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EFFECTS OF DIFFERENT BORON APPLICATIONS ON SEED YIELD AND SOME AGRONOMICAL CHARACTERISTICS OF RED LENTIL

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ABSTRACT

The purpose of the study was to determine the effect of different boron application methods on grain yield and some agricultural properties of Sakar red lentil variety (*Lens culinaris* Medic.). The study was conducted in 2018-2019 and 2019-2020 growing years in the boron lack areas of Sanliurfa in Turkey. Experimental design was randomized complete block design with four replicates. Borax and Sakar lentil variety were used as Boron source and plant material, respectively. The methods of applying boron were control (0 kg B da^{-1}), to soil (0.20 kg B da^{-1}), to foliar spraying (when plants had 5-6 leaves 0.05 kg da^{-1} B and had pre-flowering period 0.05 kg da^{-1}B) and to soil+foliar application (to soil 0.10 kg B da^{-1} + to foliar when plants had 5-6 leaves 0.05 kg da^{-1} B and had pre-flowering period 0.05 kg da^{-1} B). According to average of two years; the highest seed yield was obtained from soil + foliar applications (198.57 kg da^{-1}). Also, the highest plant height (42.49 cm), thousand seed weight (41.80 g), biological yield (582.96 g m^{-2}) values were seen on soil + foliar applications. Protein content of seed (33.29 %) and the boron content of seed (19.09 mg kg^{-1}) values increased with boron applications. The most effective boron application method was determined as soil + foliar boron application but other application methods were more effective than control applications.

Keywords*: Boron, foliar application, grain yield, red lentil, soil application*

INTRODUCTION

Lentil is one of the best and the cheapest vegetable protein sources. Because it contains about 25% protein, 1.0% fat and 56% carbohydrate in seeds and also provides a significant amount of vitamin A and B (Grusak et al., 2016). On the other hand, lentil plants may adapt extreme climate conditions such as drought. For this reason, lentil is of great importance in arid climate regions due to obtaining acceptable yield. It is also being able to grow in soil types with poor fertility. Lentils have an important place in crop rotation to maintain soil fertility and root nodules. They can fix atmospheric nitrogen by symbiotic rhizobia.

In order to meet the world need of red lentils with an increasing population, it is necessary to increase the amount of yield per unit area. One way to rise the yield is to supply that the plant nutrition. Fertilizers and soil fertility play a major role for obtaining a higher yield (Rahman et al., 2013). It's known that macro and micro nutrients play a large role in plant growing. Especially micro nutrient deficiencies can reduce the yield and quality of the crop. So, soil nutrient content must be known and macro and micro nutrients must be applied as to the soil, leaves or both of them for obtaining higher yield.

Micro-element deficiencies are much higher than estimated in the world and also in lentil grown areas. It is known that, even though the lack of micro elements in plants is not evident, micro element applications result in significant increases in productivity (Oktem et al., 2012).

Abid et al. (2017) specified that the treatment of micro nutrient fertilizer increases the lentil quality (protein %) and quantity of grain yield in arid region. Chakraborty (2009), emphasized that micronutrient application along with macronutrients could prove advantageous in increasing the grain yield of lentil in the weak soils of the dry areas.

Boron is a micronutrient that insufficiency in culture plants is more common than in other trace element deficiencies (Demirtas, 2005).

Lack of boron in the soil is one of the worldwide problem for plant growing and the boron defect has been explained in 132 countries in 80 plant varieties included lentil (Oktem, 2020). Many researchers have found that seed yield and also quality are positively affected appropriate level of boron applications. Boron intake was reduced under poor soil nutrient and drought stress conditions. Most of the boron in soil is found in organic matter. For this reason, soil boron deficiency encountered in low soil organic matter (Schulin et al., 2010). Soils with low organic matters content are more sensitive to boron deficiency because existent boron is released from organic matter (Dear and Weir, 2004). Boron affects generative growth more than vegetative growth in plants and boron accelerates flower formation and bud development. Tariq and Mott (2007) reported that dicotyledons plants require more boron than monocotyledon, because the roots of dicotyledons have a higher capacity to adsorb boron than roots of monocotyledons.

Yagmur and Kaydan (2005) reported that a 26% gain in seed yield was seen with foliar application of boron in lentils. In another study, Khurana and Arora (2012) reported that seed yield was increased by 21.4-23.3% with application of 0.75 B kg ha^{-1} boron applications. Quddus et al. (2014) explained that the highest seed yield obtained from 1.5 kg ha^{-1} boron application. Yang et al. (2009) emphasized that treatment of boron to soil rise seed yield as 46% compared to control in rapeseed. Kumar et al. (2018) said that grain yield of legumes was affected by positively 0.5 and 2.5 kg B da^{-1} of dosage. Halder et al. (2007) emphasized that the highest grain yield and 1000 kernel weight were obtained from 2 kg B ha^{-1}. Khan et al. (2019) explained that when nutrients applied on foliar, they get very quickly and directly to the leaf cells and because of that effect is very high. On the other hand, Nagula et al. (2015) stressed that the application of boron through soil or foliar application was found to be beneficial in stimulating plant growth and yield. Gupta and Solanki (2013) reported that the only way to accomplish the boron deficiency is its external application and it can be water soluable and sprayed on to the crop or the soil.

Boron deficiency appears in the vast majority of lentil growing areas in arid climate conditions such as the Southeastern Anatolia Region in Turkey where this study was conducted. Low organic matter content and boron deficiency at the soil are very common in Southeastern Anatolia Region. Oktem and Oktem (2006) reported that boron deficiency was found at 95% analyzed soil sample of Southeastern Anatolia Region. Boron levels of experiment area were 0.217 and 0.265 mg kg^{-1} in 2018 and 2019, respectively. These boron levels were below 0.5 mg kg^{-1} critical limit of boron in the soil (Vista et al., 2019).

This study, to determine the effect of different boron application methods to seed yield and some agricultural properties of Sakar red lentil cultivar. The study was carried out especially in areas with boron deficiency and in rain-fed conditions. Supplemental irrigation was not done during the growing period.

MATERIALS AND METHODS

Description of the Experimental Sites

The research was conducted in 2018-2019 and 2019-2020 for winter growth periods in Sanliurfa, Turkey.

Some of the chemical properties of the research area are shown in Table 1. The soil of the experiment area was clay, slightly alkaline and very low in salt content and organic matter. The research was set up in boron deficit soils of Sanliurfa Region. In both treatment years, soil samples were taken previous to seeding from the experiment land and some chemical characters of the soil were analyzed using the method that described by Jackson (2005). The soil characteristics of the trial area for 2018-19 and 2019-20 years were given in Table 2. It is clearly seen from table that boron levels of research area were below 0.5 mg kg^{-1} that was critical limit of boron in the soil.

Table 1. Some chemical properties of soil research area (0-20 cm)

Years	Saturation (%)	Total salt (%)	pH	Lime (%)	K_2O (kg da^{-1})	P_2O_5 (kg da^{-1})	Org. Mat. (%)	AvailableB (mg kg^{-1})
2018/19	59	0.80	7.79	26.3	133.4	4.23	0.48	0.217
2019/20	63	0.72	7.86	24.7	101.9	5.08	0.60	0.265

Table 2. Some meteorological data of Sanliurfa

Year	Parameters	**1**	**2**	**3**	**4**	**5**	**6**	**10**	**11**	**12**
	Max.Temp. (^{0}C)	17.8	18.9	26.8	32.1	36.3	43.1	34.2	27.5	18.2
	Min.Temp. (^{0}C)	2.0	4.1	6.1	9.3	12.2	16.2	9.3	5.4	0.5
	Av.Temp. (^{0}C)	8.1	10.4	15.5	19.9	23.0	28.6	21.6	13.0	8.6
2018	Av.Humidity (%)	67.0	68.2	52.9	38.4	50.1	36.6	45.6	72.5	84.9
	Rainfall (mm)	118.9	87.4	13.3	35.8	64.5	10.1	45.6	72.5	84.9
	Max.Temp. (^{0}C)	17.2	18.6	22.1	26.8	40.3	44.1	36.2	27.5	22.4
	Min Temp. (^{0}C)	-1.2	2.2	1.9	5.9	10.1	18.5	11.3	5.9	4.5
	Av.Temp. (^{0}C)	6.1	8.3	10.7	14.4	25.2	30.7	22.9	14.8	9.0
2019	Av. Humidity (%)	76.4	71.7	69.5	67.0	35.8	30.6	44.9	42.3	79.4
	Rainfall (mm)	113.8	83.8	156.7	97.4	7.3	9.9	45.1	6.7	277.7
	Max.Temp. (^{0}C)	14.0	19.4	24.7	29.4	38.0	41.6	34.2	26.1	18.7
	Min. Temp. (^{0}C)	0.2	-5.8	3.6	4.8	11.1	15.3	16.1	5.6	0.5
	Av.Temp. (^{0}C)	6.6	7.0	13.3	17.1	23.2	28.9	24.0	13.5	9.4
2020	Av. Humidity (%)	69.1	63.4	63.6	54.2	41.0	29.9	27.5	60.9	61.5
	Rainfall (mm)	76.9	24.1	90.8	68.3	39.1	0.4	0.0	84.3	17.9

Months; 1 January, 2 February, 3 March, 4 April, 5 May, 6 June, 10 October, 11 November, 12 December.
Data collected from Sanliurfa Meteorological Station (Anonymous, 2021)

Some climatic properties of the experiment area are shown in Table 2. It is seen from the detailed climatic data from Table that the weather was usually warm during winter months and rainfall were rare. During the time session for the research the most rainfall was seen on December of 2019.

Experimental Design and Treatments

Borax ($Na_2B_4O_7 10H_2O$, 11% B) was used as the boron source and Sakar red lentil variety also was used as plant substance in the research. The experimental design was the Randomized Complete Block Design (RCBD) with four replications. Boron applications consist of control (0 kg B ha^{-1}), for soil, on foliar and soil + foliar applications. Application methods and the amount of boron are given Table 3. Soil applications of boron were applied to soil before planting and mixed to soil. Foliar applications of boron were sprayed to leaves (Table 3).

Table 3. Boron application methods

Boron Applications	Application Time and Methods
Control	Without boron application
Soil	Before planting (0.2 kg da $^{-1}$B) sprayed to soil
Foliar	When plants has 5-6 leaves (0.1 kg da^{-1} B) + at pre-flowering period (0.1 kg da^{-1} B) sprayed to foliar
Soil + Foliar	0.1 kg da^{-1} B to soil + when plants had 5-6 leaves (0.05 kg da^{-1} B) + at pre-flowering period (0.05 kg da^{-1} B) sprayed soil and foliar

After the wheat harvest, which was the primary plant, the experiment area was plowed firstly and cultivated, then prepared for planting with a single pass of a disk-harrow. Planting dates were 30th November and 26th December for 2018 and 2019. Seed amount was 90 kg ha^{-1} for two years. Pneumatic seeder had been used in the planting. Plot sizes were 6 m x 1.6 m and each parcel had of 8 rows. Space between rows was 20 cm and an intra row space was 3-4 cm. Lentil seeds were planted at a 4-5 cm depth.

Nitrogen and phosphorus amounts of soil was identified before planting. Considering the amount of nitrogen and phosphorus in the soil, fertilization amount was completed to 6 kg da^{-1} N, 6 kg da^{-1} P_2O_5 (Oktem et al., 2011). Fertilizers of phosphorous and nitrogen were given with sowing as a banded. 20-20-0 fertilizer was used as phosphorous and nitrogen sources. The banded fertilizers were 50 mm to the side and 50 mm below the seed. Mechanical struggle was made against to weeds.

Lentil harvest was done by hand. Harvest dates were 28th May and 23rd May in 2019 and 2020, respectively. One row from right and left side and 0.5 m from the beginning and also end of the plot were not harvested because of plots' edge effect. After harvesting of plants from the plots, lentils yield was calculated per decar.

Statistical Analyses

Analyses of boron were extracted with hot water and defined by azomethine-H technique and also boron content in soil and seed was determined using same method (Kacar and Inal, 2008). The standard analysis of variance technics was used to analyzed the data and the combined analysis of variance (ANOVA) over two years was performed to obtain the interaction component. Least Significant Difference (LSD) test was made to determine differences between boron levels using the Mstat-C™ statistical software (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Thousand Seed Weight (g)

According to analysis of the variance, thousand seed weight value was statistically significant ($P \leq 0.01$) at year, boron treatments and year x boron treatment interaction (Table 4). The highest value of the thousand seed weight was observed at soil + foliar boron applications in both years (41.53 and 42.06 g) respectively. The lowest thousand seed weight was found in control applications at all treatment years (Table 4). At the average of two years, the highest thousand seed weight value was seen at soil + foliar boron application (41.80 g), while the lowest one was found at control applications (39.25 g).

Thousand seed weights depend on climatic factors and variety (Saracoglu and Oktem, 2021), but some agronomic activity such as fertilization can effect this value (Oktem and Oktem, 2020). In this research the thousand seed weight was affected positively from boron applications. This result may be due to better starch utilization resulting in increased grain set and grain development which improves grain size. Our findings are consistent with the findings of some researchers. Quddus et al. (2014) clarified that thousand seed weights were found significant variation with different levels of boron application and also the highest thousand seed weight was recorded at 1.5 kg B ha^{-1}. Hakkoymaz et al. (2006) reported that 3.75 kg da^{-1} B level in lentils gave the highest value of thousand seed weight. In a similar research the highest thousand seed weight values were obtained from the application of 0.2 kg B da^{-1} (Oktem et al., 2012).

Biological Yield (g m^{-2})

Biological yield value was found to be statistically significant ($P \leq 0.01$) at year, boron treatments and year x boron treatment interaction. As can be understood from

Table 4 the average values of biological yield ranged from 528.92 g m^{-2} to 582.96 g m^{-2} by boron applications. Biological yield generally depends on year and environmental conditions (Oktem and Oktem, 2019b). The lowest biological yield value was obtained from control while the highest value was found at soil + leaf applications.

Table 4. Thousand seed weight and biological yield values and LSD groups at the boron applications

Boron Applications	Thousand Seed Weight (g)			Biological Yield (g m^{-2})		
	2018/19	2019/20	Average	2018/19	2019/20	Average
Control	38.75 e†	39.76 d	39.25 C	456.46 g†	601.37 d	528.92 D
Soil	39.33 d	41.53 b	40.43 B	493.12 f	614.45 c	553.78 C
Foliar	40.94 c	42.02 ab	41.48 A	506.20 e	633.62 b	569.91 B
Soil + Foliar	41.53 b	42.06 a	41.80 A	507.90 e	658.01 a	582.96 A
Year Ave.	40.14 B	41.34 A	40.74	490.92 B	626.86 A	558.89
Year		**			**	
Boron (B)		**			**	
Year X B		**			**	

†: There is no significant difference between the averages entering the same letter group compared to the LSD test at 0.05 level.
**: Significant at the P≤ 0.01 probability levels

Some researchers have reported that treatment of B improves physiological processes in plant, resulting in enhanced growth and dry matter production (Asad and Rafique, 2000; Hussain et al., 2002). For this reason, it is thought that boron applications may have increased the biological yield of lentils. Boron application of soil + leaf was the most effective methods on biological yield.

Plant Height (cm)

The effect of different boron application methods on plant height was found to be statistically significant (P≤0.01). Plant height values varied between 37.51 cm (control) and 42.49 cm (soil + foliar applications) at the average of two years. The maximum values of the plant height were obtained from the addition of soil+ foliar while the lowest values were seen at control applications (Table 5).

Table 5. Plant height, seed yield, protein content values and LSD groups at the boron applications

Boron Applications	Plant Height** (cm)	Seed Yield** (kg da^{-1})	Protein Content ** (%)
Control	37.51 d	161.47 d	27.46 d†
Soil	39.75 c	179.32 c	29.98 c
Foliar	41.10 b	193.93 b	31.83 b
Soil + Foliar	42.49 a	198.57 a	33.29 a
Year Aver.	40.22	183.32	30.64

**: Significant at the P≤ 0.01 probability levels

Although the value of the plant height is characteristic of the variety, it can affect by the climate and growing conditions like fertilization (Khald and Oktem, 2021). In this study, the value of the plant height was positively affected by boron applications. Some researchers explained that boron applications positively affected the plant height. Dixit and Elamathi (2007) reported that boron application of 2 % significantly improved the plant height. Kaisher et al. (2010) emphasized that application of 0.5 kg da $^{-1}$ B significantly increased plant height. It was explained that significantly higher plant height with foliar application of boron (Praveena et al., 2018).

Seed Yield (kg da^{-1})

Boron application increased seed yield (Figure 1). The highest seed yield was obtained from soil + foliar in the first and second treat years, respectively (194.28 kg ha^{-1} and 201.85 kg ha^{-1}) while the lowest value was found without boron parcels in both experiment years (156.12 kg da^{-1} and 166.33 kg da^{-1}, respectively). Soil + foliar boron application (198.57 kg da^{-1}) gave the highest seed yield value, while the lowest value was obtained from control applications (161.47 kg da^{-1}) at the average of two years (Table 5).

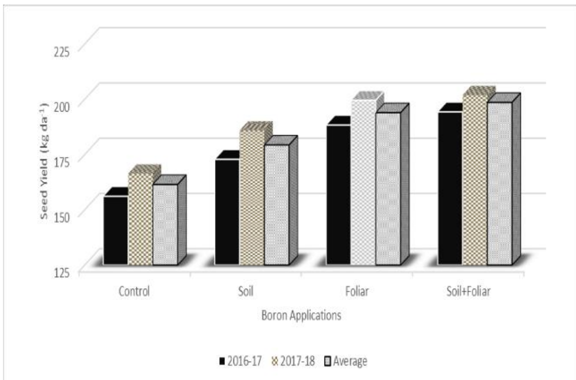

Figure 1. Seed yield values at different boron applications

Lentil cultivation is depending on rainfall in dry areas and seed yield increases in regular rainfall conditions. On the other hand, boron deficiency is often seen when the soil is calcareous and has low organic matter content. In addition, arid climatic conditions play a positive role occurring of boron deficiency. For this reason, when the sufficient amount of boron is applied to this type of soil, the seed yield increases. All these negative factors such as low rainfall, low organic matter and high calcareous are seen at our research area. Our findings are supported by Zengin (2012) who explained that boron deficiency in the soil can be eliminated by boron applications.

All boron application methods had a positive impact on seed yield and the most appropriate method was obtained from soil + foliar boron application. Our study was supported by some researchers' findings. Khurana and Arora (2012) observed that seed yield raised 25% over with the application of boron. It was reported that boron effected seed yield positively in lentil (Srivastava et al., 2000). In a similar study, Quddus et al. (2014) explained that the seed yield increased 13.8% with 1.5 kg ha^{-1} boron application according to control. Sakal et al. (2000) reported that lentils seed yield increased about 75 kg da^{-1} according the control applications with 1.5 kg ha^{-1} B applications in the calcareous soil. It was reported that 21 kg da^{-1} over seed yield obtained than control applications when 0.15 kg da^{-1} boron applied to lentils in calcareous soils (Kumar et al., 2018). It was explained that the highest wheat yield obtained from 2 kg ha^{-1} boron application which was 66% higher than control applications (Halder et al., 2007).

Protein Content of Seed (%)

Boron application methods were significant for protein content of seed at the P≤ 0.01 (Table 5). The highest protein content of seed was found at soil + foliar application (32.63 % and 33.94 % respectively) while the lowest values were seen in the control applications during two years (Figure 2). According to average of two years, the highest protein content of seed value was obtained from soil + foliar applications (33.29%), whereas the lowest one was seen at control applications (27.46%). Protein content of seed was higher at the first year than second year. In the second treatment year, the protein content of the seed may have increased due to climatic factors. During this research rainfall was lower growing season of 2019-2020 than 2018-2019. In addition, all boron applications also affected protein content of seed positively. Oktem and Oktem (2019a) reported that the protein content of the kernel increased with water stress. As the water stress increases, the protein content of the grain also increases (Oktem, 2008a; Oktem, 2008b). Some researchers have reported that boron is essential for some physiological functions of the plant such as carbohydrate and protein metabolism and also it plays an important role in protein synthesis of legumes (Kulhary et al., 2017; Naqib and Jahan, 2017). In addition, Moshiul et al. (2018) observed that agronomic bio fortification with like B increased the seed protein content of legumes. When boron is applied to soils that are deficient in boron content, the seed protein content increases. This may be due to the positive effects of boron on nodule improvement and nitrogen fixation in the roots.

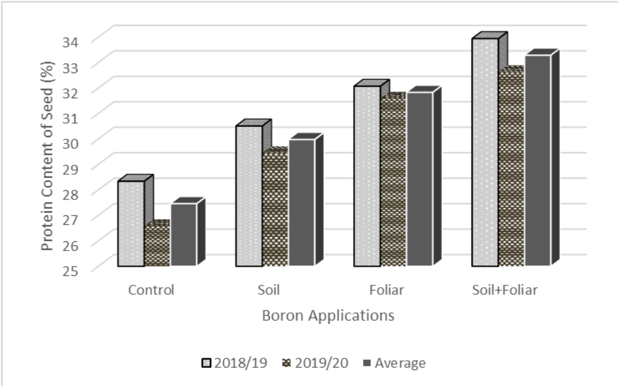

Figure 2. Protein content of seed values at different boron applications

Our results are in a good accord with some researchers' findings. Bayrak et al. (2005) said that boron fertilization to soil increased protein content of seed. Quddus et al. (2014) explained that B concentrations of seed for lentil were significant influenced by B treatment indicating that the B played a favorable role on protein synthesis. And also Singh and Singh (2014) reported that boron application with 1 kg ha^{-1} dosage to soil improved protein content in seeds.

Boron Content of Seed (mg kg^{-1})

According to the analysis of variance the boron content of seed was significant (P≤0.01) at year, boron application methods and boron x year interaction (Table 6). As can be seen from Table 6 that the boron content in the seed was the lowest in the control applications (11.79 and 13.80 mg kg^{-1}) in both years while the highest values were obtained from soil + foliar applications (18.37 mg kg^{-1} and 19.81 mg kg^{-1}). The highest boron content of seed was seen at soil + foliar applications (19.09 mg kg^{-1}) at the average of two years, while the lowest value was found at control applications (12.80 mg kg^{-1}).Boron content in the seed increased with all boron application methods. It has been reported that boron increased the boron content of lentil seed (Khurana and Arora, 2012). In another research it was stressed that B fertilization to soil increased boron content of lentil seed (Johnson et al., 2005).

Table 6. Boron content values and LSD groups at the boron applications.

Boron Applications	Boron content of seed (mg kg^{-1})		
	2018/19	2019/20	Average
Control	11.79 f	13.80 e	12.80 D
Soil	15.09 d	15.42 d	15.25 C
Leaf	16.47 c	17.76 b	17.12 B
Soil + Foliar	18.37 b	19.81 a	19.09 A
Year Aver.	15.43 B	16.70 A	16.07
Year		**	
Boron (B)		**	
Year X B		**	

†: There is no significant difference between the averages entering the same letter group compared to the LSD test at 0.05 level.
**: Significant at the P≤ 0.01 probability levels

CONCLUSION

All tested characteristics were positively affected by boron application methods. According to an average of two experiment years, the highest seed yield was found at soil + foliar applications (198.57 kg da^{-1}). Also the highest plant height (42.49 cm), thousand seed weight (41.80 g), biological yield (582.96 g/m^2) values were seen in soil + foliar applications. According to average of two years, protein content of seed (33.29%) and boron content of seed (19.09 mg kg^{-1}) values increased with boron applications. All applications of boron gave a higher seed yield than control applications. The most effective boron application method was determined as soil + foliar boron application but other application methods were more effective than control applications.

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