Boron/Nitrogen Interaction Effect on Growth and Yield of Faba Bean Plants Grown under Sandy Soil Conditions*

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Abstract: A field study was conducted during the two winter seasons of 2000/2001 and 2001/2002 with faba bean (Vicia faba L. cv. Giza 717) plants grown on sandy soil of Ismailia governorate, Egypt. The study aimed at determining the response of faba bean plants to different nitrogen levels applied to soil in the presence or absence of different doses of boron foliar treatments. Results declared that boron/nitrogen synergetic effect additively increased nutrient content within faba bean plant tissues. Boron foliar fertilization in a concentration of 25-50 ppm in the spray solution, in combination with 40 kg nitrogen/ha as soil treatment has significantly increased plant height, leaf area, total dry weight, number of pods, number of seeds per pod, seed yield. However, seed protein and carbohydrate proper accumulation required higher doses.

Key words: Boron, nitrogen, interaction, faba bean, growth, yield

Introduction

Highly graduate increase of food demand in the developed countries implies more production of carbohydrate and protein containing crops, (i.e., cereals and leguminous). Faba bean (Vicia faba, L.) is one of the most important leguminous crops used as a human diet in many countries. On the other hand, sandy soils are highly considered in agriculture horizontal expansion plans in most of the third world countries. However, nature of these soils encourages rapid lost of added fertilizers and hence, they are mostly poor in their nutrient contents. Thus, careful and sufficient fertilization programs are required to increase their crop productivity.

Unbalanced fertilization and/or nutrient deficiency caused great losses in crop yield annually. Recent studies showed that boron is one of the essential elements for plant growth and productivity, especially in sandy soils. Boron deficiency found to affect plant growth and reduced yields (Carpena et al., 2000; Shaaban et al., 2004). Better growth and good yields were obtained when crops were supplied with boron (Blamey et al., 1997; Li and Liang; 1997; Zade et al., 1997; Gupta, 1989; Harb, 1992; Hemantaranjun et al., 2000; Shaaban and El-Fouly, 2001). Marschner (1995) reported that boron application increased phosphorus uptake by faba bean roots. Mola et al. (1998) reported that Ca:B and K:Na ratios declined in leaves of faba bean as a response of boron application. Shaaban et al. (2004) found that boron foliar application led to significant increases in both concentrations and uptake of calcium, potassium and other micronutrients in wheat shoots grown under high calcium carbonate levels in the soil. They found also that a special nutrient balance between boron and other nutrients in the shoot tissues led to a good plant growth.

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The present research aimed at studying the synergistic effect of boron/nitrogen interaction on the nutrient content, growth and yield quantity and quality of faba bean plants grown under sandy soil conditions.

Materials and Methods

Sowing and Practices

Soil was ploughed using a chisel plough, leveled by wooden leveler and divided into experimental units. Plot area was 10.5 m² (3.5 m long and 3.0 m wide). Every plot contained 10 ridges each of 30 cm width and 20 cm between hills. Seeds were inoculated prior to sowing with *Rhizobium leguminosarum*, then sown at the rate of 60 kg/feddan (4200 m²) on November by hand drilling. Calcium super phosphate (15.5% P₂O₅) was added at the rate of 150 kg/fed before sowing. Potassium sulphate (50% K₂O) was added 15 days after sowing at the rate 50 kg/feddan. Iron (Fe), manganese (Mn) and zinc (Zn) in the EDTA chelated form in the rate of 0.5 g L⁻¹ in the spray solution were two times sprayed, i.e., 45 and 60 days after sowing using 200 and 250 liter/feddan, respectively. Plants were irrigated at 6 days interval using sprinkler system. No pesticides were added, while weeds were controlled by hoeing.

Experimental Design and Treatments

The experimental design was split plot with four replicates. Nitrogen treatments (30, 40 and 50 kg N/fed* *) occupied the main plots and boron treatments (0, 25, 50, 100 and 200 ppm) were allocated at random in the sub-plots. Nitrogen treatments were added in the form of ammonium sulphate (20.6% N) in five equal splits (15, 25, 35, 45 and 55 days after sowing). Boron treatments in the form of boric acid (17% B) were twice sprayed at 45 and 60 days after sowing.

Analysis

Soil

A representative soil sample was taken after soil preparation and before fertilization from the experimental sites (0-30 cm depth). The sample was air dried, ground in a wooden mortar and passed through a 2 mm pores sieve to be analyzed for physical and chemical characteristics. Data are shown in Table 1. Sand, silt and clay particle ratio were determined using the hydrometer method described by Bouyoucos (1951). pH and EC were determined in a 1: 2.5 soil/water suspension according to

<table>
<thead>
<tr>
<th>Character</th>
<th>Value</th>
<th>Evaluation</th>
<th>Nutrient</th>
<th>Value</th>
<th>Evaluation</th>
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<td>Sand (%)</td>
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<td>Exchangeable macronutrients (mg/100 g soil)</td>
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<tr>
<td>Silt (%)</td>
<td>2</td>
<td></td>
<td>P</td>
<td>1.35</td>
<td>L</td>
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<tr>
<td>Clay (%)</td>
<td>5.4</td>
<td></td>
<td>K</td>
<td>4.0</td>
<td>vL</td>
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<tr>
<td>Texture Sand</td>
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<td></td>
<td>Ca</td>
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<td>vL</td>
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<tr>
<td>EC (dS m⁻¹)</td>
<td>0.08</td>
<td>vL</td>
<td>Mg</td>
<td>9.5</td>
<td>L</td>
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<tr>
<td>pH</td>
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<td>vH</td>
<td>Available micronutrients (ppm)</td>
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<td>CaCO₃ (%)</td>
<td>1.70</td>
<td>L</td>
<td>Fe</td>
<td>3.00</td>
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<td>Organic matter (%)</td>
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<td>Mn</td>
<td>0.40</td>
<td>vL</td>
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</table>

vL = Very Low, L = Low, M = Moderate, vH = Very High, according to Arkineran and Large (1974)

* Fed = Feddan = 4200 m²
Jackson (1973). Total CaCO₃ was determined using the calcimeter method (Alison and Moodie, 1965). Organic matter content was determined according to Walkley and Black (1934). Exchangeable K, Mg and Ca were extracted by ammonium acetate (Jackson, 1973).

Phosphorus was extracted using sodium bicarbonate according to Olsen et al. (1954). Boron was extracted with hot water according to the method described by Wolf (1974). Micronutrients Fe, Mn, Zn and Cu were extracted by DTPA according to Lindsay and Norvell (1978).

**Plant Material**

Leaf sample at the age 75 days after sowing and seeds after harvest were analyzed for macro- and micronutrients. Leaf samples were washed with tap water, 0.01 N HCl-acidified bidistilled water and bidistilled water, respectively, then dried in a ventilated oven at 60°C till constant weight was obtained. The plant samples were then ground in a stainless steel mill with 0.5 mm sieve and kept in plastic containers for chemical analysis. One gram sample was dry-ashed in a muffle furnace at 550°C for 6 h. The residue was then suspended in 2.0 N HCl.

**Measurements and Determinations**

Total nitrogen (N) content of the samples was determined using Micro-Kjeldahl method (Markham, 1942 modified by Ma and Zuazage, 1942). Micronutrients and magnesium (Mg) concentrations were measured in the suspension using atomic absorption spectrophotometer (Zeiss PMQ). Phosphorus (P), was measured in the digested solution using vanado-molybdate color reaction according to Jackson (1973). Potassium (K) and calcium (Ca) were measured using the Flame photometer, (Eppendorof, Dr. Lang). Boron (B) was determined calorimetrically using azomethine-H method described by Wolf (1974). Seed protein percentage was calculated as (N%) × 6.25, while carbohydrate percentage was determined according to Shaffer and Hartmann (1921).

**Data Records**

**Growth Characteristics**

A random sample was taken at 75 days after sowing to determine plant height (cm), leaf area per plant (cm²), dry weight per plant (g), as well as macro-and micronutrient contents of leaves

**Yield and Yield Components**

At maturity (150 days after sowing) the plants were harvested. Five random samples were taken to determine number of pods per plant, number of seeds per pod, seed yield (Arab* feddan) and straw yield (ton/feddan)

**Statistical Analysis**

The obtained data were subjected to split plot analysis of variance described by Snedecor and Cochran (1967). Means were compared using the least significant difference (LSD₀.₀₅) developed by Waller and Duncan (1969).

**Results and Discussion**

**Boron/Nitrogen Interaction Effect on Leaf Nutrient Content**

Data in Table 2 show that foliar application of 25-50 ppm boron combined to 40 kg N/fed has significantly increased the content of P, K, Ca and Mg. Micronutrient contents were also significantly increased by the same doses (Table 3). However, the dose 200 ppm boron, produced a toxic B-content

*Arab = 155 kg
Table 2: Effect of boron/nitrogen interaction on macronutrient content of faba bean leaves

<table>
<thead>
<tr>
<th>Nitrogen rate (kg/ft²)</th>
<th>Boron treatment (ppm)</th>
<th>Nitrogen (N)</th>
<th>Phosphorus (P)</th>
<th>Potassium (K)</th>
<th>Calcium (Ca)</th>
<th>Magnesium (Mg)</th>
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<td>50</td>
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<td>78.6</td>
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<td>10.4</td>
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Table 3: Effect of boron/nitrogen interaction on micronutrient content of faba bean leaves

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<thead>
<tr>
<th>Nitrogen rate (kg/ft²)</th>
<th>Boron treatment (ppm)</th>
<th>Iron (Fe)</th>
<th>Manganese (Mn)</th>
<th>Zinc (Zn)</th>
<th>Copper (Cu)</th>
<th>Boron (B)</th>
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</tr>
</tbody>
</table>

which had have significant negative effects on the uptake and content of all nutrients in the leaf tissues. Since boron was hypothesized to work on the level of plasma membranes in the root system (Cakmak et al., 1995), its deficiency caused a dramatic decrease in all nutrient contents in the plant tissues (Zade et al., 1997). Significant increases in nutrient contents caused by synergistic effort of boron/nitrogen can be attributed to boron effect on nodulation and additional nitrogen fixation (Goldbach, 1997). On the other hand, the integration in nutrient uptake and balance in the presence of sufficient concentrations of the two elements gave rise to sufficient contents of other nutrients (Shaheen et al., 2004).

_Boron/Nitrogen Interaction Effect on Growth Parameters_

The highest values of faba bean plant height, dry weight accumulation and leaf area/plant were recorded with N-dose of 40 kg/ft² combined to 25 ppm boron (Fig. 1). Positive effects of increased
Fig. 1: Growth parameters of faba bean plants as affected by boron/nitrogen interaction (1 = standard error)
Fig. 2: Yield and some yield components of faba bean plants grown on sandy soil as affected by boron/nitrogen interaction (I = standard error)

Fig. 3: Protein and carbohydrate contents of faba bean seeds as affected by boron/interaction

N-doses alone on leaf area/plant may be due to the role of nitrogen in development and survival of new tillers through synthesis of nucleic acids and other cell organelles (Marschner, 1995). However, positive effect of boron alone can be attributed to its role in cell elongation and turgidity (Hu et al., 1996; Solheir, 2001). Boron and nitrogen were found to interact positively to improve the above mentioned growth parameters suggesting better assimilation of enhanced nitrogen in the presence of sufficient boron contents (Shaaban et al., 2004).
Boron/Nitrogen Interaction Effect on Yield Quantity

Figure 2 indicates that number of pods/plant, number of seeds/pod, seeds yield/plant and seed and straw yields/fed were significantly affected by the applied nitrogen levels along with boron doses. The dose 40 kg N/fed in combination with 50-100 ppm boron gave the highest values compared to other treatments. Positive effect of boron/nitrogen interaction may be associated with nitrogen enhancement for the photosynthetic activity in the presence of adequate boron contents. This may account for higher accumulation of metabolites in the reproductive organs. Boron/nitrogen interaction can also play a role in the seed yield increment through its positive effect on vitality and fertility of pollen tubes (Rizk and Abdo, 2001).

Boron/nitrogen Interaction Effect on Yield Quality

Applying nitrogen at the rate of 50 kg N/fed combined to 25 ppm boron resulted in the highest value of seed protein content, while the highest carbohydrate content was recorded when faba bean plants received 40 kg N/fed combined to 50 ppm boron (Fig. 3). Combining boron with nitrogen encouraged best assimilation of the latter which can partially contribute to increasing carbohydrate and protein synthesis and accumulation. Boron-deficient plants are known unable to effect complete protein or carbohydrate synthesis, especially plants grown in soils rich in free calcium ions (Davies, 1980). In such a case, more boron is required to prevent deficiency.

Conclusions

From the results of the present work, it could be concluded that

- Boron has a synergetic effect on nitrogen and other nutrients uptake and utilization by faba bean plants.
- In sandy soils where free calcium ions are present, faba bean plants should be fertilized with more boron. A dose of 25-50 ppm boron in the spray solution twice sprayed, in combination with 40-50 kg N/fed are enough to achieve a good growth and high yield.

Acknowledgement

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References


