Madras Agric. J., 102 (7-9): 239-243, September 2015
https://doi.org/10.29321/MAJ.10.001108

# Yield and Nutrient Uptake by Soybean as Influenced by Phosphorus and Sulphur Nutrition in Typic Haplustept

**Indraraj Meena, R.H. Meena*, S.K. Sharma and D.P. Singh**
Department of Agricultural Chemistry and Soil Science, Rajasthan College of Agriculture,
Maharana Pratap University of Agriculture & Technology, Udaipur, 313 001

**Field experiment was conducted on Typic Haplustept at Instructional Farm of Rajasthan College of Agriculture, Udaipur during *kharif* 2012 to assess the effect of phosphorus and sulphur fertilization on yield and nutrient uptake by soybean [*Glycine max* (L.) Merrill]. The experiment was laid out in factorial randomized block design with three replication and consisted four levels of phosphorus (0, 20, 40 and 60 kg $P_2O_5$ $ha^{-1}$) and four levels of sulphur (0, 15, 30 and 45 kg S $ha^{-1}$). The results revealed that increasing the levels of phosphorus and sulphur significantly increased the grain and haulm yield over the control. The uptake of N, P, K, S, Fe, Mn, Cu and Zn were significantly higher by grain and haulm over the control. The results of the experiment indicated that application of 60 kg $P_2O_5$ $ha^{-1}$ and 30 kg S $ha^{-1}$ had recorded significant uptake of N, P, K, S, Fe, Mn, Cu and Zn by grain and haulm of soybean, which also influenced the yield.**

**Key words:** Phosphorus, Sulphur, Soybean, Nutrient uptake, Yield.

Soybean [*Glycine max* (L.) Merrill] is a miracle crop of the world due to excellent nutritional quality, as it stands surrogate for nutritional security for large section of vegetarian people. It is a leguminous crop rich in high quality protein (40-42%) and oil (18-20%). In addition, it also contains good amount of minerals, salts and vitamins (thiamine and riboflavin). India ranks fifth in the world in area and production, but the productivity is very low (less than 1000 kg $ha^{-1}$). The predominant soybean growing states in India are Madhya Pradesh (74%), Rajasthan (9%) and Maharashtra (5%). Rajasthan stands second in area and production of soybean covering an area of 0.83 million ha with the production and productivity of 0.81 million tonnes and 1,412 kg $ha^{-1}$, respectively (GOI Report, 2010-11). It is quite low as compared to the productivity in USA, Brazil, Argentina and China. There is a great possibility to increase soybean production by adequate supply of nutrients especially, phosphorus and sulphur.

Soybean, being a highly nutrient exhaustive oil seed legume, it requires higher amount of nutrients particularly, P and S for higher productivity (Hasan, 1994). Phosphorus is a key element involved in various functions in the growth and metabolism of soybean. It is frequently a major limiting nutrient for plant growth in most of the Indian soils. Phosphorus is also an important constituent of major biological products in plants itself and plays a key role in the balance nutrition of the crops. Sulphur plays an outstanding role in the synthesis of sulphur containing essential amino acids like cystine, cystenine and methionine; vitamins; co-enzyme-A and metabolism of carbohydrates, protein, fats, chlorophyll formation. It also takes part in N-metabolism and promotes nodulation for $N_2$-fixation in legumes. Sulphur gives rise to bold seeds in oil seed crops. Soybean is a sulphur loving plant, like any other oilseed crop. The low productivity of soybean may be ascribed to many reasons but, inadequate and imbalanced fertilization plays an important role. Therefore, the present study was undertaken to evaluate the effect of phosphorus and sulphur on the production potential and nutrient uptake by soybean.

*Corresponding author email : ramharim@gmail.com

## Materials and Methods

A field experiment was conducted during *kharif* 2012 at the Instructional Farm of Rajasthan College of Agriculture, Udaipur. The experimental soil was sandy clay loam in texture, slightly alkaline (pH 7.9), organic carbon (0.67 %), medium with respect to available nitrogen, phosphorus and high in potassium (281.30, 15.75 and 341.50 kg $ha^{-1}$, respectively). The sulphur content in the soil was 8.90 mg $kg^{-1}$. Available Fe, Mn, Cu and Zn content were 4.21, 5.43, 2.89 and 2.67 mg $kg^{-1}$, respectively. The treatments consisted of four levels of phosphorus (0, 20, 40 and 60 kg $P_2O_5$ $ha^{-1}$) in integration with four levels of sulphur (0, 15, 30 and 45 kg S $ha^{-1}$) tested in a factorial randomized block design and replicated thrice. A promising variety of soybean, RKS-24 was sown manually in furrows maintaining optimum plant spacing of 30 x10 cm. Phosphorus and sulphur were applied through di ammonium phosphate and gypsum, respectively. All the recommended cultural operations other than the treatments were practiced to raise the crop. For determination of uptake of N, P, K, Fe, Mn, Cu and Zn by soybean, soil and plant samples in different treatments were collected and subjected to analysis. Grain and haulm yield were recorded after manual threshing and expressed as kg $ha^{-1}$.

## Results and Discussion

### *Yield of soybean*

Effect of phosphorus and sulphur application on grain and haulm yield of soybean was significantly influenced by different levels of phosphorus and sulphur (Table 1). The highest grain yield (1901.44 kg $ha^{-1}$) and haulm yield (3407.34 kg $ha^{-1}$) were recorded for plots having treatment, 60 kg $P_2O_5$ $ha^{-1}$ followed by the application of 40 and 20 kg $P_2O_5$ $ha^{-1}$. Whereas, the highest grain yield (1868.64 kg $ha^{-1}$) and haulm yield (3370.64 kg $ha^{-1}$) were recorded under treatment 45 kg S $ha^{-1}$ but, in case of grain yield; it was at par with the application of 30 kg S $ha^{-1}$. Application of phosphorus (20, 40 and 60 kg $ha^{-1}$) and sulphur (15, 30 and 45 kg $ha^{-1}$) resulted in 13.0, 23.8, 34.0% and 10.4, 21.3, and 28.8% increase in grain yield over the control, respectively. Increase in haulm yield was 12.0, 22.4, 32.0 and 10.5, 21.5, 29.1% over the control, respectively under application of phosphorus (20, 40 and 60 kg $ha^{-1}$) and sulphur (15, 30 and 45 kg $ha^{-1}$). With increased supply of sulphur, the process of tissue differentiation from somatic to reproductive, meristematic activity and development might have increased, resulting in an increase in the number and size of leaves (Mengel and Kirkby, 1987).

**Table 1. Effect of phosphorus and sulphur on grain yield and nutrient uptake by grain of soybean**

| Treatments | Grain yield (kg $ha^{-1}$) | Macro-nutrient uptake(kg $ha^{-1}$) | | | | Micro-nutrient uptake(g $ha^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| P- Levels | | N | P | K | S | Fe | Mn | Cu | Zn |
| $P_0$ | 1418.32 | 85.31 | 8.04 | 15.80 | 2.57 | 44.01 | 58.54 | 20.06 | 78.16 |
| $P_{20}$ | 1603.74 | 98.85 | 9.38 | 18.48 | 3.22 | 49.95 | 69.78 | 22.19 | 86.86 |
| $P_{40}$ | 1756.58 | 109.40 | 10.45 | 20.35 | 3.61 | 54.94 | 80.15 | 24.14 | 91.62 |
| $P_{60}$ | 1901.44 | 120.12 | 11.42 | 22.06 | 3.99 | 59.80 | 87.07 | 25.87 | 96.76 |
| SEm± | 38.269 | 2.397 | 0.215 | 0.463 | 0.080 | 1.153 | 2.049 | 0.624 | 2.087 |
| CD at 5 % | 110.528 | 6.923 | 0.621 | 1.339 | 0.231 | 3.329 | 5.918 | 1.801 | 6.027 |
| S - Levels | | | | | | | | | |
| $S_0$ | 1450.12 | 86.70 | 8.26 | 16.24 | 2.68 | 44.95 | 57.16 | 19.59 | 71.08 |
| $S_{15}$ | 1602.08 | 99.18 | 9.40 | 18.44 | 3.07 | 49.62 | 68.48 | 21.78 | 82.90 |
| $S_{30}$ | 1759.22 | 109.40 | 10.38 | 20.31 | 3.67 | 54.77 | 81.06 | 24.27 | 94.27 |
| $S_{45}$ | 1868.64 | 118.39 | 11.25 | 21.70 | 3.97 | 59.35 | 88.84 | 26.61 | 105.15 |
| SEm± | 38.269 | 2.397 | 0.215 | 0.463 | 0.080 | 1.153 | 2.049 | 0.624 | 2.087 |
| CD at 5 % | 110.528 | 6.923 | 0.621 | 1.339 | 0.231 | 3.329 | 5.918 | 1.801 | 6.027 |

**Table 2. Effect of phosphorus and sulphur on haulm yield and nutrient uptake by haulm of bean**

| Treatments | Haulm yield (kg $ha^{-1}$) | Macro-nutrient uptake(kg $ha^{-1}$) | | | | Micro-nutrient uptake(g $ha^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| P- Levels | | N | P | K | S | Fe | Mn | Cu | Zn |
| $P_0$ | 2580.47 | 23.19 | 5.10 | 39.65 | 1.95 | 148.96 | 161.54 | 13.99 | 109.35 |
| $P_{20}$ | 2890.39 | 26.66 | 5.87 | 44.91 | 2.39 | 167.87 | 190.28 | 15.34 | 109.05 |
| $P_{40}$ | 3159.24 | 29.43 | 6.47 | 49.63 | 2.64 | 184.04 | 218.66 | 16.42 | 117.42 |
| $P_{60}$ | 3407.34 | 32.27 | 7.07 | 54.09 | 2.91 | 199.61 | 244.58 | 17.69 | 122.83 |
| SEm± | 69.755 | 0.912 | 0.157 | 1.364 | 0.069 | 3.931 | 5.458 | 0.510 | 3.059 |
| CD at 5 % | 201.467 | 2.634 | 0.455 | 3.940 | 0.198 | 11.352 | 15.763 | 1.473 | 8.835 |
| S - Levels | | | | | | | | | |
| $S_0$ | 2609.45 | 23.32 | 5.00 | 39.78 | 2.00 | 150.54 | 157.76 | 13.56 | 85.95 |
| $S_{15}$ | 2885.80 | 25.88 | 5.82 | 44.08 | 2.28 | 166.65 | 188.59 | 14.89 | 104.94 |
| $S_{30}$ | 3171.56 | 30.12 | 6.54 | 50.43 | 2.71 | 184.54 | 223.56 | 16.77 | 123.50 |
| $S_{45}$ | 3370.64 | 32.23 | 7.16 | 53.99 | 2.90 | 198.76 | 245.16 | 18.24 | 144.26 |
| SEm± | 69.755 | 0.912 | 0.157 | 1.364 | 0.069 | 3.931 | 5.458 | 0.510 | 3.059 |
| CD at 5 % | 201.467 | 2.634 | 0.455 | 3.940 | 0.198 | 11.352 | 15.763 | 1.473 | 8.835 |

The interaction effect of phosphorus and sulphur also influenced the grain and haulm yield of soybean. The combined application of P and S, further enhanced grain and haulm yield of soybean (Table 3). The maximum grain and haulm yield (2141.70 kg $ha^{-1}$) and (3847.76 kg $ha^{-1}$) were

**Table 3. Interaction effect of phosphorus and sulphur on grain and haulm yield of soybean**

| P- levels (kg $ha^{-1}$) | S-levels (kg $ha^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Grain yield (kg $ha^{-1}$) | | | | Haulm yield (kg $ha^{-1}$) | | | |
| | 0 | 15 | 30 | 45 | 0 | 15 | 30 | 45 |
| **0** | 1250.01 | 1439.96 | 1281.79 | 1701.50 | 2273.2 | 2618.64 | 2331.0 | 3099.05 |
| **20** | 1402.72 | 1486.93 | 1729.46 | 1795.83 | 2523.64 | 2676.77 | 3117.82 | 3243.30 |
| **40** | 1447.12 | 1732.67 | 1883.93 | 1962.59 | 2595.27 | 3114.56 | 3389.65 | 3537.47 |
| **60** | 1700.63 | 1748.77 | 2141.70 | 2014.66 | 3045.66 | 3133.20 | 3847.76 | 3602.71 |
| SEm± | 76.54 | | | | | 139.51 | | |
| CD at 5% | 221.06 | | | | | 402.93 | | |

recorded at the highest level of phosphorus (60 kg $ha^{-1}$) along with sulphur 30 kg $ha^{-1}$, which was found to be statistically at par with highest level of phosphorus and sulphur (60 kg $P_2O_5$ $ha^{-1}$ + 45 kg S $ha^{-1}$). Whereas, the lowest grain and haulm yield of soybean (1520.01 kg $ha^{-1}$) and (2273 kg $ha^{-1}$) were recorded when phosphorus and sulphur ($P_0S_0$) were not applied. The magnitude of increase in grain and haulm yield was 71.3 and 69.2% due to the combined application of 60 kg $P_2O_5$ $ha^{-1}$ and 30 kg S $ha^{-1}$ over control, respectively.

The synergistic effect of P and S may be due to the utilization of higher quantities of nutrients through their well developed root system and nodules, which might have resulted in better growth

**Table 4. Interaction effect of P and S on total uptake of phosphorus, sulphur and micro-nutrients by soybean**

| Treatment | P uptake (kg $ha^{-1}$) | S uptake (kg $ha^{-1}$) | Fe uptake (g $ha^{-1}$) | Mn uptake (g $ha^{-1}$) | Cu uptake (g $ha^{-1}$) | Zn uptake (g $ha^{-1}$) |
|---|---|---|---|---|---|---|
| $T_1=P_0S_0$ | 11.34 | 3.80 | 172.60 | 178.56 | 26.57 | 143.37 |
| $T_2=P_1S_0$ | 13.13 | 4.44 | 189.29 | 197.93 | 32.79 | 153.66 |
| $T_3=P_2S_0$ | 13.25 | 4.69 | 194.09 | 218.55 | 33.19 | 154.41 |
| $T_4=P_3S_0$ | 15.32 | 5.80 | 223.68 | 264.64 | 40.06 | 176.69 |
| $T_5=P_0S_1$ | 13.41 | 4.42 | 195.98 | 218.20 | 34.34 | 183.42 |
| $T_6=P_1S_1$ | 14.34 | 4.97 | 200.82 | 232.14 | 35.04 | 176.33 |
| $T7=P_2S_1$ | 16.48 | 5.89 | 233.43 | 285.83 | 37.91 | 196.47 |
| $T_8=P_3S_1$ | 16.62 | 6.14 | 234.97 | 292.11 | 39.40 | 195.14 |
| $T_9=P_0S_2$ | 11.88 | 4.24 | 176.42 | 207.28 | 32.86 | 173.41 |
| $T_{10}=P_1S_2$ | 16.65 | 6.37 | 235.43 | 293.80 | 40.27 | 216.04 |
| $T_{11}=P_2S_2$ | 17.97 | 7.02 | 256.08 | 327.97 | 43.55 | 229.82 |
| $T_{12}=P_3S_2$ | 21.16 | 7.90 | 290.25 | 389.43 | 47.49 | 251.78 |
| $T_{13}=P_0S_3$ | 15.93 | 5.63 | 238.89 | 276.28 | 42.44 | 249.87 |
| $T_{14}=P_1S_3$ | 16.88 | 6.63 | 248.65 | 316.40 | 42.03 | 237.58 |
| $T_{15}=P_2S_3$ | 19.98 | 7.43 | 270.65 | 362.90 | 47.60 | 255.45 |
| $T_{16}=P_3S_3$ | 20.86 | 7.76 | 273.19 | 380.42 | 47.31 | 254.75 |
| SEm± | 0.72 | 0.28 | 10.86 | 13.52 | 2.16 | 10.17 |
| CD at 5% | 2.08 | 0.81 | 31.37 | 39.06 | 6.26 | 29.38 |

and yield at 60 kg $P_2O_5$ $ha^{1}$ and 30 kg S $ha^{1}$. The present studies are in accordance with the finding of Tomar *et al.* (2004) and Majumdar *et al.* (2001), who reported greater increase in grain and haulm yield of soybean with combined application of phosphorus and sulphur. Similar results were reported by Nasreen and Farid (2006), Ijgude and Kadam (2008), Saxena and Nainwal (2010) in soybean and Nawange *et al.* (2011) in chickpea.

***Macro-nutrient uptake***

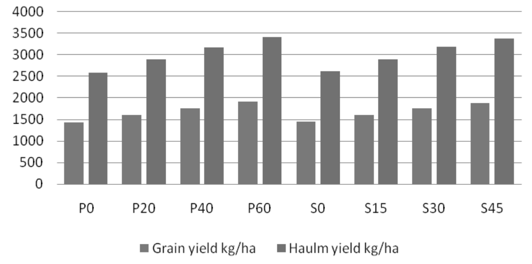
It is evident from the data on Table 1 and 2 that the nutrient uptake by soybean grain and haulm increased significantly due to application of phosphorus and sulphur. The maximum uptake of macro and micro nutrients were recorded with the application of 60 kg P $ha^{-1}$ and 30 kg S $ha^{-1}$. Application of phosphorus and sulphur either alone or in combination significantly increased N, P, K, and S uptake by soybean grain and haulm over the control; while, the lowest N, P, K, and S uptake were observed under the control plot. Phosphorus applied at the rate of 60 kg $P_2O_5$ $ha^{1}$ resulted in significant uptake of N by 40.6 and 39.5% over the control by soybean grain and haulm, respectively; whereas, 36.5 and 38.2% increase in N uptake was observed in grain and haulm due to application of 45 kg S $ha^{-1}$, respectively.

Significantly increased trend of P uptake in grain and haulm was recorded with increased levels of phosphorus upto 60 kg $P_2O_5$ $ha^{-1}$, resulting in 42.0

and 38.6% increased P uptake over control, respectively. Minimum P uptake in grain as well as haulm was noticed in control. Results indicated that application of sulphur significantly increased P uptake in grain and haulm with successive levels of sulphur upto 45 kg S ha$^{-1}$ (Table 1), resulting in 36.1 and 43.2% increased P uptake over the control, respectively.

Application of 2, 40 and 60 kg $P_2O_5$ ha$^{-1}$ showed a significant increase of 16.9, 28.7 and 39.6% potassium uptake in grain and 13.2, 25.1 and 36.4% in haulm over the control, respectively. Sulphur application (15, 30 and 45 kg ha$^{-1}$) resulted in increase of K uptake by 13.5, 25.0 and 33.6% in grain and 10.8, 26.7 and 35.7% in haulm over the control, respectively.

**Figure 1: Effect of phosphorus and sulphur on grain and haulm yield of soybean**

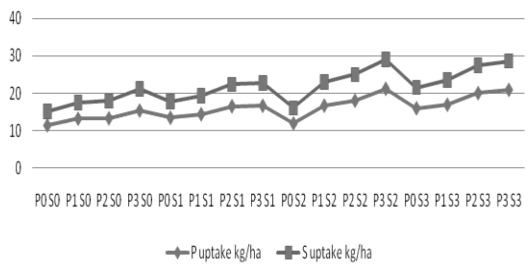



Uptake of sulphur by grain and haulm showed a significant variation with the application of different levels of phosphorus and sulphur (Table 1). Sulphur uptake significantly increased with application of 60 kg $P_2O_5$ ha$^{-1}$ in grain and haulm by 55.2 and 49.2% over the control, respectively. Increasing sulphur levels upto 45 kg S ha$^{-1}$ resulted an increase in S uptake in grain and haulm by 48.1 and 45.0% over the control. The highest S uptake was found, when sulphur was applied @ 45 kg ha$^{-1}$ and the lowest from no sulphur application. The above results revealed that the increase in S dose, increase the uptake of sulphur due to high S content, which and resulted in higher grain yield. Among S and P interactions, the highest total P (21.16 kg ha$^{-1}$) and S uptake (7.90 kg ha$^{-1}$) were recorded in $P_3S_2$ (60 kg $P_2O_5$ ha$^{-1}$ + 30 kg S ha$^{-1}$), which was statistically at par with $P_3S_3$ (60 kg $P_2O_5$ ha$^{-1}$ + 45 kg S ha$^{-1}$). On the other hand, the minimum total uptake of P (11.34 kg ha$^{-1}$) and S (3.80 kg ha$^{-1}$) were recorded in $P_0S_0$. These results are in agreement with those of Ganeshamurthy (1996), who reported that application of sulphur significantly increased the S uptake. Similar result was reported by Chand *et al*. (1997) in mustard. Nimje (2003) also reported an increase in the nutrient uptake with the increase in fertility levels.

***Micro-nutrient uptake***

Phosphorus (20, 40 and 60 kg ha$^{-1}$) and sulphur (15, 30 and 45 kg ha$^{-1}$) application resulted in 13.4, 24.8 and 35.8%; 10.3, 21.8 and 32.0% Fe uptake by grain over control, respectively. Maximum Fe uptake was recorded with application of 60 kg $P_2O_5$ ha$^{-1}$ and 30 kg S ha$^{-1}$ followed by 40 kg $P_2O_5$ ha$^{-1}$ and 45 kg S ha$^{-1}$. The P and S interaction was also significant with the highest total Fe uptake (290.25 g ha$^{-1}$) observed in $P_4S_3$ (60 kg $P_2O_5$ & 30 kg S ha$^{-1}$), which was statistically at par with $P_4S_4$ (60 kg $P_2O_5$ and 45 kg S ha$^{-1}$). Minimum Fe uptake (172.60 g ha$^{-1}$) was recorded in $P_0S_0$. Due to acidifying effect of S oxidation, the availability and uptake of Fe increased (Hilal *et al.* 1990). Sulphur application resulted in increased Fe uptake, as reported by Malewar and Ismail (1997). They observed that application of 80 mg S/kg increased Fe availability by 49%. They concluded that there existed a close relationship between Fe and S metabolism in plants. Similar results were also reported by Togay *et al.* (2008) and Islam *et al.* (2009) in chickpea.

**Figure 2: Interaction effect of P and S on total uptake of phosphorus and sulphur and by soybean**




Application of phosphorus (20, 40 and 60 kg ha$^{-1}$) had significant effect on Mn uptake in grain by 19.2, 36.9 and 48.7% increase over control. Sulphur (15, 30 and 45 kg S ha$^{-1}$) application resulted in 19.8, 41.8 and 55.4% increase in Mn uptake by grain (Table 2). Maximum uptake was recorded with application of 60 kg ha$^{-1}$ and 45 kg S ha$^{-1}$. Almost similar trend was observed regarding Mn uptake by haulm (Table 2). Havlen *et al.* (2007) reported that availability of Mn increased due to application of acid ($NH_4$+) forming fertilizers. Modaihsh *et al.* (1989) and Hilal *et al.* (1990) reported that S application increased Mn availability in soil. Possibility of increase in Mn uptake by soybean might be due to increased root growth and high availability of Mn in soil. Similar results regarding Mn uptake influenced by P and S was also reported by Togay *et al.* (2008) and Islam *et al.* (2009) in chickpea.

Phosphorus (20, 40 and 60 kg ha$^{-1}$) and sulphur (15, 30 and 45 kg ha$^{-1}$) application resulted in increased Cu uptake by grain over control. Application of higher level of phosphorus (60 kg ha$^{-1}$) had significant effect in Cu uptake by haulm over control; but, it showed non significant effect over its lower dose (20 and 40 kg ha$^{-1}$); while, Cu uptake significantly increased with increase in the level of sulphur application upto 45 kg S ha$^{-1}$. Modaihsh *et* *al.* (1989) observed that S application significantly increased the availability of Cu in soil. Increase in Cu uptake with P and S application might be due to increased root growth, which would have resulted in better exploration of soil volume. These results were in conformity with the findings of Togay *et al.* (2008) and Islam *et al.* (2009), who reported an increase in Cu uptake by chickpea with the application of P and S.

P, S and their interaction had significant effect on Zn uptake in grain (Table 2). Phosphorus (20, 40 and 60 kg $ha^{-1}$) and sulphur (15, 30 and 45 kg $ha^{-1}$) application resulted in increased Zn uptake by 11.1, 17.2 and 23.8% and 16.6, 32.6 and 47.9% in grain, respectively. Among the P and S interactions, the highest uptake (100.95 g $ha^{-1}$) was recorded with application of 60 kg $P_2O_5$ $ha^{-1}$ and 45 kg S $ha^{-1}$. Minimum zinc uptake (74.62 g $ha^{-1}$) was recorded in $P_0S_0$. Effect of individual application of P and S as well as their interaction was significant for Zn in haulm (Table 2). Increase in Zn uptake due to S (15, 30 and 45 kg $ha^{-1}$) application was 21.0, 43.68 and 67.84%, respectively. Uptake at higher level of P (60 kg $P_2O_5$ kg $ha^{-1}$) was significant than lower level of P (20 and 40 Kg $P_2O_5$ $ha^{-1}$). Due to acidifying effect of S oxidation, the availability of Zn increased (Hilal *et al.* 1990). Application of P and S resulting in increased uptake of Zn by plant might be due to their increased availability in soil. The hypothesis that P application resulted in the formation of insoluble zinc phosphate is not true and many workers have shown that P application has no effect on available Zn in soil (Tandon, 2001). Increase in zinc uptake in response to S application has been reported earlier (Babhulkar *et al.* 2000) due to increased root surface area resulting from better growth due to S supply.

## References


Babhulkar, M.S., Kar, D., Badole, W.P. and Balpande, S.S. 2000. Effect of sulphur and Zn on yield, quality and nutrient uptake by safflower in vertisol. *J. Indian Soc. Soil Sci.* **48**:541-543.

Chand, L., Sharma, A.S. & Jat, S.C. 1997. Quality and uptake of nutrients in mustard as affected by foliar spray of urea and sulphur application. *Ann. Biol*., Ludhiana, **13**:103-106.

Ganeshamurthy, A.N. 1996. Critical plant S content and effect of sulphur application on grain and oil yield of rainfed soybean in vertic ustochrepts. *J. Indian Soc. Soil Sci*., **44**: 290-294.

GOI Report. 2010-11. Agriculture statistics at a glance. Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Govt. of India.

Hasan, R 1994. Phosphorus fertility status of soils in India. (In) *Phosphorus Researches in India,* Potash and phosphate of Canada-India Programme, Gurgaon, Haryana, p. 7-13.

Havlen, J. L., Beaton, J.D., Tisdale, S.L. and Nelson, W.L. 2007. Soil fertility and fertilizers, An Introduction to Nutrient Management, 7th Ed. Pearson Education Inc. and Dorling Kindersley Publishing Inc. New Delhi, India.

Hilal, M.H., El- Lakkany, H. and El- Sheemy, H. 1990. Effect of sulphur and long term fertilizer application program on rhizosphere and yield of peanut in sandy soils In: Proceedings of Symposium on Middle East Sulphur, 12-16 February, 1990, Cairo, p.217-220.

Islam, M.S., Ali, S. and Hayat, R. 2009. Effect of integrated application of phosphorus and sulphur on yield and micronutrient uptake by Chickpea (*Cicer arietinum*). *Int. J. Agri. Biol.* **11**: 33.38.

Ijgude, M. B.and Kadam, J. R 2008. Effect of phosphorus and sulphur on yield and quality of soybean. *Asian Journal of Soil Science,* **3**: 142-143.

Mengel, K. & Kirkby, E.A. 1987. *Principles of plant nutrition*. International Potash Institute, Bern. Switzerland, p. 589-601.

Majumdar, B., Venkatesh, M.S., Lal, B., Kumar, K., 2001. Response of soybean (*Glycine max*) to phosphorus and sulphur in acid alfisol of Meghalaya. *Indian J. Agron.* **46**(3): 500-505.

Malewar, G.U. and Ismail, S. 1997. Sulphur in balanced fertilization in Western India. In: *Proceedings of the TSI/FAI/IFA Symposium on sulphur in balanced fertilization,* New Delhi, India, p.14

Modaihsh, A.S., Al- Mustafa, W.A. and Metwally, A.I. 1989. Effect of elemental sulphur on chemical changes and nutrient avability in calcareous soils. *Plant and Soil,* **116**: 95-101.

Nimje, P M 2003. Effect of phosphorus fertilization on soybean (*Glycine max*) – based cropping sequences under rainfed conditions. *Indian J. Agric. Sci.* **73**(4): 191-193.

Nasreen, S. and Farid, A.T.M. 2006. Sulphur uptake and yield of soybean influenced by sulphur fertilization. *Pakistan J. Agric Res.,* **19**: 4-10.

Nawange, D.D., Yadav, A.S. and singh, R.V. 2011. Effect of phosphorus and sulphur application on growth, yield attributes and yield of chickpea. *Legume Research*, **34**: 48-50.

Saxena, S.C. and Nainwal R.C. 2010. Effect of sulphur and boron nutrition on yield, yield attributes and economics of soybean. *Soy. Res.*, **8:** 7-10.

Tandon, H.L.S. 2001. Management of Nutrient Interactions in Agriculture (Ed.). Fertilizer Development and Consultation Organization, New Delhi. India. P.142.

Togay, N., Togay, Y., Cimrin, K.M. and Turan, M. 2008. Effect of rhizobium inoculation, Sulphur and phosphorus applications on yield, yield components and nutrient uptakes in Chickpea (*Cicer arietinum* L.). *African J. Biotech.* **7**: 776-782.

Tomar, S.S., Singh, R., Singh, S.P., 2004. Response of phosphorus, sulphur and rhizobium inoculation on growth, yield and quality of soybean (*Glycine max* L.). *Prog. Agri.* 4(**1**): 72-73.


Received after revision: September 20, 2015; Accepted: September 28, 2015