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Full Length Research Paper

Response of common bean (*Phaseolus vulgaris* L.) cultivars to foliar and soil applied boron in boron-deficient calcareous soils

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Yield losses in common bean (*Phaseolus vulgaris* L.) may occur due to boron (B) deficiency when the susceptible cultivars are grown in calcareous boron deficient soils. The study was therefore aimed at investigating the effects of three B doses: control (0.0 kg ha^{-1}), soil application (3.0 kg ha^{-1}) and foliar fertilization (0.3 kg ha^{-1}) on yield and some yield components of six common bean genotypes in the B deficient soil (with available 0.19 mg B kg^{-1}). Plant height, pods per plant, seeds per pod, seed yield, protein content, 100-seed weight and B concentration in leaf were studied. Yield was obtained higher B applied genotypes than those of check. Applications both of soil and foliar B increased yield average of 10 and 20%, respectively. Genotypes had the highest seed yield when B was foliar applied indicating that soil factors affected available B. The highest seed yield was obtained from Karacaşehir-90 with 4078.2 kg ha^{-1}. Yunus-90 was found to be B tolerant, while the other genotypes appeared to be highly B sensitive. The result showed that B deficiency in common bean might lead to significant yield losses and foliar application should be advised.

Key words: Boron, common bean, foliar fertilization, seed yield, soil fertilization.

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is frequently consumed as dry beans and immature green pods, called snap beans. Dry bean is an important food staple worldwide and provides a significant source of protein, calories, vitamins, minerals, and fiber (Akcin, 1988). Seeds of beans are the most important protein and mineral food sources in the world, especially developing countries including Turkey. It is grown on 129051 ha areas and produced 195970 tons with 1520 kg ha^{-1} average yield. Its globally covered areas, production and yield are over 24 million ha, 18 million tones and 748 kg ha^{-1}, respectively (FAOSTAT, 2006). Considerable yield losses due to abiotic and biotic stresses were reported (Graham and Ranalli, 1997).

Boron (B)'s role within the plant includes cell wall synthesis, sugar transport, cell divison, differentiation, membrane functioning, root elongation, regulation of plant hormone levels and generative growth of plants (Marschner, 1995). B content in legumes is higher than other species. B is mobile in the xylem, but once it reaches the leaves, it becomes immobile. Hence, the first symptoms appear in the young part of plant. B deficiency does not impede bean development by slowing down activity in the meristematic tissue, but when deficiency is severe, it can kill the growing point because B strongly influences cell division (Oerili and Richardson, 1970). B is also recognized as a commonly deficient micronutrient in agriculture, with reports of deficiencies in 132 crops in 80 countries (Shorrocks, 1997). Currently it is estimated that about 26.6% of the soils in Central Southern Anatolian in Turkey are B deficient (Gezgin et al., 2002).

Soil-applied B at the optimal dose to 1 kg·ha^{-1} increases the length of pods, pods number per plant, and seed yield (Singh and Singh, 1990; Kotur, 1998; Janeczek et al., 2004). The exceeding dose of 1 kg B·ha^{-1} results in toxicity of for bean and B considerably reduces the plant weight, the number of plants per unit area and seed yield (Singh et al., 1989; Singh and Singh, 1990;

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Kotur, 1998). Although the effects of soil applied B fertilization on growth and yield of common bean (Singh and Singh, 1990; Kotur, 1998; Janeczek et al., 2004) has been investigated, limited studies have been performed of the response of common bean to foliar-applied B fertilization. This study was aimed at investigating the effect of B soil and foliar application on yield and some of the yield components of most commonly cultivated six dry beans on a typical Central Anatolian soil.

MATERIAL AND METHODS

The field experiments were carried out on a soil that contains 0.19 mg kg^{-1} extractable B using a 0.01 M Mannitol + 0.01 M $CaCl_2$ solution before reading in ICP-AES (Varian-Vista Model). The experiments were conducted during the 2002 and 2003 growing seasons at the Research Institute of Rural Affairs, Konya, Turkey. B content of the experimental soil is low according to critical levels for bean (Howeler et al., 1978). Common bean genotypes were Şehirali-90, Yunus-90, Karacaşehir-90, Önceler-90, Göynük-98 and Akman-98 registered by Anatolia Agricultural Research Institute, Eskişehir, Turkey. The genotypes are the most popular varieties, currently grown in Turkey.

The experiments were designed according to split-split plots of randomized complete blocks experimental design with four replications. B applications (control, 0 kg ha^{-1}; soil application of 3 kg ha^{-1} and foliar fertilization of 0.3 kg ha^{-1}) were placed on the main plots, whereas sub-plots contained dry bean genotypes. B soil application was sprayed on the soil surface using 0.86% H_3BO_3 solution, and then incorporated into soil depth of 10 - 15 cm prior to sowing. B foliar fertilization was applied in the form of 0.086% solution of H_3BO_3 at the flowering stages. Before sowing, 150 kg ha^{-1} was applied in the form of diammonium phosphate (18% N; 46% P_2O_5).

Seeds were sown by hand in the second week of May, 2002 and the third week of May, 2003. Each plot was 2.5 m width with 5 rows and 3 m length. Weeds were controlled by hand. In the both years, anthracnose (*Colletotrichum lindemuthianum* Sacc. et Magn.) was controlled with Propineb + Cymoxanil during pod formation stage. In the second year, Pirimicarb was used to control of bean aphid (*Aphis fabae* Scop.). Plants were irrigated with sprinkler irrigation system five times. Plots were harvested by hand both years in the second week of September. Three middle rows were harvested, after two outer rows from each plot were left.

Total rainfalls were recorded as 139.3 mm in 2002 and 49.5 mm in 2003. Seasonal average temperatures and average relative air humidity were 19.9°C and 47.2% in 2002 and 20.7°C and 38.4% in 2003. Monthly climatic data with a 20-year average were shown in Table 2.

Plant height, pods per plant and seeds per pod were measured on 10 randomly selected plants per plot at maturity. Seed yield was determined using all of the plants in the harvested area. 1000-seed weight was calculated according to Akcin (1974). Seeds were cleaned to remove foreign material and broken seeds before protein analysis. Protein contents were determined according to the Kjeldahl methods. Kjeldahl nitrogen values were multiplied by 6.25 to obtain crude protein values. During the pod formation stage, 30 leaves of each plot were collected and washed with water, and then samples were dried at 70°C for 48 h before dry weights measured. Samples were finely ground and 0.5 g plant material was digested with concentrate HNO_3 in a microwave system. The extracts were analyzed for B by ICP-AES (Varian-Vista Model) (Nyomora et al., 1997). Data were subjected to analysis of variation (ANOVA) using MSTAT-C. The least significant difference (LSD) test was used to compare the treatment means (Steel and Torrie, 1980).

Table 1. Physicochemical properties of topsoil samples (0 -30cm) collected from locations at experimental area (Gezgin et al., 2002).

Property	Mean	Property	Mean
Ph	7.6	Mg (me/100 g)	5.3
$CaCO_3$	20.7	K (me/100 g)	0.6
E.C (µScm^{-1})	94	Na (me/100 g)	0.13
Organic matter (%)	1. 4	P (mg kg^{-1})	8.5
Sand (%)	26.7	B (mg kg^{-1})	0.19
Silt (%)	68.1	Mn (mg kg^{-1})	2.3
Clay (%)	5.2	Zn (mg kg^{-1})	0.3
Ca (me/100 g)	20.2	Fe (mg kg^{-1})	0.4

RESULTS

ANOVA results

The years have been significant for seed yields, pods per plant, protein content and B concentration of the leaf (Tables 3, 4, 8 and 9). There were statistically significant differences within the genotypes for all traits (Tables 3, 4, 5, 6, 7, 8 and 9). Year by genotype interaction was significant for seed yield, 1000- seed weight and B concentration of the leaf (Tables 3, 7 and 9). B application had significant effect on the seed yield, 1000-seed weight, protein content and B concentration of the leaf (Tables 3, 7, 8 and 9). B application by genotype interaction was significant for seed yield, plant height and seeds per pod, 1000-seed weight, protein content and B concentration of the leaf (Tables 3, 5, 6, 7, 8 and 9). Significant interactions existed between year by B application for seed yield and B concentration of the leaf (Tables 3 and 9). Statistically significant B application by genotype by year interactions was observed for seed yield, 1000-seed weight and B concentration of the leaf (Tables 3, 7 and 9).

Seed yield

As seen in Table 3, the highest seed yield was obtained from B foliar application (4063.7 kg ha^{-1}) and followed by B soil application (3733.3 kg ha^{-1}). B applications in general increased seed yield in all common bean cultivars compared with check, whereas B soil application in Karacaşehir-90 had the highest yield. As average of years, the highest seed yield was obtained from Karacaşehir-90 (4078.2 kg ha^{-1}), whereas other varieties (Göynük-98, Akman-98, Yunus-90, Şehirali-90 and Öncüler-98) gave 3913.6, 3785.0, 3651.3, 3608.3 and 3356.2 kg ha^{-1}, respectively.

Pods per plant

As average of years, the highest pods per plant was obtained from Karacaşehir-90 (24.8) and followed by

Table 2. Total monthly rainfall, relative air humidity and mean air temperature during 2002 and 2003 growing seasons and 20-yr average.

Month	Rainfall (mm)			Relative Air Humidity (%)			Mean Air Temperature (°C)		
	2002	2003	20-year	2002	2003	20-year	2002	2003	20-year
May	22.9	30.6	39.8	53.9	47.0	56.0	15.2	17.2	15.4
June	15.3	2.3	26.5	47.5	34.9	46.9	19.8	21.2	19.8
July	27.1	0.0	8.1	39.8	32.6	39.3	24.1	23.6	23.3
August	8.7	0.0	7.4	42.0	32.4	41.6	22.2	23.6	23.0
September	65.3	16.6	6.5	52.6	45.1	42.9	18.1	18.0	18.6
Total/Mean	139.3	49.5	88.3	47.2	38.4	45.3	19.9	20.7	20.0

Table 3. Seed yield (kg ha^{-1}) of dry bean genotypes when grown in two consecutive years with three B application.

Year	Boron application	Genotypes						Mean
		Şehirali-90	Yunus -90	Karacaşehir-90	Önceler-98	Göynük-98	Akman-98	
2002	Control	3487.3 g-j	4141.8 bcd	3854.0 def	3104.3 k-n	3476.0 g-j	3613.0 e-h	3612.7 c
	Soil	3023.8 mn	3927.3 cde	4744.8 a	3439.0 g-k	4317.0 b	4366.3 b	3969.7 b
	Foliar	4864.8 a	4266.3 bc	4739.0 a	3929.0 cde	4365.8 b	4894.5 a	4509.9 a
	Mean	3791.9 cd	4111.8 b	4445.9 a	3490.8 def	4052.9 bc	4291.3 ab	4030.8
2003	Control	3535.5 f-ı	2867.3 n	3204.3 i-n	3005.0 mn	3445.5 g-k	3057.5 lmn	3185.8 d
	Soil	3339.0 h-m	3156.0 j-n	4301.3 b	3196.0 ı-n	3753.5 efg	3236.3 l-m	3497.0 c
	Foliar	3399.5 g-l	3549.5 f-ı	3625.8 e-h	3464.0 g-k	4124.0 bcd	3542.5 f-ı	3617.5 c
	Mean	3424.7 ef	3190.9 f	3710.4 de	3221.7 f	3774.3 cd	3278.8 f	3433.5
Mean	Control	3511.4 fg	3504.5 fg	3529.1 fg	3054.6 l	3460.8 fg	3335.3 gh	3399.3 c
	Soil	3181.4 hı	3541.6 fg	4523.0 a	3317.5 gh	4035.3 bcd	3801.3 de	3733.3 b
	Foliar	4132.1 bc	3907.9 cde	4182.4 b	3696.5 ef	4244.9 b	4218.5 b	4063.7 a
	Mean	3608.3 c	3651.3 c	4078.2 a	3356.2 d	3913.6 ab	3785.0 bc	
Variation (%)[a]	S/C	-10	1	28	9	17	14	10
	F/C	18	12	19	21	23	27	20
$LSD_{1\%}$[b]: B=10.47, G=21.85, Y x B=14.81, Y x G=30.90, B x G=25.66, Y x B x G=36.28								

[a] Variation (%) was expressed as percentage of the value at control to that at soil and foliar.
[b] Least significant difference for comparisons between individual means: B; G; Y x B; Y x G; B x G; Y x B x G indicate B applied main effect (B), genotype main effect (G), interaction of year with B applied (Y x B), interaction of year with genotype (Y x G), interaction of B applied with genotype (B x G), interaction of year with B applied and genotype (Y x B x G).

Akman-98 (24.2), Öncüler-98 (21.5), Şehirali-90 (21.0), Göynük-98 (20.7) and Yunus-90 (18.9). The foliar applied B resulted in the highest pods per plant (11 %) (Table 4).

Plant height

The highest mean plant height was obtained from Akman 98 (77.4 cm). On the other hand, the Şehirali-90 had the lowest plant height with 52.8 cm (Table 5). Average plant heights of genotypes increased by 4% in B soil application and 9% in B foliar application over control.

Seeds per pod

Karacaşehir-90 (5.9) had higher seeds per pod than the other cultivars. B applications in general increased seeds per pod in all common bean cultivars compared with check, whereas B foliar application in Önceler-98 and Şehirali-90 had the highest seeds per pod (Table 6).

1000-seed weight

The mean over two year indicate that Göynük-98 (432.8 g) had higher 1000-seed weight than the other cultivars. Compared to the check, B applications in general increased 1000-seed weights in all common bean cultivars, and B soil application in Karacaşehir-90 and Akman-98 had the highest 1000-seed weight genotype (Table 7).

Protein content

Based on mean of years and genotypes, the maximum

Table 4. Pods per plant (number) of dry bean genotypes when grown in two consecutive years with three B application.

Year	Boron application	Genotypes						Mean
		Şehirali-90	Yunus -90	Karacaşehir-90	Önceler-98	Göynük-98	Akman-98	
2002	Control	19.0	19.0	13.8	24.5	20.8	28.3	20.9
	Soil	24.5	18.0	24.8	23.0	26.0	23.5	23.3
	Foliar	23.3	19.5	37.8	20.3	21.5	27.8	25.0
	Mean	22.3	18.8	25.4	22.6	22.8	26.5	23.1
2003	Control	20.8	17.3	23.5	21.0	16.8	22.0	20.2
	Soil	23.3	18.8	25.0	21.5	18.5	21.0	21.3
	Foliar	15.5	21.0	24.3	18.5	20.8	22.5	20.4
	Mean	19.8	19.0	24.3	20.3	18.7	21.8	20.7
Mean	Control	19.9	18.1	18.6	22.8	18.8	25.1	20.5
	Soil	23.9	18.4	24.9	22.3	22.3	22.3	22.3
	Foliar	19.4	20.3	31.0	19.4	21.1	25.1	22.7
	Mean	21.0 bc	18.9 c	24.8 a	21.5 abc	20.7 bc	24.2 ab	
Variation (%)	S/C	20	1	34	-2	17	-11	9
	F/C	3	12	67	-15	12	1	11
$LSD_{5\%}$[b]: G =3.614								

[a]Variation (%) was expressed as percentage of the value at control to that at soil and foliar.
[b]Least significant difference for comparisons between individual means: G indicate genotype (G) main effect.

Table 5. Plant height (cm) of dry bean genotypes when grown in two consecutive years with three B application.

Year	Boron application	Genotypes						Mean
		Şehirali-90	Yunus -90	Karacaşehir-90	Önceler-98	Göynük-98	Akman-98	
2002	Control	58.8	56.0	79.0	63.5	59.3	87.0	67.3
	Soil	53.0	60.0	82.8	61.8	58.0	88.0	67.3
	Foliar	56.5	66.8	95.0	61.0	62.5	89.3	71.8
	Mean	56.1 cd	60.9 bc	85.6 a	62.1 bc	59.9 bc	88.1 a	68.8
2003	Control	51.0	50.8	48.0	50.8	63.0	62.0	54.3
	Soil	46.5	59.8	59.3	59.3	66.3	66.3	59.5
	Foliar	51.3	57.3	68.8	57.5	58.8	72.0	60.9
	Mean	49.6 d	55.9 cd	58.7 bc	55.8 cd	62.7 bc	66.8 b	58.2
Mean	Control	54.9 e-h	53.4 gh	63.5 cd	57.1 d-h	61.1 d-f	74.5 ab	60.8
	Soil	49.8 h	59.9 d-g	71.0 bc	60.5 d-g	62.1 de	77.1 ab	63.4
	Foliar	53.9 f-h	62.0 de	81.9 a	59.3 d-g	60.6 d-g	80.6 a	66.4
	Mean	52.8 c	58.4 bc	72.1 a	59.0 b	61.3 b	77.4 a	
Variation (%)	S/C	-9	12	12	6	2	4	4
	F/C	-2	16	29	4	-1	8	9
$LSD_{1\%}$[b]: B= 4.564, G=6.315, B x G=11.18								

[a]Variation (%) was expressed as percentage of the value at control to that at soil and foliar.
[b]Least significant difference for comparisons between individual means: B; G;
B x G indicate B applied main effect (B), genotype main effect (G), interaction of B applied with genotype (B x G).

protein content (21.68%) was obtained from control. Compared to the check, generally, B application decreased protein content in the genotypes (Table 8).

B concentration of the leaf

As average of the years and B applications, the highest B

Table 6. Seeds per pod (number) of dry bean genotypes when grown in two consecutive years with three B application.

Year	Boron application	Genotypes						Mean
		Şehirali-90	Yunus -90	Karacaşehir-90	Önceler-98	Göynük-98	Akman-98	
2002	Control	4.3	4.3	6.3	4.5	4.8	5.3	4.9
	Soil	5.0	4.0	6.5	4.0	4.8	5.0	4.9
	Foliar	5.0	4.3	5.8	5.5	4.3	4.8	4.9
	Mean	4.8	4.2	6.2	4.7	4.6	5.0	4.9
2003	Control	4.0	3.5	6.0	3.5	5.0	4.8	4.5
	Soil	4.5	4.8	5.5	5.0	4.5	4.0	4.7
	Foliar	5.0	4.5	5.5	4.8	4.3	4.3	4.7
	Mean	4.5	4.3	5.7	4.4	4.6	4.3	4.6
Mean	Control	4.1 e-f	3.9 g	6.1 a	4.0 fg	4.9 b-e	5.0 b-d	4.7
	Soil	4.8 c-f	4.4 c-g	6.0 a	4.5 c-g	4.6 c-g	4.5 c-g	4.8
	Foliar	5.0 b-d	4.4 c-g	5.6 ab	5.1 bc	4.3 d-g	4.5 c-g	4.8
	Mean	4.6 b	4.2 b	5.9 a	4.5 b	4.6 b	4.7 b	
Variation (%)	S/C	17	13	-2	13	-6	-10	2
	F/C	21	13	-8	28	-12	-10	2
$LSD_{1\%}$[b]: G=0.643; $LSD_{5\%}$: B x G=0.764								

[a]Variation (%) was expressed as percentage of the value at control to that at soil and foliar.
[b]Least significant difference for comparisons between individual means: G; B x G indicate genotype main effect (G), interaction of B applied with genotype (B x G).

Table 7. Thousand seed weight (g) of dry bean genotypes when grown in two consecutive years with three B application.

Year	Boron application	Genotypes						Mean
		Şehirali-90	Yunus -90	Karacaşehir-90	Önceler-98	Göynük-98	Akman-98	
2002	Control	381.2 f-h	378.7 g-i	182.5 o	252.8 n	426.9 b-d	293.0 lm	319.2
	Soil	370.3 hi	383.6 f-h	189.3 o	295.7 lm	442.9 a-c	299.3 k-m	330.2
	Foliar	382.1 f-h	386.3 f-h	183.4 o	302.8 kl	416.0 c-e	302.5 k-m	328.9
	Mean	377.8 c	382.9 c	185.1 g	283.8 e	428.6 a	298.3 e	326.1
2003	Control	423.7 b-e	397.0 e-h	178.6 o	325.7 jk	417.9 c-e	259.0 n	333.6
	Soil	427.1 b-d	402.3 d-g	186.8 o	304.3 kl	429.4 b-d	273.7 mn	337.3
	Foliar	449.5 ab	408.8 d-f	174.4 o	351.3 ıj	463.9 a	258.1 n	351.0
	Mean	433.4 a	402.7 b	179.9 g	327.1 d	437.0 a	263.6 f	340.6
Mean	Control	402.4 cde	387.8 e	180.5 i	289.2 gh	422.4 abc	276.0 h	326.4 b
	Soil	398.7 de	392.9 e	188.1 i	300.0 g	436.2 ab	286.5 gh	333.7 ab
	Foliar	415..8 bcd	397.5 de	178.9 i	327.1 f	439.9 a	280.3 gh	339.9 a
	Mean	405.6 b	392.8 c	182.5 f	305.4 d	432.8 a	280.9 e	
Variation (%)	S/C	-1	1	4	4	3	4	2
	F/C	3	3	-1	13	4	2	4
$LSD_{1\%}$[b]: B=9.21, G=11.58, Y x G=16.37, Y x B x G=31.89								

[a]Variation (%) was expressed as percentage of the value at control to that at soil and foliar.
[b]Least significant difference for comparisons between individual means: B; G; Y x G; Y x B x G indicate B applied main effect (B), genotype main effect (G), interaction of year with B applied (Y x B), interaction of year with genotype (Y x G), interaction of B applied with genotype (B x G), interaction of year with B applied and genotype (Y x B x G).

concentration of the leaf was obtained from (50.5 mg kg^{-1}) Yunus-90. All genotypes showed significant concentration of the leaf increases when applicated with B. Genotypic means revealed that foliar applied B resulted 37% B concentration of the leaf increase, whereas 12% B concentrations of the leaf increases were recorded at soil applied B over the control. B applications in general increased B concentrations of the leaf in all common bean

Table 8. Protein content (%) of dry bean genotypes when grown in two consecutive years with three B application.

Year	Boron application	Genotypes						Mean
		Şehirali-90	Yunus -90	Karacaşehir	Önceler-98	Göynük-98	Akman-98	
2002	Control	20.88	20.69	27.31	19.81	21.98	20.93	21.93
	Soil	20.41	20.52	22.93	19.26	21.94	20.49	20.93
	Foliar	20.76	19.78	21.92	20.67	20.37	20.42	20.65
	Mean	20.68	20.33	24.05	19.91	21.43	20.61	21.17
2003	Control	20.52	20.47	27.00	18.66	20.76	21.14	21.42
	Soil	19.80	20.34	23.48	19.38	20.97	19.68	20.61
	Foliar	20.02	19.69	21.26	20.47	19.82	20.50	20.29
	Mean	20.11	20.16	23.91	19.50	20.51	20.44	20.77
Mean	Control	20.70 def	20.58 ef	27.15 a	19.24 h	21.37 cd	21.03 cde	21.68 a
	Soil	20.11 fg	20.43 efg	23.21 b	19.32 h	21.46 c	20.09 fg	20.77 b
	Foliar	20.36 efg	19.73 gh	21.59 c	20.57 ef	20.09 fg	20.46 efg	20.47 b
	Mean	20.40 c	20.25 c	23.98 a	19.71 d	20.97 b	20.53 c	
Variation (%)	S/C	-3	-1	-14	1	1	-4	-4
	F/C	-1	-4	-20	7	-6	-3	-6
$LSD_{1\%}$[b]: B=0.319, G=0.426, B x G=0.780								

[a]Variation (%) was expressed as percentage of the value at control to that at soil and foliar.
[b]Least significant difference for comparisons between individual means: B; G; B x G indicate B applied main effect (B), genotype main effect (G), interaction of B applied with genotype (B x G).

Table 9. B concentration ($mgkg^{-1}$) of dry bean genotypes when grown in two consecutive years with three B application.

Year	Boron application	Genotypes						Mean
		Şehirali-90	Yunus -90	Karacaşehir-90	Önceler-98	Göynük-98	Akman-98	
2002	Control	35.9 n-q	50.8 d-g	41.0 j-o	41.7 i-n	46.6 f-j	39.2 k-p	42.5 c
	Soil	50.1 d-h	45.1 f-k	54.6 de	40.2 j-o	43.4 h-m	56.3 d	48.3 b
	Foliar	66.0 c	86.3 a	75.9 b	44.9 f-k	66.3 c	77.9 b	69.6 a
	Mean	50.7 b	60.7 a	57.2 a	42.3 cd	52.10 b	57.8 a	53.5
2003	Control	30.9 q	38.1 l-p	32.5 pq	37.1 m-q	41.5 i-n	32.4 pq	35.4 e
	Soil	40.8 j-o	38.7 k-p	38.6 k-p	44.5 g-l	34.4 o-q	35.4 n-q	38.7 d
	Foliar	51.0 d-g	51.4 d-f	44.3 g-l	48.3 e-ı	44.5 g-l	44.7 f-l	47.3 b
	Mean	40.7 cde	42.7 c	38.5 de	43.3 c	40.2 cde	37.5 e	40.1
Mean	Control	33.3 h	44.4 d	36.8 gh	39.4 efg	44.1 de	35.8 gh	39.0 c
	Soil	45.4 d	41.9 def	46.6 d	42.3 def	38.9 fg	45.8 d	43.5 b
	Foliar	58.4 bc	68.8 a	60.1 bc	46.6 d	55.4 c	61.3 b	53.4 a
	Mean	45.7 b	51.7 a	47.8 b	42.8 c	46.1 b	47.6 b	
Variation (%)	S/C	36	-5	27	7	-12	28	12
	F/C	75	54	63	18	27	71	37
$LSD_{1\%}$[b]: B=1.986, G=2.472, Y x B=2.809, Y x G=3.495, B x G=4.865, Y x B x G=6.881								

[a]Variation (%) was expressed as percentage of the value at control to that at soil and foliar.
[b]Least significant difference for comparisons between individual means: B; G; Y x B; Y x G; B x G; Y x B x G indicate B applied main effect (B), genotype main effect (G), interaction of year with B applied (Y x B), interaction of year with genotype (Y x G), interaction of B applied with genotype (B x G), interaction of year with B applied and genotype (Y x B x G).

cultivars compared with check. B foliar application in Yunus-90, Akman-98 and Karacaşehir-90 had the highest B concentrations of the leaf (Table 9).

DISCUSSION

Seed yields of all cultivars were higher in the first year

than the second year (Table 2) since higher total rainfall was recorded in the first year than the second year (Table 1). According to Akcin (1988), the optimal temperature and minimum relative air humidity significantly decreased seed yield. High air temperature and low relative air humidity results in a poor pod setting and flower abortion. Jareczek et al. (2004) reported that weather considerably affected the seed yield.

As reported by Shorrocks (1997), low B soils are common throughout the world and B deficiency in leguminous was reported in many countries, e.g. China, India, Nepal and Bangladesh (Anantawiroon et al., 1997) and Turkey (Gezgin et al., 2002). The soil and foliar fertilization with boron had favorable effect on the seed yield and yield components of bean (Padma et al., 1989a; Padma et al., 1989b; Sing and Sing, 1990), while the highest increases in the seed yield were recorded with B foliar application of 0.3 kg B ha^{-1}. The B foliar application resulted in the highest seed yields (20%) when compared with soil application (Table 3).

Common bean genotypes had shown significant variability to B application in B deficient soils in the present research. Higher seed yields were obtained from all genotypes with B applications when compared with the control. B soil and foliar applications increased yield average of 10 and 20%, respectively. Kotur (1998) reported that B soil application to soil of 1 kg ha^{-1} increased seed yield in common bean. Similarly, Sing and Sing (1990) and Ceyhan et al. (2007) reported that B application in B deficient soils increased seed yields of bean genotypes. The results of our experiments were in agreement with the findings of Jareczek et al. (2004).

Among bean cultivars, Karacaşehir-90, Göynük-98 and Akman-98 were determined as the most B sensitive cultivars. Şehirali-90 can be an indicator cultivar in experiments for testing B sensitivity of bean genotypes. Janeczek et al. (2004) reported that B increased the 1000-seed weight of common bean. B application increased the pods per plant and seeds per pod (Padma et al., 1989b; Kotur, 1998; Janeczek et al., 2004; Ceyhan et al., 2007).

Padma et al. (1989ab) and Ceyhan et al. (2007) recorded that B application increased plant height of bean and chickpea genotypes. Yunus -90, Karacasehir-90, Akman-98 and Göynük-98 had the highest response to B application indicating that these cultivars could be sensitive to B deficiency. In contrast, Şehirali-90 was tolerant of B deficiency since it had negative response to seed yield.

The B application x cultivar interaction with respect to the protein content was significant. Protein content reduced in the all cultivars after B application. Otherwise B application did not affect protein content as stated Janeczek et al. (2004).

B deficiency symptoms were not observed in control plants, as they contained more than 30 mg B kg^{-1}, which was reported as a critical level for leaves (Wilcox and Fageria, 1976). Boron application increased the B concentration of the leaf. The B concentration of the leaf increased 12% in the B soil application and 37% for B foliar application when compared to the control. The best genotypic responses to B applications were obtained from Yunus-90, Akman-98 and Karacaşehir-90. The results showed that B concentrations in leaves could predict the seed yield of the bean cultivars.

Conclusions

Karacaşehir-90, Akman-98, Göynük-98 responded positively to B fertilization in field experiments while the lowest positive response was obtained from the Yunus-90 cultivar. Yunus-90 can be grown successfully without B fertilization due to its tolerance to B deficient. The other genotypes were found to be sensitive to B deficiency and these cultivars must be fertilized with B for adequate yield.

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