INFLUENCE OF PHOSPHORUS AND SULPHUR ON YIELD AND MICRONUTRIENT UPTAKE BY CLUSTERBEAN
[CYAMOPSIS TETRAGONOLOBA (L.) TAUB]

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ABSTRACT
A pot experiment was conducted with three levels of P (0, 20 and 40 kg P₂O₅/ha) and three levels of S (0, 10 and 20 kg S/ha). Grain and straw yield of clusterbean increased significantly (p=0.05) with increase in level of P and S individually as well as in various combinations. Phosphorus application increased the micronutrient uptake by 22.7 to 40.3% (Fe), 18.4 to 28.2% (Cu), 22.7 to 40.3% (Zn) and 19.1 to 35.7% (Mn) in grain, however 17.2 to 30.4% (Fe), 13.1 to 19.6% (Cu), 17.1 to 31.3% (Zn) and 11.4 to 23.6% (Mn) increase in uptake was recorded in straw. Almost similar observations were recorded regarding effect of S application on micronutrient uptake in both grain and straw. Micronutrient uptake increased by 14.2 to 17.0% (Fe) and 11.8 to 17.3% (Fe), 9.7 to 12.6% and 9.0 to 11.4 % (Cu), 14.5 to 16.3% and 13.8 to 16.5% (Zn) and 11.7 to 15.2 and 7.6 to 14.3% (Mn) in grain and straw, respectively. Both P and S application resulted in increased in Fe by 28.7 to 65.4% (grain) and 28.3 to 54.8% (straw). Increased in Cu uptake reported by 21.0 to 54.6% (grain) and 20.6 to 42.8% (straw) with interaction of P and S. There was 28.6 to 65.0% and 29.1 to 54.8% increased in Zn uptake in grain and straw with application of P and S. The Mn uptake was in range of 26.6 to 62.9% for grain and 24.7 to 55.8% for straw.

Key words: Phosphorus, Sulphur, Clusterbean, Yield, Micronutrient, Uptake.

INTRODUCTION
Phosphorus (P) and sulphur (S) are major nutrient elements for all leguminous crops. Phosphorus in the soil has developmental activity in the plant's root growth. Depending on the phosphorus application, the contact area of the root expands with the growth of roots which in turn, gives rise to a flourishing in productivity, also making it easier for the plant to benefit for the other nutritional elements in higher proportions (Marschner, 1995). Sulphur plays a vital role in plant metabolism. It constitutes the main element of amino acids such as cysteine and methionine, which are of essential nutrient value. In addition to these functions, ferrous sulphur proteins play an important role in nitrogen fixation and electron movement in photosynthesis (Kadioglu, 2004). Both P and S are known to interact with almost all essential macronutrients, secondary nutrients and micronutrients (Abdin et al., 2003). In India, a number of studies have been conducted regarding effect of S on yield of leguminous crops and on an average 22% increase in yield of legume crop (chickpea, pigeon pea, lentil, pea, urd bean and ground nut) has been recorded (Shrinivasarao et al., 2004; Raina and Tanawade, 2005). Research work regarding interaction of P and S and their role in clusterbean growth and nutrient uptake is very rare. Therefore, present study was conducted to assess the influence of P and S application on yield and micronutrient (Fe, Cu, Zn and Mn) uptake in clusterbean under pot culture.

MATERIALS AND METHODS
Pot experiment was conducted using clusterbean cultivar RGC-936 at Department of Agricultural Chemistry and Soil Science, Rajasthan College of Agriculture, Udaipur during Kharif 2009. Some physico-chemical properties of the experimental soil were as pH (8.2), EC (0.48dS/m),
organic matter (11.9 g/kg). The available phosphorus and sulphur in experimental soil were 4.5 and 9.2 mg/kg, respectively. The DTPA extractable Fe, Cu, Zn and Mn were 3.42, 2.62, 4.25 and 5.86 mg/kg, respectively. Nine treatments consisting of three levels of P (0, 20 and 40 kg P₂O₅/ha) and three levels of S (0, 10 and 20 kg S/ha) were laid in a CRD with four replications. The treatments consisted of (i) T₁ - P₀S₀ (ii) T₂ - P₂₀S₀ (iii) T₃ - P₄₀S₀ (iv) T₄ - P₀S₁₀ (v) T₅ - P₀S₂₀ (vi) T₆ - P₂₀S₁₀ (vii) T₇ - P₄₀S₁₀ (viii) T₈ - P₂₀S₂₀ (ix) T₉ - P₄₀S₂₀. The phosphorus and sulphur were applied through diammonium phosphate and gypsum, respectively. Ten seeds of clusterbean were sown in each pot and five plants were maintained after germination. At maturity plants from each pot were harvested separately. Soil pH and EC were determined using 1:2.5, soil: water suspension whereas, organic carbon and phosphorus were determined following standard methods of analysis (Jackson, 1973). Available S was determined by extracting soil samples with 0.15% CaCl₂ (Williams and Steinbergs, 1959) and S in the extract was estimated by turbidimetric method (Chesnin and Yien, 1951). The soil was extracted with 0.005 M DTPA for available micronutrients (Lindsay and Norvell, 1978). The plant samples were dried and data were recorded for grain and straw yield. For micronutrient analysis plant samples were digested in HNO₃:HClO₄ (4:1) diacid mixture and micronutrient (Fe, Cu, Zn and Mn) in the extract (both plant and soil) were determined by atomic absorption spectrometer (GBC- Avanta Ver-1.33). Data on all observations were subjected to analysis of variance (ANOVA) as per the procedure outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The effect of P and S application on clusterbean grain yield was significant (Table 1). Highest grain yield (1.94 g/plant) was recorded from treatment T₉ (P₄₀S₂₀) followed by treatment T₇ (P₄₀S₁₀) and T₈ (P₂₀S₄₀), which differed significantly from treatment T₅ (P₂₀S₂₀) but were at par with each other. Sole application of P (20 and 40 kg P₂O₅/ha) and S (10 and 20 kg S/ha) resulted (13.8 and 22.5%) and (6.5 and 8.0%) increase in grain yield over control, respectively. The straw yield of clusterbean was significantly influenced by the levels of P and S application except treatment T₄ (P₀S₁₀) (Table 2). The straw yield increased more due to P as compared to S application. Maximum straw yield (2.91 g/plant) was recorded with application of 40 kg P₂O₅ and 20 kg S/ha (T₉) followed by treatment T₇ (P₄₀S₁₀) and T₈ (P₂₀S₂₀). Application of phosphorus (20 and 40 kg P₂O₅/ha) resulted in 9.0 and 15.5% increase in straw yield, while application of S (10 and 20 kg S/ha) increased the straw yield by 6.8 and 8.6% over control, respectively. Growth is a function of many controllable and uncontrollable factors and balanced nutrition has key role among these factors. Sulphur availability may influence photosynthetic rate since ferredoxin and acetyl-CoA contain S and play a significant role in the reduction of CO₂ and production of organic compounds (Von Uexkull, 1986). Several studies have shown the positive effect of P and S application on root growth and morphology (Bagayoko et al., 2000). Singh et al. (2003) reported that the highest yield in chickpea was obtained from 40 kg S/ha application. This investigation has been found coherent between the results of the study and those of the previous studies. Sulphur decrease pH in calcareous and alkaline soils increase the intake of the other nutrients and thus facilitate the enhancement of productivity and yield. The results confirm the earlier findings of Nagar et al. (1993) in soybean, Sinha et al. (1995) in winter maize, Choudhary and Das (1996) in black gram. Randhawa and Arora (2000) observed a highly significant positive interaction between P and S in terms of P uptake leading to higher seed yield of wheat at low rate of S application.

P, S as well as P and S interaction had significant effect on Fe uptake in grain (Table 1). An increase of 22.7 and 40.3% was observed in Fe uptake over control due to P application (20 and 40 kg P₂O₅/ha), whereas 14.2 and 17.0% increase in Fe uptake was recorded due to application of 10 and 20 kg S/ha respectively. Difference between higher dose of P (40 kg P₂O₅/ha) and lower dose of P (20 kg P₂O₅/ha) was significant, however higher level of S (20 kg S/ha) and its lower level (10 kg S/ha) was non significant for Fe uptake in grain. Maximum uptake (74.6 µg/plant) was recorded in treatment T₉ (P₄₀S₂₀) followed by treatment T₇ (P₄₀S₁₀) and T₈ (P₂₀S₂₀). Effect of individual application of P and S as well as their interaction was significant for Fe uptake in straw (Table 2). Increase in Fe uptake due to P (20 and 40 kg P₂O₅/
Phosphorus (20 and 40 kg P<sub>2</sub>O<sub>5</sub>/ha) and S (10 and 20 kg S/ha) application resulted in 18.4 and 28.2% and (9.7 and 12.6%) increase in Cu uptake by grain over control, respectively. Higher level of P (40 kg P<sub>2</sub>O<sub>5</sub>/ha) was significant to lower level of P (20 kg P<sub>2</sub>O<sub>5</sub>/ha), while higher level of S (20 kg S/ha) as well as P and S interaction were significant on Cu uptake in straw over control (Table 2). An increase of 13 and 19.6% was observed in Cu uptake over control due to P application (20 and 40 kg P<sub>2</sub>O<sub>5</sub>/ha), while 9 and 11.4% in Cu uptake was reported due to S (10 and 20 kg S/ha) application over control. Maximum uptake (11.02 µg/plant) was recorded in treatment T<sub>9</sub> (P<sub>40</sub>S<sub>20</sub>) which was significantly higher than treatment T<sub>7</sub> (P<sub>40</sub>S<sub>10</sub>) and T<sub>8</sub> (P<sub>20</sub>S<sub>20</sub>). 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 results in better

### TABLE 2: Effect of phosphorus and sulphur on straw yield, micronutrient content and uptake* by straw.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Straw yield (g/plant)</th>
<th>Fe (µg/plant)</th>
<th>Cu (µg/plant)</th>
<th>Zn (µg/plant)</th>
<th>Mn (µg/plant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T&lt;sub&gt;1&lt;/sub&gt;-P&lt;sub&gt;0&lt;/sub&gt;S&lt;sub&gt;0&lt;/sub&gt;</td>
<td>2.20</td>
<td>19.70 (43.34)</td>
<td>3.51 (7.72)</td>
<td>8.72 (19.91)</td>
<td>7.04 (15.49)</td>
</tr>
<tr>
<td>T&lt;sub&gt;2&lt;/sub&gt;-P&lt;sub&gt;20&lt;/sub&gt;S&lt;sub&gt;0&lt;/sub&gt;</td>
<td>2.40</td>
<td>21.16 (50.78)</td>
<td>3.63 (8.74)</td>
<td>9.71 (23.31)</td>
<td>7.19 (17.25)</td>
</tr>
<tr>
<td>T&lt;sub&gt;3&lt;/sub&gt;-P&lt;sub&gt;40&lt;/sub&gt;S&lt;sub&gt;0&lt;/sub&gt;</td>
<td>2.54</td>
<td>22.25 (56.51)</td>
<td>3.63 (9.23)</td>
<td>10.30 (26.15)</td>
<td>7.54 (19.15)</td>
</tr>
<tr>
<td>T&lt;sub&gt;4&lt;/sub&gt;-P&lt;sub&gt;0&lt;/sub&gt;S&lt;sub&gt;10&lt;/sub&gt;</td>
<td>2.35</td>
<td>20.63 (48.47)</td>
<td>3.58 (8.42)</td>
<td>9.64 (22.66)</td>
<td>7.09 (16.66)</td>
</tr>
<tr>
<td>T&lt;sub&gt;5&lt;/sub&gt;-P&lt;sub&gt;0&lt;/sub&gt;S&lt;sub&gt;20&lt;/sub&gt;</td>
<td>2.39</td>
<td>21.27 (50.83)</td>
<td>3.60 (8.60)</td>
<td>9.71 (23.20)</td>
<td>7.18 (17.70)</td>
</tr>
<tr>
<td>T&lt;sub&gt;6&lt;/sub&gt;-P&lt;sub&gt;20&lt;/sub&gt;S&lt;sub&gt;10&lt;/sub&gt;</td>
<td>2.58</td>
<td>21.54 (55.58)</td>
<td>3.61 (9.31)</td>
<td>9.96 (25.70)</td>
<td>7.49 (19.32)</td>
</tr>
<tr>
<td>T&lt;sub&gt;7&lt;/sub&gt;-P&lt;sub&gt;40&lt;/sub&gt;S&lt;sub&gt;10&lt;/sub&gt;</td>
<td>2.76</td>
<td>22.42 (61.87)</td>
<td>3.65 (10.07)</td>
<td>10.28 (28.37)</td>
<td>8.05 (22.21)</td>
</tr>
<tr>
<td>T&lt;sub&gt;8&lt;/sub&gt;-P&lt;sub&gt;20&lt;/sub&gt;S&lt;sub&gt;20&lt;/sub&gt;</td>
<td>2.62</td>
<td>22.69 (59.46)</td>
<td>3.68 (9.63)</td>
<td>10.35 (27.13)</td>
<td>7.81 (20.47)</td>
</tr>
<tr>
<td>T&lt;sub&gt;9&lt;/sub&gt;-P&lt;sub&gt;40&lt;/sub&gt;S&lt;sub&gt;20&lt;/sub&gt;</td>
<td>2.91</td>
<td>23.05 (67.07)</td>
<td>3.79 (11.02)</td>
<td>10.59 (30.82)</td>
<td>8.29 (24.13)</td>
</tr>
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</table>

* Values in the parentheses are nutrient uptake.
exploration of soil volume. Results were in conformity with the findings of Togay et al. (2008) and Islam et al. (2009), who reported increase in Cu uptake by chickpea with application of P and S.

Individual application of P and S had significant effect on Zn uptake by grain. P (20 and 40 kg P\textsubscript{2}O\textsubscript{5}/ha) application resulted in 22.7 and 40.3% increase in Zn uptake, while 14.5 and 16.3% increase in Zn uptake was recorded by S (10 and 20 kg S/ha) application as compared to control (Table 1). The P and S interaction was also significant with the highest Zn uptake (66.0 µg/plant) observed in treatment T\textsubscript{9} (P\textsubscript{40-S\textsubscript{20}}), which was significantly higher than treatment T\textsubscript{7} (P\textsubscript{40-S\textsubscript{10}}) followed by treatment T\textsubscript{8} (P\textsubscript{20-S\textsubscript{20}}) and T\textsubscript{6} (P\textsubscript{20-S\textsubscript{10}}). Different P and S rates as well as their interaction had significant effect on Zn uptake in straw (Table 2). Phosphorus (20 and 40 kg P\textsubscript{2}O\textsubscript{5}/ha) and sulphur (10 and 20 kg S/ha) application resulted in increase in Zn uptake by 17.0 and 31.3% and by 13.8 and 16.5% respectively. Differences between 20 and 40 kg P\textsubscript{2}O\textsubscript{5}/ha was significant and 10 and 20 kg S/ha was non significant in respect of Zn uptake by straw. Among P and S interaction Zn uptake by straw was significantly increased with highest uptake 30.8 µg/plant under treatment T\textsubscript{9} (P\textsubscript{40-S\textsubscript{20}}), followed by 28.4 µg/plant and 27.1 µg/plant under treatment T\textsubscript{7} (P\textsubscript{40-S\textsubscript{10}}) and T\textsubscript{8} (P\textsubscript{20-S\textsubscript{20}}) respectively. Due to acidifying effect of S oxidation, the availability of Zn increased (Hilal et al., 1990). Application of P and S resulted 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.

Sole application of phosphorus (20 and 40 kg P\textsubscript{2}O\textsubscript{5}/ha) had significant effect on Mn uptake in grain by increase in 19.1 and 35.4% uptake over control. Sulphur (10 and 20 kg S/ha) application resulted in 11.7 and 15.2% increase in Mn uptake by grain (Table 1). Differences between 10 and 20 kg S/ha was non significant for Mn uptake by grain. Individual application of P as well as P and S interaction had significant effect on Mn uptake in grain. The maximum uptake (45.6 µg/plant) was recorded with treatment T\textsubscript{9} (P\textsubscript{40-S\textsubscript{20}}) followed by T\textsubscript{7} (P\textsubscript{40-S\textsubscript{10}}) which was significant to treatment T\textsubscript{8} (P\textsubscript{20-S\textsubscript{20}}) and T\textsubscript{6} (P\textsubscript{20-S\textsubscript{10}}). Almost similar trend was observed regarding Mn uptake by straw (Table 2). P (20 and 40 kg P\textsubscript{2}O\textsubscript{5}/ha) application resulted in 11.4 and 23.6% increase Mn uptake, however 7.6 and 14.3% increase in Mn uptake by straw was reported due to sole application of S. Difference between 20 and 40 kg P\textsubscript{2}O\textsubscript{5}/ha was significant, while non significant effect was reported between 10 and 20 kg S/ha application. P and S interaction was also significant with the highest Mn uptake (24.13 µg/plant), was observed in T\textsubscript{9} (P\textsubscript{40-S\textsubscript{20}}) which was significantly higher than treatment T\textsubscript{7} (P\textsubscript{40-S\textsubscript{10}}) followed by T\textsubscript{8} (P\textsubscript{20-S\textsubscript{20}}). P and S application had significant effect on Mn uptake. Among micronutrients, interaction between P, S and Mn is least studies. Havlen et al. (2007) reported that availability of Mn increased due to application of acid (NH\textsubscript{4}+) forming fertilizers. Modaihsh et al. (1989) and Hilal et al. (1990) reported S application increased Mn availability in soil. Possibility of increase in Mn uptake by clusterbean 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.

REFERENCES


