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Effect of Boron and Sulfur Application on Yield and Yield Components of *Brassica napus* L. In a Calcareous Soil

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Abstract: Afield experiment was conducted to study the interaction between boron (B) and sulfur (S) on yield and yield components of canola (*Brassica napus* L.) in a calcareous soil. The experiment had a completely randomized design consisting of a 4×3 factorial combination of four B rates (0, 2.5, 5.0, 7.5 and 10.0 kg ha^{-1}) and three S rates (0, 400 and 800 kg ha^{-1}) arranged in four replications. The results showed that interaction between B and S was significant on yield of dry matter, grain yield, oil and protein yields. The highest grain yield of canola (3002.4 kg ha^{-1}) was observed when 2.5 kg B and 800 kg S ha^{-1} were applied. Application of 10 kg B ha^{-1} resulted in a significant decline in canola grain yield (2279.2 kg ha^{-1}). The detrimental effects of the highest B application on yield components, grain protein and oil were also observed. Interaction between B and S application led to the highest leaf B concentration at rate of 10 kg B and 800 kg S ha^{-1}. The decreased quantity and quality yields of canola with increasing B might be due to the toxicity effect of high boron application particularly with S application.

Key words: Boron · Sulfur · Canola · Oil · Protein · Grain yield

INTRODUCTION

Crops require a sufficient, but not excessive, supply of essential mineral elements for optimal productivity. An insufficient supply of mineral elements may lead to limit in plant growth. In some agricultural soils, particularly in calcareous soil, insufficient micronutrients like boron (B) are often common. Hence, these elements can be supplied as fertilizers in both intensive and extensive agricultural systems. However, excess B can be toxic to both plants and animals. Increased fertilizer use efficiency can be achieved agronomically, through improved fertilizer-management practices by cultivating crops that acquire and/or utilize mineral elements more effectively [1, 2]. Canola is one of the most sensitive crops to low B supply, developing characteristic B deficiency symptoms on leaves, stems and reproductive parts [3]. Plant root growth is significantly influenced by soil B content. It has been shown that sunflower roots are sensitive to B deficiency as they stop their growth in less than 6 h after the removal of B from the growth media [4]. Similarly, a considerable increase in root dry weight of sunflower by foliar application of 28 mM B has been reported [5]. B foliar application, not only increased root growth but also increased shoot dry weight of sunflower [5].

In recent years S-deficiency has become an increasing problem for agriculture resulting in decreased crop quality parameters and yields [6]. Plants vary considerably in their S requirements. Oilseed rape, as with most *Brassicaceae*, has greater S requirements than other large crop species such as wheat or maize. For example, the production of 1 ton of rape seeds requires 16 kg of S [7, 8], compared with 2–3 kg for each ton of grain in wheat [6]. The agronomic consequences of insufficient S are well documented with decreased yields and a substantial impact on S-content under extreme deficiency [6]. In many cases of mild S- deficiency stress there may be little impact on yield but important consequences for quality, with substantially modified N:S ratio [9]. Calcareous soils which are usually located in arid and semi arid regions have low organic matters and consequently are low in organic S. Addition of S to a calcareous may increase availability of micronutrients like B. Because canola like other oilseeds has high B and S requirements and there

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have been no reports of how interaction between S and B may affect yield and yield components of canola in a calcareous soil, this study was amid to investigate this interaction.

MATERIALS AND METHODS

A field experiment was conducted in Research Station of Ramin University of Agriculture and Natural Resources, Mollasani, Iran. The experiment was arranged in a completely randomized design consisting of a 4x3 factorial combination of four B levels (0, 2.5, 5.0, 7.5, 10.0 kg ha^{-1}) and three S levels (0, 400 and 800 kg ha^{-1}). The treatments were replicated four times. Phosphorus (as ammonium phosphate) and nitrogen fertilizers (as urea) at the recommended rates were equally added to the all plots. S (along with *Thiobacillus thiooxidanse*) and B fertilizers (as boric acid with 17% B), in a broadcast application method, at the above rates were incorporated into the surface 15 cm of the soil before seeding of canola (*Brassica napus* L.). In each plot, there were nine seeding lines with 3 m length. Plots were thinned to final plant density of about 90 plants m^{-2} at seedling stage. Weeds were controlled mechanically as needed. Grain yields were taken at maturity by harvesting the 1.2 area of the two inner rows of each plot at the end of April. Grain yield was adjusted to a 10.0% moisture basis. Ten plants were chosen randomly from the central of two rows and the following growth and yield component variables were recorded for each plot: plant height, number of branches per plant, pod number per plant and 1000-seed weight. Grain oil content was determined by the soxholet apparatus and seed N concentration was measured by micro-kjeldahl method. Shoot B concentration was determined by a spectrophotometer using korcamin indicator at 540 nm wavelength. All data were analyzed by the GLM procedure using the SAS statistical software [10]. Means were compared using Duncan's Multiple Range Test at 5% probability level. Some important chemical and physical characteristics of the soil are given in Table 1. The soil classified as Typic Torrifluvent (USDA), Calcaric Fluvisols (FAO).

RESULTS AND DISCUSSION

Yield and Yield Components: Results showed that B application had significant effects on grain yield and some yield components of canola (Table 2). The highest grain yield of canola (3002.4 kg ha^{-1}) was obtained in treatment with 2.5 kg boron ha^{-1} (Fig. 1). Increasing boron fertilizer from 2.5 to 10.0 kg ha^{-1} significantly decreased grain yield (2279.2 kg ha^{-1}). One possible explanation for the decreased grain yield of canola at the highest B application is the antagonism relation between Ca and B. It has been shown that the relative uptake rates of calcium significantly decreased in both shoot and root of canola as solution B concentrations was increased [11]. There are different reports on the effect of B on grain yield of canola. An increase in canola yield with increasing B has been reported [12, 13]. In contrast, Karamanous *et al.* [14] observed that the grain yield of canola decreased as B fertilizes was increased [14]. No significant effect of B

Table 1: Some chemical and physical characteristics of the soil used in this experiment

					Mechanical composition		
pH^A	EC^B (dS m^{-1})	Available B^C (mg kg^{-1} soil)	Available P^d (mg kg^{-1} soil)	Organic C (g kg^{-1} soil)	Sand	Silt	Clay (%)
7.6	2.8	0.29	3.2	3.1	25.2	33.4	41.4

^{A}1:5 w:v, soil:water ^{B} Electrical conductivity ^{C} Hot-water extractable B (Gupta and Cutcliffe, [20]) ^{d} $NaHCO_3$ extraction (Olsen and Sommers, [21])

Table 2: Mean square of analysis of variance for some measurements in this study

SOV	df	Grain Yield (Kg ha^{-1})	1000 grain wt. (g)	Plant height (Cm)	Grain oil (Kg ha^{-1})	Grain protein (Kg ha^{-1})	Shoot boron conc. (µ 100 mg)
Block	3	20477.8^{ns}	0.008^{ns}	54.56^{ns}	11331.2^{ns}	929.4^{ns}	209.2^{ns}
Boron (B)	3	1061463.2^{*A}	0.078^{ns}	55.4^{ns}	258816.8*	842.3**	9.5^{ns}
Sulfur (S)	2	146732.8^{nsB}	0.085^{ns}	103.6^{ns}	20304.5^{ns}	1010.1^{ns}	89.6^{ns}
B×S	6	779643.4*	0.089^{ns}	93.97*	191427.4	662.9**	9.0^{ns}
error	33	248408.0	0.063	36.26	81563.0	1744.5	27.2
CV (%)	-	18.9	6.85	4.15	23.8	20.3	28.6

$^{A:}$ *, ** significant at the 0.05 and 0.01 probability level, respectively

$^{B:}$ ns, not significant at p=0.05

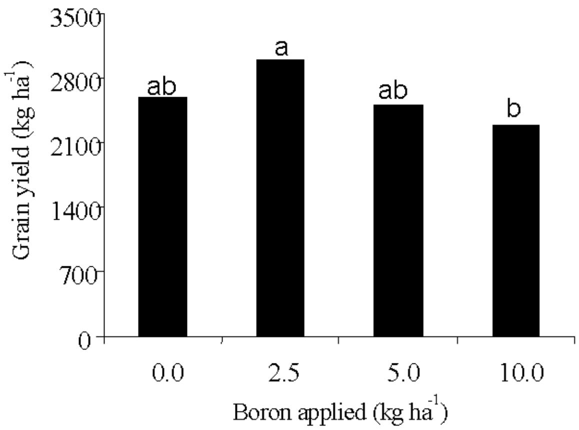

Fig. 1: Effect of boron application on grain yield of canola

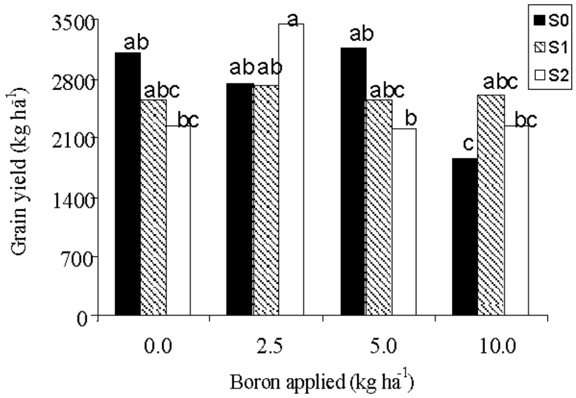

Fig. 2: Grain yield of canola as affected by boron and sulfur application

application on grain yield of canola has also been reported [5]. S application at the rate of 400 and 800 kg ha^{-1} had no significant effect on canola yield (result not shown). This is in agreement with the previous results [15]. There was an interaction between S and B application in their effects on the grain yield. In treatment with 2.5 kg B ha^{-1}, the highest grain yield of canola was observed when 800 kg S ha^{-1} was applied (Fig. 2). The yield of grain was decreased with increasing B from 2.5 kg to10 kg ha^{-1} at the highest level of S application. This indicates that the availability of B increases to a toxicity level, particularly with increasing S as reported by Nuttal *et al.* [16].

B application had no significant effect on silique number m^{-2}. Similarly, it was reported that in spite of increase in grain yield of canola, silique number m^{-2} was not affected by B application [17]. In the present study there was a trend toward increase in silique number m^{-2} with increasing S (result not shown). Interaction between S and B applications was not significant in their effect on

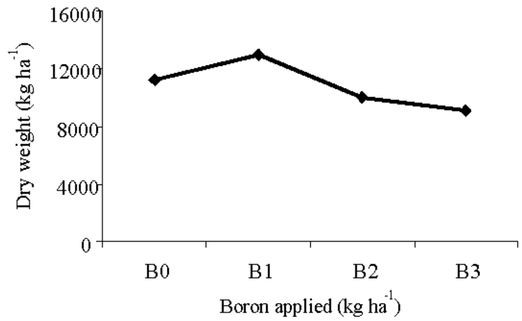

Fig. 3: Effect of 0 (B0), 2.5 (B1), 5.0 (B2) and 10.0 (B3) kg boron ha^{-1} on canola dry weight

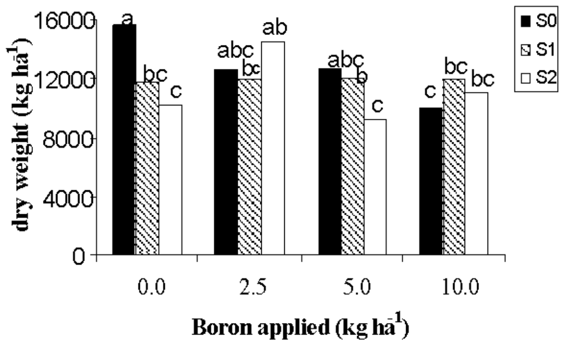

Fig. 4: Dry weight of canola as affected by interaction between boron and sulfur

silique number m^{-2}. A similar trend to that of silique number m^{-2} was observed for 1000 grain weight of canola with increasing B and S.

Dry Weight, Branching and Height of Canola: Canola dry weight was significantly affected by B and S application. The highest dry weight of canola (12824 kg ha^{-1}) was obtained with application of 2.5 kg B ha^{-1}. Application of B at the rate of 10 kg ha^{-1} significantly decreased (9300 kg ha^{-1}) canola dry weight (Fig. 3). It has been shown that excess boron application led to a significant reduction in Photosynthesis and Growth of *Cucurbita pepo* [18]. The decline in the growth of *Cucurbita pepo* was attributed to the inhibition of root elongation and lateral root development. Interaction between B and S was significant on dry weight of canola. In no added B treatment, application of S significantly decreased dry weight of canola (Fig. 4) while, the highest dry weight of canola was observed in treatment with 2.5 kg B ha^{-1} and 800 kg S ha^{-1} (Fig. 4).

No significant interaction between B and S application was observed in their effect on branching of canola. The highest and the lowest number of branching were observed when 2.5 10.0 kg B and 400 kg S ha^{-1} were applied, respectively (result not shown).

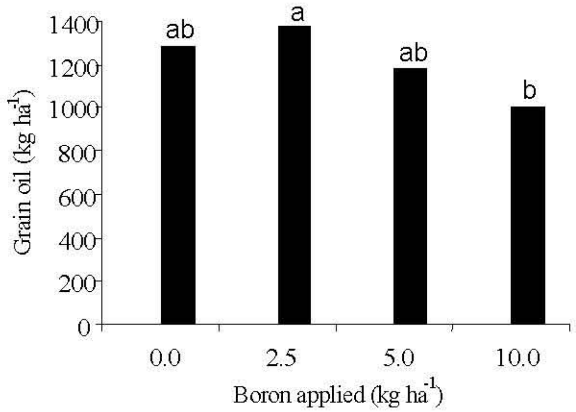

Fig. 5: Effect of boron application on grain oil of canola

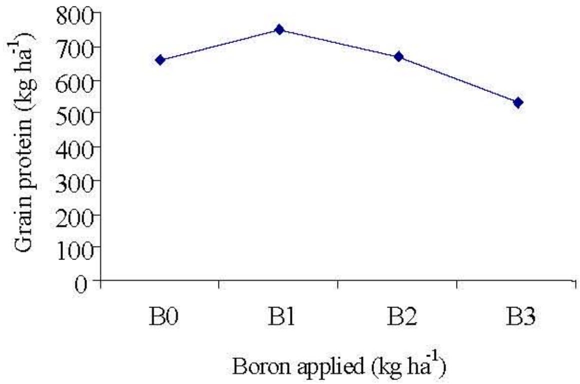

Fig. 6: Effect of boron on grain protein of canola

Boron and sulfur application had no significant effect on canola height (Table 2). Similarly, it has been shown that B application had no significant effect on vegetative growth and height of canola [13, 17]. This is in agreement with the general idea that the B requirement of many plants during the reproductive growth is reputedly much higher than during vegetative growth, a finding recently demonstrated in sunflower [3].

Grain Oil and Protein: Oil yield of canola was significantly affected by B application. The highest oil yield (1383 kg ha^{-1}) was obtained in treatment of 2.5 kg B ha^{-1} and the lowest oil yield (1039 kg ha^{-1}) was observed when 10 kg B ha^{-1} was applied (Fig. 5). Concentration (Percentage) of grain oil was not significantly affected by B and S application. Similarly, it has been shown that B application had no significant effect on the percentage of grain oil of canola [13, 14]. S application had no significant effect on oil yield of canola, although there was a trend toward higher oil yield in treatment with application of 400 kg S ha^{-1} (result not shown). Interaction between B and S was not significant in their effect on oil yield of canola.

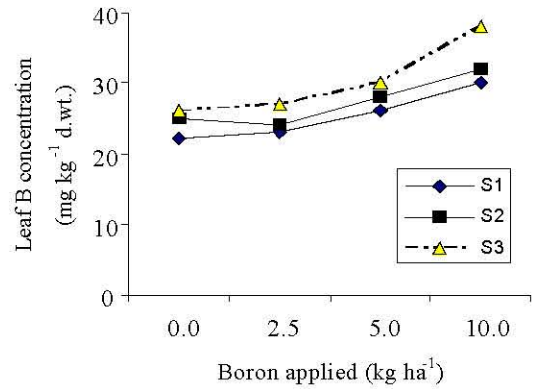

Fig. 7: Effect of boron and sulfur applications on leaf boron concentration

A similar trend to that of percentage of grain oil was observed for the percentage of protein as affected by B and S application. Protein yield was significantly decreased with increasing B application from 2.5 to 10.0 kg ha^{-1}. Since percentage of grain protein was not affected by B application, the observed decrease in protein yield with increasing B from 2.5 to 10.0 kg ha^{-1} is due to the effect of B on grain yield of canola. The highest and the lowest protein yields was observed when 2.5 and 10.0 kg B ha^{-1} were applied, respectively (Fig. 6). It has been shown that B application (2.2 kg ka^{-1}) in addition to S increased protein content of canola seed, whereas N combined with B decreased protein and increased percent oil [16].

Leaf Boron Concentration: Leaf B concentration increased as B application was increased (Fig. 7). Similarly, it has been reported that B concentration in shoot and/or root of canola increased with increasing B application [11, 13, 14]. A significant interaction between B and S led to the highest leaf B concentration at rate of 10 kg B and 800 kg S ha^{-1}. In fact, the highest S application increased the availability of B and this may explain the reason for the reduction of grain and oil yields as have been shown by [19]. The highest leaf B content observed in treatment of 10 kg B and 800 kg S ha^{-1} which was due to the high leaf boron concentration.

CONCLUSION

The result of this study indicated that application of S had no significant effect on yield and most components of yield. However, application of both S and B resulted in a significant effect on yield and yield components of canola. Application of 2.5 kg B ka^{-1} along with 800 kg S ka^{-1} led to the highest grain yield of canola.

Application of B fertilizer more than 2.5 ka^{-1} decreased grain yield, grain oil and grain protein. This decline was significant when 10 kg B ka^{-1} along with 800 kg S ka^{-1} were applied. The decline in the yield parameters of canola might be due to the toxicity of high B application particularly in the presence of S fertilizer. The results showed that *Brassica napus* L. grown a calcareous soil doesn't need more than 2.5 kg B ha^{-1}.

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