INFLUENCE OF LOW BORON ON YIELD AND SEED QUALITY OF SOYBEAN

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ABSTRACT

Soybean (Glycine max. L.) cv. JS 80-21 was grown in refined sand till maturity at deficient (0.3 μM), subnormal (3.0 μM) and normal (30 μM) boron supply. In soybean boron deficiency depressed growth, biomass, pod and seed yield, concentration of boron and ribonuclease activity in leaves and increased that of peroxidase, acid phosphatase and starch phosphorylase. The quality of seeds deteriorated with low boron as reflected in decreased content of boron, starch, protein and oil along with stimulated concentrations of sugars and phenols.

INTRODUCTION

Soybean is one of the most popular pulse crops of Northern India and its yield is decreased significantly due to poor soil conditions. The demand for boron by legumes is more as compared to most of the field crops (Murphy and Walsh, 1972). Legumes and crucifers are more sensitive to B deficiency and have a higher B requirement than cereals and other crops. In Indian agriculture the deficiency of B is wide spread particularly in alluvial soils (Sakal and Singh, 1995). Deficiency of B effects the development of meristematic tissue resulting in growth inhibition (Marschner, 1995) and has a specific role in the maintenance of cell wall integrity (Hu and Brown, 1994). B being a less mobile element in the phloem, its deficiency usually appears on young growth (Shu et al., 1993). The role of B has not been established as a constituent, of any enzyme nor does as a co-factor of any enzyme activity or for its synthesis (Marschner, 1995). B plays a vital role in transport of carbohydrates as well as in cell wall metabolism (Dugger, 1983), permeability and stability of cell membranes (Pilbeam and Kirkby, 1983) and phenol metabolism, with a primary role in lignin biosynthesis (Levis, 1980). Deficiency of B restricts stomatal opening and transpiratory water loss (Roth Bejerano and Itai, 1981) and also leads to enhanced leakage of solutes across the plasma membrane (Tang and Dela Fuenute, 1986). Besides, involvement of boron in diverse metabolic processes, it has been shown to play an outstanding role in reproductive development of plants. Boron has been implicated in pollen tube growth (Jackson, 1991), leads to male sterility, prevents fertilization and failure to set seeds (Rawson and Nappakonwone, 1996; Rawson, 1996) under deficient condition. Its requirement for reproductive growth is much higher than for vegetative growth (Sherrel, 1983; Loomis and Durst, 1992). In addition it has an important role in improving the quality of produce (Mahajan et al., 1994). The information on boron requirement by oil crops and legumes is sporadic, hence, this paper describes the changes in protein content and oil produced in seeds along with disturbances in biomass, seed yield, contents of protein, carbohydrates and phenols in seeds apart from some enzyme activity in soybean when grown in refined sand at different B level.

MATERIAL AND METHODS

Soybean (Glycine max L.) cv. JS 80-21 was grown during the rainy season (kharif) and 1998 and was repeated in 1999 at Lucknow in refined and (Agarwala and Chatterjee, 1996) in glass house at ambient temperature at deficient (0.3 μM), Subnormal (3.0 μM) and normal (30 μM). Boron was supplied as boric acid. Plants were grown in
polyethylene containers having a central drainage hole covered with an inverted watch glass lined with glass wool. There were three replicates in each treatment. The composition of the nutrient solution excluding B was as follows:

\[4 \text{ mM Ca} \left(\text{NO}_3\right)_2; 4 \text{ mM KNO}_3; 2 \text{ mM MgSO}_4; 1.33 \text{ mM NaH}_2\text{PO}_4; 0.1 \text{ mM Fe EDTA}; 0.1 \text{ mM NaCl}; 10 \mu\text{M MnSO}_4; 1 \mu\text{M CuSO}_4; 1 \mu\text{M ZnSO}_4; 0.2 \mu\text{M Na}_2\text{MoO}_4; 0.1 \mu\text{M NiSO}_4 \text{ and } 0.1 \mu\text{M CoSO}_4.\]

All the solutions were prepared in boron free deionized water. Macronutrients were purified by recrystallization of analytical grade reagent salts. The total contribution of boron from sand, distilled water, nutrients and containers was <0.09 µM which was taken into account while supplying nutrient solution with different B levels. Nutrition was supplied daily except on Sundays when pots were flushed with B-free distilled water to remove deleterious substances from the pots and root surface. Plants were maintained in sand culture till maturity (d 82).

A periodic record was made of visual symptoms of boron deficiency. At d 82, plants were sampled for dry matter and seed yield. Thoroughly washed plant material was dried in an electric oven at 70°C for 48 hrs. Tissue boron was estimated in oven dried leaves and air dried seeds (Chatterjee, et al., 1987). At d 49, activities of peroxidase, ribonuclease, starch phosphorylase were assayed in young leaves along with proteins in enzyme extracts as per procedure described elsewhere (Chatterjee et al., 1987). At d 49, activity of acid phosphatase was assayed according to Agarwala and Chatterjee (1996). The concentration of tissue boron in seeds, sugars, starch, phenols protein and oil were estimated according to Sinha et al. (1999). All data were analysed statistically (Panse and Sukhatme, 1985).

**RESULTS AND DISCUSSION**

In boron deficient soybean, depression in growth was apparent prior to development of visible symptoms of B deficiency (d 32), when grown at low (0.3 µM) boron in refined sand. The symptoms of boron deficiency initiated as chlorosis of young leaves. Later chlorosis changed into larger interveinal patches and these leaves turned thick, puckered and brittle. At this stage growth of the plants was highly reduced due to condensation of internodes. Chlorotic leaves and growing points gradually turned necrotic and dry might be due to loss of water, accumulation of phenolics and auxins at the apical growing points (Marschner, 1995). These foliar symptoms of low B in soybean are in accord with observations on legumes other than soybean (Hewitt, 1983). In soybean B deficiency reduced the number and weight of pods and seeds (Table 1) more significantly than the biomass. The biomass and economic yield of soybean was highest at 30 µM boron (Table 1). The reduction in biomass being more significant in acute deficiency (0.3 µM) (-42%) than at subnormal (3.0 µM) B (-10%), which might be due to reduced rate of protein formation and disturbed carbohydrate and nitrogen metabolisms (Mengel and Kirkby, 1987). As reported earlier in red clover (Sherrell, 1983) and lucerne (Misra and Patil, 1987) in acute boron deficiency (0.3 µM) the depression in weight of total seeds (-72%) was significant as compared to that of adequate plants. The decrease in pod weight with poor seed development might be the result of production and premature shedding of large number of immature flowers, or low viability of pollen grains or due to specific relationship between the boron levels and pollen producing capacity of anthers (Agarwala et al., 1981; Rowson, 1996).

In leaves (Table 1) and seeds (Fig. 1) of soybean the concentration of boron
Table 1. Boron deficiency and dry weight, pod weight, seed yield boron concentration in soybean (±SE)

<table>
<thead>
<tr>
<th>µM boron supply</th>
<th>0.3</th>
<th>3.0</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>d 82: Dry wt. g/plant</td>
<td>40.98±4.32</td>
<td>63.78±5.21</td>
<td>71.0±2.20</td>
</tr>
<tr>
<td>No. of pods/plant</td>
<td>79</td>
<td>122</td>
<td>184</td>
</tr>
<tr>
<td>Pod wt. g/plant</td>
<td>8.19±0.28</td>
<td>13.0±0.52</td>
<td>18.35±1.02</td>
</tr>
<tr>
<td>Seed wt. g/plant</td>
<td>2.10±0.05</td>
<td>3.46±0.12</td>
<td>7.41±0.18</td>
</tr>
<tr>
<td>Weight of 100 seeds: g</td>
<td>2.89±0.24</td>
<td>3.10±0.12</td>
<td>4.69±0.22</td>
</tr>
<tr>
<td>d 82: leaves: µg B/g dry matter</td>
<td>6.0±0.02</td>
<td>19.0±0.81</td>
<td>59.0±4.2</td>
</tr>
</tbody>
</table>

Table 2. Effect of boron deficiency on activities of some enzymes in soybean (±SE)

<table>
<thead>
<tr>
<th>µM boron supply</th>
<th>0.3</th>
<th>3.0</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>d 49: Peroxidase: Change in OD/mg protein</td>
<td>0.28±0.30</td>
<td>0.08±0.001</td>
<td>0.06±0.0</td>
</tr>
<tr>
<td>Acid phosphatase: g Pi liberated/mg protein</td>
<td>55±1.2</td>
<td>48±0.5</td>
<td>43±0.10</td>
</tr>
<tr>
<td>Ribonuclease: change in OD/mg protein</td>
<td>1.02±0.001</td>
<td>1.14±0.0</td>
<td>1.50±0.02</td>
</tr>
<tr>
<td>Starch Phosphorylase: g Pi liberated/mg protein</td>
<td>12.3±0.19</td>
<td>11.0±0.02</td>
<td>9.5±0.002</td>
</tr>
</tbody>
</table>

Increased with an increase in boron from low to adequate and its concentration was higher in leaves than in seeds. This might be due to immobility of boron under stress conditions (Mengel and Kirkby, 1987). Compared to 59 µg B/g dry matter in leaves at adequate (30 µM) boron, at low (0.3 µM) boron the concentration of boron in leaves was 6.0 µg/g dry matter, whereas in relation to 24 µg/g in adequate seeds the deficient seeds had 4.5 µg/g boron concentration (Sinha et al., 1999). The increased activity of peroxidase (Table 2) in soybean leaves under boron deficiency (0.3 µM) could account for the increased accumulation of phenolic compounds and this in turn decrease lignin biosynthesis (Lewis, 1980). The increase in peroxidase activity at low boron is almost 5 times of that of adequate leaves. Enhanced activity of acid phosphatase in low B (Table 2) might be due
to the accumulation of inorganic phosphorus or increased hydrolysis of organic monoesters of phosphoric acid under such conditions (Ilyushchenko et al., 1981) and is in accord with the results of Hewitt and Thatam (1960) under low boron conditions. The activity of RNAse decreased in soybean leaves (Table 2), is in contrast to the observations on bean leaves and maize pollen (Dave and Kannan, 1980; Agarwala et al., 1981) might be due to low concentration of RNA in such conditions. In leaves of soybean, the activity of starch phosphorylase increased (Table 2) in low B which might be due to reduced protein formation in boron deficiency.

In boron deficient seeds (Fig. 1) of soybean the concentration of sugars increased which might be due to involvement of boron in sufficient amounts in formation of carbohydrate borate complexes thus controlling the transport of carbohydrates (Dugger, 1983) or improper utilization of sugars for synthesis.
of starch in boron deficient conditions. In soybean seeds, a marked reduction in the starch concentration (Fig. 1) as a result of low B might be due to retarded synthesis of enzyme involved in starch production (Dugger, 1983). These observations are in accordance with some of the earlier results on rice and wheat (Swamy, 1980; Esteban et al., 1985). The accumulation of phenols in acutely deficient soybean seeds (Fig. 1) is because boron plays an important role in regulation of the pentose phosphate cycle via the formation of acid borate complexes, this might indirectly affect the formation and development of seeds. The accumulation of phenols in edible parts causes poor digestibility of proteins, thus ultimately affecting the quality of soybean (Sikka et al., 1989). The concentration of protein decreased considerably in B deficient seeds, as was also reported by Mahajan et al. (1994). It might be attributed to impaired synthesis of amino acids which are the essential building blocks of proteins. These results are in consonance with the findings on lucerne (Misra and Patil, 1987). Low B decreased the oil content (Fig. 1) in soybean seeds might be due to indirect effect of B on fat synthesis (Gaina and Silli, 1973).

REFERENCES