Effects Of Boron Toxicity On The Yield Of Spring Canola Cultıvars

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Abstract: Eight spring canola cultivars (*Brassica napus* L. cvs. Marinka, Briol, Pactol, Helios, Star, Prota, Spok and Semu 209/82) were studied in field experiments for their responses to toxic B application at Central Anatolia, Turkey during the 2002 and 2003 growing seasons. The canola cultivars were grown under B moderate deficiency (extractable B 0.56 mg kg^{-1}) and toxic B applied (15 kg B ha^{-1}) conditions. In this study, oil yield and protein yield were investigated. According to the results, oil yield and protein yield varied significantly among the cultivars and B application decreased the oil yield and protein yield by 37.5 % and 38.6 % on average, respectively. Among canola cultivars, Briol, Marinka, and Spok were the most sensitive to B toxicity applications that had the highest oil yield and protein yield decrease when treated with B. On the other hand, Star and Pactol cultivars showed tolerance to B toxicity applications.

Keywords: Boron toxicity, spring canola, oil yield, protein yield

Introduction

The element boron is unique among the essential elements in that a narrow range in concentration can mean the difference between plant deficiency and plant toxicity. Boron toxicity has long been recognised as a common mineral nutritional problem particularly in arid and semiarid regions where B levels are frequently high in the soil or irrigation waters around the world, causing significant decreases in growth and yield as reported for many countries (Nable et al., 1997). Boron toxicity is a factor in reducing crop yield in Turkey (particularly in Central Anatolia), Syria, India, South Australia, and Iran. Widespread B toxicity is also suspected in

Afghanistan (Yau & Erskine, 2000). Nearly 10 % of the soils sampled in Central Anatolia contained more than 5 mg extractable B per kg soil which is a widely accepted critical concentration for occurrence of B toxicity in crop plants (Nable et al., 1997). Boron toxicity symptoms in leaves are not distinctive (Cartwright & Hirsch, 1986) and easily confused with symptoms from other nutritional and pathogenic disorders in field-grown areas. Toxic effects are more marked in dry seasons when roots penetrate deeper into the soil. Excess B cannot be removed from soil or treated in any way under dry-land conditions. Therefore, use of tolerant crop varieties is the best option to overcome this problem (Rehman et al., 2006).

Canola is one of the main oil crops world-wide and it usually requires B concentrations greater than 0.5 mg kg^{-1} of hot water-extracted B (HWB) in the soil to complete its growth and development (Liu, 1995). Existence of larger variations in tolerance of canola to B toxicity than barley and wheat has been reported by several researchers (Hughes-Games, 1991; Hocking et al., 2003). Tolerance was reported to be releated to the origin of a cultivar (Du et al., 2002).

The present study was carried out to investigate the differential response of different spring canola cultivars (8 cultivars of each) to B toxicity in field under irrigated conditions in a typical Central Anatolian soil low in extractable B and with relatively high lime content.

Materials And Methods

The field experiments were carried out the Research Institute of Rural Affairs, Konya, Turkey during the 2002 and 2003 growing seasons. Soil containing 0.56 mg of B kg^{-1} extracted using 0.01 M Mannitol + 0.01 M $CaCl_2$ solution before reading in ICP-AES (Varian-Vista Model), other soil characteristics are given in Table 1.

Normally receiving about 112 mm of total precipitation annually based on a 30 –yr average from 1974 to 2003, the area received 33 mm higher and 28 mm lower precipitation than the long- term average for 2002 and 2003, respectively. Temperatures during the study period were similar to the 30-yr average for the area. The mean growing season temperatures from April to August were 18.2 ^{0}C and 19.0 ^{0}C for 2002 and 2003, respectively.

The experiments were performed in a split plot design in randomized complete blocks with 3 replications. Eight spring canola (Brassica napus L.cvs. Marinka, Briol, Pactol, Helios, Star, Prota, Spok and Semu 209/82) cultivars were studied. Plants were grown with (+ B= 15 kg B ha^{-1}) and without (-B) B applications. B treatments were administered to main plots where the sub-plots contained plant cultivars. Before sowing in both years, B at a rate of 15 kg ha^{-1} was broadcasted onto the soil surface using borax ($Na_2 B_4 O_7 .10 H_2O$), followed by incorporation to a 0-20 cm depth of soil prior to sowing. Plots were basically fertilised with 120 kg ha^{-1} N, 60 kg ha^{-1} P_2O_5. Entire quantities of phosphorous fertilizers and 60 kg ha^{-1} of the nitrogenous fertilizers were applied on bands in the form of ammonium phosphate (18% N, 46% P_2O_5), by a driller during the sowing. Fifty percent of the remaining quantities of nitrogen were dispersed onto the soil surface before flowering in the form of ammonium sulphate (21% N).

Plots were sown in 5 rows (30 cm apart and 1-2 cm deep) with 2.5 m long (1.5 x 2.5 =3.75 m^2) on April each year. Seeds were sown by hand. Plants within rows were spaced 15 cm apart by thinning at 2 to 4 leaf stage. Routine management practices were followed. Plots were irrigated after sowing, during flowering, and pod filling with sprinklers. Crops were harvested at maturity for seed yield by hand yield and seed yield was adjusted to 9 % moisture level (Yusuf & Bullock, 1993). Harvested area (HA) of a plot was 1.35 m^2 of the internal part after removing the 2 outer rows. Oil yield and protein yield were obtained each year. Oil yield was calculated on the basis of oil percentage and seed yield. Protein yield was calculated on the basis of protein percentage and seed yield.

All data were analyzed as a split plot design using a computerized statistical software package (MSTATC). Differences among treatments were tested by analysis of variance and were compared using LSD Tests at the 0.01 or 0.05 level of significance.

Results And Discussion

Oil yield

Effect of year, cultivar, B x cultivar interaction has been significant for oil yield. Cultivars showed significantly varying responses to toxic B treatment. All cultivars showed significant oil yield decreases when treated with +B (Table 2). Highest oil yield decrease was recorded at Briol and Spok (56.6 % and 56.3 %, respectively) while lowest yield decreases were determined at Star and Pactol (8.3 % and 12.1 %) over the control when applied with +B (Table 2). Thus, sensitivity to B toxicity in respect of oil yield depended on the genotypes.

The oil yield of canola is the combined expression of seed oil content and seed yield. Canola cultivars showed significantly varying responses to toxic B treatment for seed yield. All cultivars showed significant yield decreases when treated with high B whereas control plant yielded the highest. Cultivar means revealed that B treatment resulted in -31.23 % seed yield decrease, whereas highest and lowest seed yield decreases were recorded at Spok and Star cultivars as -52.66 % and -3.75 % respectively over the control (data was not shown). Pactol cultivar was the most yielding genotype at +B (2095.8 kg ha^{-1}) whereas Pactol (2183.5 kg ha^{-1}) and Prota (2469.2 kg ha^{-1}) cultivars yielded best at -B. According to mean of treatment, Briol (682.5 kg ha^{-1}) and Spok (738.8 kg ha^{-1}) cultivars were the lowest yielding among the genotypes (data was not shown). Very few studies have been conducted on canola regarding borax toxicity. Wang et al. (1999) reported that application of borax, at 3.3 kg B ha^{-1}, significantly reduced canola yield in only one out of 11 experiments. In the single experiment where B toxicity depressed growth, the effect was relatively small, equivalent to only 5 % of maximum seed yield. Moreover, application rates of up to 6.6 kg B ha^{-1} did not cause any depression in oilseed rape yield in a single experiment. In addition, there was no indication that a total of 9.9 kg B ha^{-1} depressed seed yield of canola.The risk of B toxicity from the soil application of borax at 4-8 times the minimum rates required to correct deficiency was not as high as previously assumed. Therefore, while soil application of B fertilizer at 1.1-1.65 kg ha^{-1} can be recommended to correct B deficiency of oilseed rape, even at rates substantially higher, oilseed crops are unlikely to exhibit B toxicity symptoms or decrease yield (Wang et al., 1999). Application of a dose of 15 kg ha^{-1} B in our study was far above this amount and caused significant decreases in yield.

In the present experiment, oil contents varied widely among cultivars, and relatively slightly with high B treatments. High boron fertilizer decreased the oil content of all canola cultivars. The lowest decrease in oil content was observed in Prota by 5.11 % while the highest decrease was in Briol variety by 21.24 % as a result of a high boron treatment. The highest oil rate was found in the Star variety (44.23 %) with a decrease of 5.35 % (data was not shown). Mandal & Sinha (2004) reported that essential elements like sulphur, boron and zinc probably promote the synthesis of oils.In our study, the extraction of boron from soil at toxic level probably caused a decrease in oil synthesis and a decrease in oil contents of canola varieties. As oil yield is calculated from seed yield and oil rate values, the fact that oil yield (Table 2) at -B were higher from that of + B led to the difference was an expected result. The results here clearly show that Pactol and Star canola cultivars can be successfully grown under high natural or fertilizer B conditions because of their tolerance to B oversupply. From this point of view, both cultivars can be considered B-inefficient.

Properties	Mean	Properties	Mean
pH	7.6	Mg (me 100 g^{-1})	5.3
$CaCO_3$ (%)	20.7	K (me 100 g^{-1})	0.6
E.C (µS cm^{-1})	94	Na (me 100 g^{-1})	0.13
Organic matter (%)	1.4	P (mg kg^{-1})	8.5
Sand (%)	26.7	B (mg kg^{-1})	0.56
Silt (%)	68.1	Mn (mg kg^{-1})	2.3
Clay (%)	5.2	Zn (mg kg^{-1})	0.3
Ca (me 100 g^{-1})	20.2	Fe (mg kg^{-1})	0.4

Table 1. Selected physical and chemical properties of topsoil samples (0-30 cm depth) collected from the experimental area (mean of soil samples collected before sowing each year)

Protein Yield

Canola is not only an oilseed crop, but also contains a relatively high protein concentration in the seed (>400 g kg^{-1} of the oil-free meal) and its meal is used as a protein supplement for animals and possibly will be food for humans in the near future.

Cultivars	Oil yield (kg ha^{-1})		Significance of differences between +B & -B	Protein yield (kg ha^{-1})		Significance of differences between +B & -B
	+B	-B		+B	-B	
Marinka	280.8	608.1	**	181.2	366.5	*
Briol	198.7	458.2	**	155.3	314.6	*
Pactol	628.6	714.9	**	401.3	473.6	*
Helios	423.7	564.4	**	301.8	429.8	*
Star	663.1	723.1	**	302.4	374.9	*
Prota	486.1	958.8	**	299.5	584.9	*
Spok	268.3	614.4	**	160.2	350.9	*
Semu	323.9	594.0	**	197.3	361.6	*

Mean	409.1	654.5		249.9	407.1

-B = Control (0.19 mg kg^{-1} B content soil), +B= Boron application (0.19 mg kg^{-1}B content soil + 15 kg ha^{-1} B application)
LSD = Least significant difference for comparisons between individual means; C; B x C; indicates cultivar (C) main effect, interaction of B application (B) with cultivars, ** significant at $P < 0.01$, * significant at $P < 0.05$.

Table 2. Oil yield (kg ha^{-1}) and Protein yield (kg ha^{-1}) of 8 canola cultivars when grown in two consecutive years with two levels of B supply (kg B ha^{-1}). Values are means of two years

The protein yield of canola cultivars was influenced significantly by B treatment. Boron application significantly ($P < 0.01$) decreased protein yield in cultivars (Table 2). The highest decrease in protein yield as a result of B treatment was found in the Spok variety of 54.3 % while the lowest decrease was in the Pactol variety by 15.3 %.

In this research, the protein contents of the varieties used in the study varied between 20.48 % (Pactol) and 24.73 % (Helios). The highest decrease in protein content as a result of B treatment was found in the Star variety of 15.12 % while the lowest decrease was in the Spok variety by 5.71 %. The highest value in the study in terms of protein content was determined in the Helios variety by 24.73 % and the reaction of this variety to high B treatment emerged in the form of a 12.44 % decrease in protein content (data was not shown). Ilisulu (1970) stated that the commonest substance in canola seeds after oil was protein and that it generally constituted one-fifth of the seed. Weiss (1983) reported that protein content in canola seeds was 25 % on average. As some researches (Schuster, 1970; Atakişi, 1977) stated, although protein content may be affected by environmental conditions, they vary to a great extent depending on the genetic properties of variety.

The protein yield of canola is the combined expression of seed protein content and seed yield. Protein yield of canola cultivars was decreased with boron application because of decreased seed yield and protein content of canola cultivars with boron.

As a result of this research, Pactol and Star canola cultivars can be successfully grown under high B conditions without important oil and protein yield losses. Both cultivars can be considered B-inefficient. In addition, both cultivars may serve as suitable parental materials for the development of B-inefficient genotypes for B toxicity. Other cultivars showing sensitivity to B toxicity (e.g. Marinka, Briol, Spok and Semu) can be grown under normal B conditions for adequate crop yield.

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