | 8 29 30 |

Table 2.2: Effect of phosphorus and phosphorus solubilizing bacteria on nutrients uptake by summer groundnut

| Treatments | Zn uptake (g ha\(^{-1}\)) | Cu uptake (g ha\(^{-1}\)) |
|------------|-----------------------------|-----------------------------|
|            | Pod Haulm Total             | Pod Haulm Total             |
| P levels (kg P\(_2\)O\(_5\) ha\(^{-1}\)) | | | |
| P\(_0\) – 0 | 141 144 285 | 65 93 158 |
| P\(_1\) – 12.5 | 142 144 286 | 67 94 161 |
| P\(_2\) – 25 | 150 150 301 | 73 101 174 |
| P\(_3\) – 50 | 158 154 312 | 81 107 188 |
| S.Em.± | 5 5 6 | 2 3 4 |
| C. D. at 5% | 18 7 9 | 11 |
| PSB levels (lit PSB ha\(^{-1}\)) | | | |
| PSB\(_0\) – 0 | 141 141 283 | 66 91 157 |
| PSB\(_1\) – 1 | 143 145 287 | 68 95 163 |
| PSB\(_2\) – 2 | 150 152 303 | 73 102 176 |
| PSB\(_3\) – 3 | 157 155 312 | 78 106 185 |
| S.Em.± | 5 5 6 | 2 3 4 |
| C. D. at 5% | 18 7 9 | 11 |

Fig 1: Effect of P and PSB on N uptake by pod, haulm its total uptake
Fig 2: Effect of P and PSB on P uptake by pod, haulm and its total uptake

Fig 3: Effect of P and PSB on K uptake by pod, haulm and its total uptake

Fig 4: Effect of P and PSB on S uptake by pod, haulm and its total uptake

Fig 5: Effect of P and PSB on Fe uptake by pod, haulm and its total uptake
Fig 6: Effect of P and PSB on Mn uptake by pod, haulm and its total uptake

Fig 7: Effect of phosphorus and PSB on Cu uptake by pod, haulm and its total uptake

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