Original Research Article

Potential of Plant Growth Promoting Bacteria on Nutrient Availability in Soil, Nutrient Uptake and Yield of Summer Groundnut Grown on Entisol

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Abstract

A field experiment was conducted during the year 2017-18 at Post Graduate Institute Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri. The experiment was laid out in Randomised block design with three replication and eleven treatments. The treatments comprised of T1: Absolute control, T2: only ZnSB, T3: GRDF(25:50 kg ha\(^{-1}\) N:P₂O₅ + FYM @ 5 t ha\(^{-1}\)), T4 to T7 were GRDF + 100%, 75%, 50% and 25% RD of Zn through ZnSO₄+ ZnSB and T8 to T11 were GRDF + 100%, 75%, 50% and 25% RD of Zn through ZnO + ZnSB. The biofertilizer zinc solubilizing bacteria was given as a seed treatment as well as soil drenching @ 5% at 30 days of sowing. The soil pH, EC, organic carbon and calcium carbonate content in soil at initial as well as at harvest did not find any differences amongst treatments. The available N, P and K status of soil at harvest were found to be significantly improved due to application of 100% Zn through ZnSO₄ along with ZnSB and GRDF. The DTPA-Fe, Zn, Mn and Cu status of soil at harvest was also found to be significantly increased due to application of 100% Zn through ZnSO₄ + GRDF. Total uptake of nitrogen, phosphorus and potassium by groundnut crop was significantly increased (132.29, 15.60 and 65.63 kg ha\(^{-1}\), respectively) due to application of 100% Zn through ZnSO₄ + GRDF. The DTPA-Fe, Zn, Mn and Cu status of soil at harvest was also found to be significantly increased due to application of 100% Zn through ZnSO₄ + GRDF. The oil per cent was significantly increased in treatment of T4 (40.96 %) over all the treatments. The pod yield of groundnut was significantly increased in treatment of T4 (30.63 t ha\(^{-1}\)) over all the treatments except treatment T3 (29.44 t ha\(^{-1}\)) which was at par with T4. Haulm yield of groundnut was significantly increased (62.70 t ha\(^{-1}\)) in treatment of T4 (100% GRDF (25:50:00 kg ha\(^{-1}\) N:P₂O₅ + FYM @ 5 t ha\(^{-1}\)) over all the treatments. It can be thus concluded that, the application of 100% recommended dose of Zn through Zinc Sulphate @ 20 kg ha\(^{-1}\) + 5 % ZnSB to seed treatment at sowing and through drenching at 30 DAS along with 100% recommended dose of nutrients (25:50 kg ha\(^{-1}\) N:P₂O₅ + FYM @ 5 t ha\(^{-1}\)) to summer groundnut was found beneficial for increased in available macro and micronutrients status of soil, total uptake of macro and micronutrient.

Keywords

ZnSB, GRDF, ZnSO₄, ZnO, Available nutrients, Total nutrients, yield

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**Introduction**

India is blessed with the agro-ecological condition favourable for growing nine major oilseeds including seven edible oilseed namely, groundnut, rapeseed, mustard, soybean, sunflower, safflower, sesame and niger and two non-edible sources, namely castor and linseed, apart from wide range of other minor oilseeds and oil bearing species. Among all the oilseed crops, groundnut occupies the first place in India accounting for more than 28% of acreage and 32% of production in the country. However, except for castor, the productivity of oilseed crops in India is one of the lowest in the world.

Groundnut or peanuts originated in South America. Groundnut is grown in five states namely Andhra Pradesh, Gujarat, Tamilnadu, Karnataka and Maharashtra and together they account for about 90% per cent of the cultivated area. Andhra Pradesh and Gujarat states share about 28 and 24 per cent of the total cultivated area, respectively. About 8% of the total groundnut area is in the state of Maharashtra.

Zinc is one of the most important micronutrients. It plays vital role in the plant life. It has vital role in transformation of carbohydrates, regulation of consumption of sugar and increase source of energy for the production of chlorophyll. Zinc is also required for maintenance of auxin in an active state. The zinc is essential for the synthesis of tryptophan a precursor of auxin. Zinc deficiency in groundnut crop causes chlorotic strips on leaves and this band on the leaf portion nearest to petiole. Also it result in stunted growth while, the young leaves smaller than normal. This deficiency similar to iron deficiency only the difference is that chlorosis occur full length of the leaves and in peanut lower half of the leaves.

Among the bacterial species, strains belonging to the genera *Acinetobacter, Bacillus, Gluconacetobacter* and *Pseudomonas* have been reported (Simine Di et al., 1998; Fasim et al., 2002; Saravanan et al., 2007) as zinc solubilizers, fertilizers and manures, to enhance soil fertility and crop productivity has often negatively affected the complex biogeochemical cycles (Perrott et al., 1992; Steinshamn et al., 2004). Continuous application of fertilizers as well as their low use efficiency has caused leaching and runoff of nutrients, especially N and P leading to environmental degradation (Tilman, 1998 and Gyaneshwar et al., 2002). On the other hand, high cost associated with the application of Zn fertilizers in order to correct Zn deficiency places considerable burden on resource poor farmers (Wissuwa et al., 2006). One of the possible ways to increase crop productivity as well as food quality without creating the environmental issues is by the use of plant growth promoting rhizobacteria (PGPR). The PGPR were capable of colonizing the rhizosphere, root surface and internal tissues in plants. The main microbial mechanisms by which PGPR improved plant growth include N-fixation, inorganic P solubilisation, siderophore production, phytohormone synthesis and by controlling plant pathogens (Lugtenberg and Kamilova, 2009). Different plant growth promoting bacteria including free living and associative such as *Azospirillum, Azotobacter, Bacillus* and *Pseudomonas* have been used in agricultural systems as biofertilizers. Various criterias for their beneficial effects on plant growth (Tilak et al., 1982). Hitchins et al., (1986) reported that *Thiobacillus thioxidance*, *T. ferroxidance* and facultative thermophilic iron oxidizers solubilized zinc from sulphide ore ( sphalerite). Exogenous application of zinc sources, similar to fertilizer application has been advocated to various crops. This causes transformation of about 96 to 99 per cent of applied available zinc to various unavailable forms. The zinc thus, made unavailable can be reverted back
to available form by inoculating bacterial strain capable of solubilizing it. Since zinc is a limiting factor in crop production, this study on zinc solubilization by bacteria has an immense importance in zinc nutrition to plant.

Materials and Methods

The field experiment was conducted on groundnut (CV: TG - 26) during Summer in 2016-17 in randomized block design with three replication on the soil belonging to order Entisol (Typic Ustorthent) at Post Graduate Institute, Mahatma Phule Agricultural University, Rahuri, Maharashtra, located between 19°34’ N latitude and 74°64’ E longitude. The treatment comprised of T1: Absolute control, T2: only ZnSB, T3: GRDF(25:50 kg ha⁻¹ N: P₂O₅ + FYM @ 5 t ha⁻¹), T4 to T7 were GRDF + 100%, 75%, 50% and 25% RD of Zn through ZnSO₄+ ZnSB and T8 to T11 were GRDF + 100 %, 75%, 50% and 25% RD of Zn through ZnO + ZnSB. ZnSB was given through seed treatment at the time of sowing @ 5% and second 5% ZnSB was given by drenching in soil at 30 DAS. The soil sample was collected before sowing and harvest of groundnut analysed as per standard methods.

Results and Discussion

Soil chemical properties

Soil available nutrients

Soil available nitrogen content at initial stage was low in status (143 kg ha⁻¹), however, at harvest was significantly increased in treatment of T4 (198 kg ha⁻¹) over all the treatments except T9 (192 kg ha⁻¹), which was at par with treatment T4. Overall, available nitrogen status showed low in soil at harvest. The increase in the available nitrogen content in soil at harvest might be due to 100% fertilizer nitrogen dose and 100% RD of Zn through ZnSO₄ along with ZnSB. Similar results were also reported by Kayalvizhi et al., (2001) in sugarcane and Kumar et al., (2004) (Table 2).

Available phosphorus in soil at initial showed low status (10.89 kg ha⁻¹), however, at harvest, it significantly increased in treatment of T4 (11.02 kg ha⁻¹) over all the treatments. This might be due to increased in P use efficiency by the application of ZnSO₄ @ 20 kg ha⁻¹ in soil + ZnSB along with 100% GRDF. Overall, available P showed low status in soil at harvest in all the treatment under study, which might be due to higher fixation of P under alkaline condition. Low phosphorus availability in calcareous soil might be due to their transformation to more complicated forms with CaCO₃ and these changed forms...
are rendered less available to growing plants. Similar results were also recorded by Bashour et al., (1983). The effect of low P solubility in alkaline and calcareous soil was due to poor fertilizer P efficiency. The similar results were also supported by Stark and Westermann (2003) and Javid and Rowell (2003).

Available potassium content in soil at initial stage was medium status (185 kg ha\(^{-1}\)), however, at harvest the treatment T\(_4\) was found to be significantly increased (198 kg ha\(^{-1}\)) over all the treatment T\(_3\), T\(_4\), T\(_5\), T\(_6\), T\(_7\), T\(_9\), T\(_{10}\) and T\(_{11}\) except treatment T\(_2\) and T\(_8\) which were at par. Overall, available potassium showed medium status at harvest in all the treatment under study.

### Soil available micronutrients

DTPA micronutrients content in soil at soil Zn. However, sufficient in available Mn and Cu. The soils were deficient in DTPA-iron as the critical limit of DTPA-iron is 4.5 ppm. The soil available Fe at initial stage was deficient (4.11 mg kg\(^{-1}\)), however, at harvest it showed significantly higher content in treatment of T\(_4\) (3.91 mg kg\(^{-1}\)) over T\(_1\), T\(_3\), T\(_7\), T\(_9\) and T\(_{11}\) treatment however, treatment T\(_4\) were at par with treatments of T\(_2\), T\(_5\), T\(_6\), T\(_8\) and T\(_9\). The same trend of increasing in micronutrients status was observed at harvest stage with slight decrease in the values which may be due to uptake of micronutrients. Similar results have been reported by Stein (2010) (Table 3).

The soil of experimental site was deficient in available Zn (0.35 mg kg\(^{-1}\)) as the critical limit of DTPA-Zn in soil is 0.6 ppm. At harvest, available Zn in soil found to be significantly increased in T\(_4\) (0.58 mg kg\(^{-1}\)) over all the treatment. The increase in DTPA-Zn content in soil was slightly higher in treatments of application of ZnSO\(_4\) as compared to ZnO treatments along with seed treatment and soil drenching treatment of ZnSB @ 5%. Similar results were also reported by Fasim et al., (2002).

The soil available Mn content at initial and at harvest, it showed non significant results. The soil available Cu content at initial showed sufficient status (1.82 mg kg\(^{-1}\)), however, at harvest it did not influenced. Application of ZnSO\(_4\) fertilizer treatment showed the higher values of DTPA-Cu in soil as compared to application of ZnO fertilizer, it may be due to limited solubility of ZnO fertilizer in soil.

### Nutrient uptake by groundnut

The effect of application of zinc fertilizer and zinc solubilizing bacteria on total nutrient uptake of N, P and K as influenced by different treatments are presented in table 4.

The data in respect of total nitrogen uptake by groundnut was found significant results. However, treatment T\(_4\) showed higher uptake of total N (132.29 kg ha\(^{-1}\)) over all the treatment. Higher uptake of nitrogen was due to application of ZnSO\(_4\) and use of ZnSB as a seed treatment and drenching treatment. Potarzycki and Grzebisz (2009) also reported similar result that zinc exerts a great influence on basic plant life processes such as nitrogen metabolism and uptake of nitrogen.

The highest total P uptake by groundnut plant was significantly found to be observed in treatment of T\(_4\) (15.60 kg ha\(^{-1}\)) over all the treatment except total uptake of P in treatment T\(_3\) which was at par with T\(_4\). This is because of soil application of ZnSO\(_4\) @ 20 kg ha\(^{-1}\) with ZnSB increased the availability of P in soil. These finding are in consonance with Manna et al., (2007) who reported that the activity of alkaline phosphates was significantly increased with increase in FYM levels and PSM inoculation resulting more
The solubilization of P and uptake by soybean plant. The total K uptake by groundnut was significantly higher in T4 treatment (65.63 kg ha\(^{-1}\)) over all the treatment. The increase in total N and K uptake could be attributed to synergistic effect between N and Zn and due to the positive interaction of K and Zn, respectively. The present findings support the results of Ashoka et al., (2008), Morshedi and Farahbakhsh (2010).

**Total micronutrients**

The total uptake of Fe, Zn, Mn and Cu by groundnut as influenced by different treatment are presented in table 5.

| Tr. No | Treatment                                                                 | pH (1:2.5) | EC (dSm\(^{-1}\)) | Organic carbon (%) | CaCO\(_3\) (%) |
|--------|---------------------------------------------------------------------------|------------|--------------------|--------------------|----------------|
| T1     | Absolute control                                                          | 8.17       | 0.26               | 0.40               | 5.40           |
| T2     | ZnSB alone                                                                | 8.14       | 0.24               | 0.41               | 5.41           |
| T3     | 100% GRDF (25:50 kg ha\(^{-1}\) N:P\(_2\)O\(_5\)FYM+ @ 5 t ha\(^{-1}\)) | 8.06       | 0.27               | 0.49               | 5.54           |
| T4     | T3 + 100 % RD of Zn through Zinc sulphate ZnSB                             | 8.02       | 0.30               | 0.50               | 5.33           |
| T5     | T3 + 75 % RD of Zn through Zinc sulphate + ZnSB                           | 8.04       | 0.28               | 0.48               | 5.17           |
| T6     | T3 + 50 % RD of Zn through Zinc sulphate + ZnSB                           | 8.04       | 0.27               | 0.46               | 5.21           |
| T7     | T3 + 25 % RD of Zn through Zinc sulphate + ZnSB                           | 8.08       | 0.25               | 0.44               | 5.08           |
| T8     | T3 + 100 % RD of Zn through Zinc oxide + ZnSB                            | 8.16       | 0.26               | 0.46               | 5.71           |
| T9     | T3 + 75 % RD of Zn through Zinc oxide + ZnSB                              | 8.16       | 0.27               | 0.44               | 5.75           |
| T10    | T3 + 50 % RD of Zn through Zinc oxide + ZnSB                              | 8.14       | 0.28               | 0.48               | 5.87           |
| T11    | T3 + 25 % RD of Zn through Zinc oxide + ZnSB                              | 8.16       | 0.27               | 0.49               | 5.08           |
| S.E.m+ |                                                            | 0.016      | 0.011              | 0.013              | 0.023          |
| CD at 5%|                                                            | NS         | NS                 | NS                 | NS             |

**Table.2 Effect of zinc fertilizer and zinc solubilizing bacteria on residual soil available nitrogen, phosphorus and potassium**

| Tr. No | Treatment                                                                 | Av. N (kg ha\(^{-1}\)) | Av. P (kg ha\(^{-1}\)) | Av. K (kg ha\(^{-1}\)) |
|--------|---------------------------------------------------------------------------|-------------------------|-------------------------|-------------------------|
| T1     | Absolute control                                                          | 178                     | 9.12                    | 171                     |
| T2     | ZnSB alone                                                                | 170                     | 8.95                    | 182                     |
| T3     | 100% GRDF (25:50 kg ha\(^{-1}\) N:P\(_2\)O\(_5\)FYM+ @ 5 t ha\(^{-1}\)) | 186                     | 9.78                    | 190                     |
| T4     | T3 + 100 % RD of Zn through Zinc sulphate ZnSB                             | 198                     | 11.02                   | 198                     |
| T5     | T3 + 75 % RD of Zn through Zinc sulphate + ZnSB                           | 184                     | 9.51                    | 184                     |
| T6     | T3 + 50 % RD of Zn through Zinc sulphate + ZnSB                           | 180                     | 9.24                    | 186                     |
| T7     | T3 + 25 % RD of Zn through Zinc sulphate + ZnSB                           | 174                     | 8.96                    | 180                     |
| T8     | T3 + 75 % RD of Zn through Zinc sulphate + ZnSB                           | 180                     | 8.92                    | 180                     |
| T9     | T3 + 50 % RD of Zn through Zinc sulphate + ZnSB                           | 190                     | 8.24                    | 178                     |
| T10    | T3 + 25 % RD of Zn through Zinc sulphate + ZnSB                           | 180                     | 8.98                    | 174                     |
| T11    | T3 + 25 % RD of Zn through Zinc sulphate + ZnSB                           | 180                     | 8.98                    | 174                     |
| S.E.m+ |                                                            | 2.32                    | 0.047                   | 3.724                   |
| CD at 5%|                                                            | 6.92                    | 0.14                    | 10.98                   |
Table 3: Effect of zinc fertilizer and zinc solubilizing bacteria on available micronutrient content in soil (mg kg⁻¹)

| Tr. No | Treatment                                                                 | DTPA-Fe | DTPA-Zn | DTPA-Mn | DTPA-Cu |
|--------|---------------------------------------------------------------------------|---------|---------|---------|---------|
| T₁     | Absolute control                                                          | 3.82    | 0.40    | 5.16    | 1.21    |
| T₂     | ZnSB alone                                                                | 3.88    | 0.46    | 5.20    | 1.30    |
| T₃     | 100% GRDF (25:50 kg ha⁻¹ N:P₂O₅:FYM @ 5 t ha⁻¹)                            | 3.80    | 0.52    | 5.89    | 1.26    |
| T₄     | T₃ + 100 % RD of Zn through Zinc sulphate ZnSB                              | 3.91    | 0.58    | 5.17    | 1.44    |
| T₅     | T₃ + 75 % RD of Zn through Zinc sulphate + ZnSB                            | 3.86    | 0.54    | 5.81    | 1.39    |
| T₆     | T₃ + 50 % RD of Zn through Zinc sulphate + ZnSB                            | 3.88    | 0.51    | 5.58    | 1.38    |
| T₇     | T₃ + 25 % RD of Zn through Zinc sulphate + ZnSB                            | 3.74    | 0.48    | 5.73    | 1.38    |
| T₈     | T₃ + 100 % RD of Zn through Zinc oxide + ZnSB                              | 3.90    | 0.50    | 5.12    | 1.41    |
| T₉     | T₃ + 75 % RD of Zn through Zinc oxide + ZnSB                               | 3.87    | 0.48    | 5.05    | 1.32    |
| T₁₀    | T₃ + 50 % RD of Zn through Zinc oxide + ZnSB                               | 3.80    | 0.46    | 5.75    | 1.28    |
| T₁₁    | T₃ + 25 % RD of Zn through Zinc oxide + ZnSB                               | 3.81    | 0.49    | 5.60    | 1.30    |
| S.E.m+ |                                                                         | 0.02    | 0.01    | 0.38    | 0.046   |
| CD at 5%|                                                                         | 0.06    | 0.03    | NS      | NS      |

Table 4: Effect of zinc fertilizer and zinc solubilizing bacteria on Total nutrient uptake (kg ha⁻¹)

| Tr. No | Treatment                                                                 | Total uptake of macronutrient (kg ha⁻¹) |
|--------|---------------------------------------------------------------------------|----------------------------------------|
|        |                                                                          | N          | P          | K          |
| T₁     | Absolute control                                                          | 72.80      | 9.81       | 44.40      |
| T₂     | ZnSB alone                                                                | 93.40      | 11.66      | 47.51      |
| T₃     | 100% GRDF (25:50kg ha⁻¹ N:P₂O₅:FYM @ 5 t ha⁻¹)                             | 114.62     | 15.19      | 62.18      |
| T₄     | T₃ + 100 % RD of Zn through Zinc sulphate ZnSB                             | 132.29     | 15.60      | 65.63      |
| T₅     | T₃ + 75 % RD of Zn through Zinc sulphate + ZnSB                            | 119.27     | 14.26      | 54.51      |
| T₆     | T₃ + 50 % RD of Zn through Zinc sulphate + ZnSB                            | 91.12      | 13.73      | 50.71      |
| T₇     | T₃ + 25 % RD of Zn through Zinc sulphate + ZnSB                            | 94.77      | 12.41      | 49.97      |
| T₈     | T₃ + 100 % RD of Zn through Zinc oxide + ZnSB                              | 105.64     | 14.50      | 50.77      |
| T₉     | T₃ + 75 % RD of Zn through Zinc oxide + ZnSB                               | 105.59     | 13.38      | 51.50      |
| T₁₀    | T₃ + 50 % RD of Zn through Zinc oxide + ZnSB                               | 100.03     | 11.97      | 50.71      |
| T₁₁    | T₃ + 25 % RD of Zn through Zinc oxide + ZnSB                               | 84.60      | 11.33      | 49.17      |
| S.E.m+ |                                                                         | 19.90      | 1.405      | 0.419      |
| CD at 5%|                                                                         | 59.11      | 4.175      | 1.245      |
Table 5 Effect of zinc fertilizer and zinc solubilizing bacteria on Total micronutrient uptake (g ha\(^{-1}\))

| Tr. No | Treatment                                                                 | Total uptake of micronutrient (g ha\(^{-1}\)) |
|-------|---------------------------------------------------------------------------|----------------------------------------------|
|       |                                                                           | Fe   | Zn   | Mn   | Cu   |
| T₁    | Absolute control                                                          | 897  | 207  | 401  | 36   |
| T₂    | ZnSB alone                                                                | 972  | 235  | 431  | 43   |
| T₃    | 100% GRDF (25:50 kg ha\(^{-1}\) N:P₂O₅ + FYM @ 5 t ha\(^{-1}\))         | 1344 | 307  | 598  | 53   |
| T₄    | T₃ + 100 % RD of Zn through Zinc sulphate + ZnSB                          | 1352 | 377  | 619  | 67   |
| T₅    | T₃ + 75 % RD of Zn through Zinc sulphate + ZnSB                           | 1213 | 336  | 504  | 61   |
| T₆    | T₃ + 50 % RD of Zn through Zinc sulphate + ZnSB                           | 1107 | 292  | 485  | 48   |
| T₇    | T₃ + 25 % RD of Zn through Zinc sulphate + ZnSB                           | 1051 | 265  | 457  | 47   |
| T₈    | T₃ + 100 % RD of Zn through Zinc oxide + ZnSB                             | 1130 | 311  | 498  | 54   |
| T₉    | T₃ + 75 % RD of Zn through Zinc oxide + ZnSB                              | 1069 | 286  | 455  | 45   |
| T₁₀   | T₃ + 50 % RD of Zn through Zinc oxide + ZnSB                              | 1060 | 276  | 451  | 49   |
| T₁₁   | T₃ + 25 % RD of Zn through Zinc oxide + ZnSB                              | 1007 | 260  | 441  | 43   |
| S.E.m⁺|                                                                           | 19.90| 4.13 | 8.58 | 0.74 |
| CD at 5%|                                                                          | 59.11| 12.26| 25.47| 2.19 |

Table 6 Effect of application of zinc fertilizer and zinc solubilizing bacteria on pod and haulm Yield

| Tr. No | Treatment                                                                 | Pod yield (q ha\(^{-1}\)) | Haulm yield (q ha\(^{-1}\)) | Per cent increased pod yield over T₃ |
|--------|---------------------------------------------------------------------------|---------------------------|-----------------------------|-------------------------------------|
| T₁     | Absolute control                                                          | 20.82                     | 42.50                       | -                                   |
| T₂     | ZnSB alone                                                                | 21.77                     | 44.20                       | -                                   |
| T₃     | 100% GRDF (25:50 kg ha\(^{-1}\) N:P₂O₅ + FYM @ 5 t ha\(^{-1}\))           | 26.56                     | 62.70                       | -                                   |
| T₄     | T₃ + 100 % RD of Zn through Zinc sulphate + ZnSB                           | 30.63                     | 58.90                       | 15.32                               |
| T₅     | T₃ + 75 % RD of Zn through Zinc sulphate + ZnSB                            | 29.44                     | 53.72                       | 10.84                               |
| T₆     | T₃ + 50 % RD of Zn through Zinc sulphate + ZnSB                            | 27.41                     | 48.60                       | 3.20                                |
| T₇     | T₃ + 25 % RD of Zn through Zinc sulphate + ZnSB                            | 26.65                     | 45.90                       | 0.33                                |
| T₈     | T₃ + 100 % RD of Zn through Zinc oxide + ZnSB                              | 27.22                     | 50.42                       | 2.48                                |
| T₉     | T₃ + 75 % RD of Zn through Zinc oxide + ZnSB                              | 27.06                     | 47.34                       | 1.88                                |
| T₁₀    | T₃ + 50 % RD of Zn through Zinc oxide + ZnSB                              | 26.90                     | 46.91                       | 1.28                                |
| T₁₁    | T₃ + 25 % RD of Zn through Zinc oxide + ZnSB                              | 26.41                     | 44.98                       | 1.43                                |
| S.E.m⁺ |                                                                           | 0.478                     | 1.027                       |                                     |
| CD at 5%|                                                                          | 1.42                      | 3.05                        |                                     |

The total uptake of Fe was found to be significantly higher in T₄ treatment (1352 g ha\(^{-1}\)) over all the treatment except T₃ (1344 g ha\(^{-1}\)) which was at par with T₄. Total uptake of Zn significantly higher in treatment of T₄ (377 g ha\(^{-1}\)) over all the treatment. Amalraj et
al., (2012) also reported increase in zinc uptake by soybean due to seed inoculation of PSB and solubilizers. The total uptake of Mn was significantly increased in T₄ treatment (619 g ha⁻¹) over all the treatment except treatment T₃ (598 g ha⁻¹) which was at par with T₄ in respect of Mn uptake. This might be due to exudation of phytase which is important for Mn uptake from high pH soils. Similar results were also observed by George et al., (2014). The total uptake of Cu was observed significantly higher in T₄ (67 g ha⁻¹) over all the treatment. The zinc sulphate treatment was higher than the other treatment. Gururmurthy et al., (2009) reported increase in uptake in grain and straw with N, P and K application of PSB to soybean.

**Pod and haulm yield**

Pod and haulm yield of groundnut as influenced by different treatments are presented in table 6. The pod yield of groundnut was found to be significantly increased (30.63 q ha⁻¹) in treatment of T₄ over all the treatment except treatment T₅ (29.44 q ha⁻¹) which was at par. Overall, the per cent increase in treatments of application of ZnSO₄ + ZnSB were found higher in pod and haulm yield of groundnut as compare to treatments of application of ZnO + ZnSB. Application of zinc in soil resulted in increased in yield of groundnut was in the range of 15.32 to 0.33 % in treatments of soil application of ZnSO₄ over GRDF (T₃).

The haulm yield of groundnut was found to be significantly increased (62.70 q ha⁻¹) in treatment of GRDF T₃ over all the treatments under study. However, the treatments of application of ZnSO₄ + ZnSB were increased in pod and haulm yield of groundnut as compare to treatments of application of ZnO + ZnSB. Application of zinc in soil resulted in increased in yield of groundnut was reported by Talukdar and Islam (1982).

From the above findings, It is concluded that, the application of 100 % recommended dose of Zn through Zinc sulphate @ 20 kg ha⁻¹ + 5% ZnSB to seed treatment at sowing and through drenching at 30 DAS along with 100 % (25:50:0 kg ha⁻¹ N:P₂O₅:K₂O + FYM @ 5t ha⁻¹) to *summer* groundnut was found beneficial for increased in available macro and micronutrients status of soil, total uptake of macro and micronutrient and pod yield of groundnut in Entisol.

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