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GROWTH AND YIELD OF CAULIFLOWER AS AFFECTED BY BORON SPRAY AND IN-ROW PLANT SPACING

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ABSTRACT

A field experiment was tested in the Central Laboratory for Agricultural Climate Experimental Farm, Dokki, Giza Governorate, Egypt, during the two growing seasons of 2019/2020 and 2020/2021 on cauliflower. The aim of this research was to study the effect of plant spacing foliar spraying with different concentrations of application of boron (B) on the vegetative growth, chemical content and curds yield of cauliflower cv. Amshiry under field conditions. Plants were sprayed with 50, 100 and 200 ppm at 20, 40, 60 and 80 days after transplanting, whilst the in-row plant spacing was 0.3 and 0.5 m between plants. Results showed that boron foliar application significantly improved vegetative growth parameters, curds yield and its components and chemical composition of leaves and cauliflower plant. Likewise, using 0.50 m plant spacing significantly enhanced plant fresh weight, plant height, leaves fresh weight and leaves dry weight and chemical composition of leaves and curds.

The highest yield per plant was obtained by plant spacing 0.5m combined with 200 ppm boron followed by plant spacing 0.50 m combined with 100 ppm boron. On the other hand, the production from land units increased by using 0.3 m in-row plant spacing while the production of individual plants was less than 0.5m treatment. The 200 ppm boron application gave the highest net profit per feddan followed by 100 ppm. The lowest net profit was obtained by 0.30 m plant spacing combined with control treatment.

Keywords: Cauliflower, boron foliar spraying, plant spacing

Introduction

Cauliflower (*Brassica oleraceae* var. botrytis L.) is one of the most popular cruciferous vegetable crops cultivated for its white curds as an edible part. It is being grown round the year for its white and tender curd vegetables and thrives best in a cool, moist climate and it does not withstand very low temperature or too much heat (Sani *et al.,* 2018)

Plant spacing is an important aspect of crop production for maximizing the yield. It helps to increase the number of leaves, branches and healthy foliage. Densely planted crops obstruct proper growth and development. On the other hand, wider spacing ensures the basic requirements but decreases the total number of plants as well as total yield Crop yield may be increased up to 25% by using optimum spacing (Hossain *et al.,* 2015).

Number of plants is mostly dependent upon spacing which also plays an important role in its development. The height of the plant was found to increase maximum at 60cm spacing. The plants of the spacing of 45cm were smaller than 60cm spacing at 30cm spacing plants were significantly shorter. Plants which were grown in wider spacing improved their fresh and dry weight characters, number of leaves, showed best results at 60cm spacing and with decrease in spacing the characters were decreased and worst results were obtained at 30cm spacing (Singh *et al.,* 2019).

Cauliflower responds well to macronutrients as well as nitrogen, phosphorus and potassium. However, micronutrients are also essential for its proper growth and yield, especially boron and molybdenum (Rahman *et al.,* 2007). Boron application increased plant height, number of leaves per plant, length and width of the leaf, plant spread, main head weight and head yield both per plant and per hectare (Moniruzzaman *et al.,* 2007).

In brassica crops like cauliflower, broccoli and cabbage, the boron requirement is very high. Application of different levels of B influenced the growth and yield in different crops also reported by Sohel *et al.* (2006).

Cauliflower has a high micronutrients requirement, particularly boron. Boron is very important for growth and development of cauliflower and is involved in cell division and hence helps in root elongation and shoot growth. It is associated with several physiological processes such as calcium metabolism, hormone synthesis, sugar metabolism, translocation of solutes and protein synthesis. Boron plays an essential role in the development and growth of cells in the plant meristem (Singh *et al.,* 2017).

Chattopadhyay, and Mukhopadhyay (2003) show that boron spray application enhance plant growth (i.e. Plant height, number of leaves per plant, root length, stem length, stem diameter and plant weight) and yield attributing

characters (i.e. Curd height, curd weight and curd diameter) over the control.

The present study was undertaken to evaluate the effect of boron spray application and different spacing distance on the growth and yield characteristics of cauliflower.

Material and Methods

Plant Materials and Growing Conditions: Two field experiments were conducted at the farm of the Central Laboratory for Agricultural Climate, Giza, Egypt during the winter growing season of 2019/2020 and 2020/2021. Climatic data (Table 1) of the experimental site was collected from automated weather station belongs to the Central Laboratory for Agricultural Climate. The coordinate of the farm is 30.04588 N and 31.20463 E. Experiments were conducted in clay soil with pH 7.26, EC 3.92dS/m, HCO 1.78meq/l, SO_4 22.1 meq/l, Cl 10.487 meq/l, Mg 9.90, Ca 10.95meq/l and K 0.33meq/l. Chemical analysis of the soil was determined according to procedures described by Ryan *et al*. (1996).

Experimental Design

Five-week old seedlings of healthy cauliflower cv. Amshiry were transplanted on row at a distance of 0.60 m on November 24th and 28th in 2019/2020 and 2020/2021 season, respectively. Drip irrigation system was used for irrigate plants.

The experimental layout was split-plot with three replicates. Plant spacing was allocated in the main plot at 0.30 and 0.5 m between each two plants. The distance between drippers was the same distance between plants. Inline dripper was used with discharge 2l/hr. the distance between drippers was 0.3 and 0.5m according to the applied treatments. On the other hand, boron was applied at 50, 100 and 200 ppm as well as control treatment in the sub main plots. Boron treatment was applied at 25, 40 and 60 days after transplanting. Boric acid (H_3BO_3 17% B) was used to prepare different foliar spray concentrations. Tap water was sprayed to the control plants.

Each sub-plot consisted of five rows 5.0 m length and 75 cm width and the plot area was 20 m^2. Guard rows were set between the experimental units. Common cultural practices were used for the cauliflower production such as irrigation, fertilization …etc., according to recommended practices for cauliflower in the commercial fields. The harvesting period was achieved from March 5th to March 28thin 2019 and from March 10th to April 2nd in 2020. At the end of each growing season, cauliflower plants were harvested 3-5 days intervals when heads were well-developed. Cauliflower heads were cut, trimmed to marketable form and used to determine fresh weight yield. The yield was determined per plant (g) and per square meter (kg).

Vegetative Growth Parameters: At harvesting time, plant height (cm), foliage fresh weight (g), foliage dry weight (g), number of leaves/plant.Stem diameter (cm), was measured one week before starting harvest date as mentioned above.

Plant Analysis: At harvesting stage, ten leaves were separated from five cauliflower plants that were selected from the middle row of each plot. Nutrient element composition (N, P, K and B) were measured in the leaves according to AOAC (2009).

Economic analysis of applied treatments: Economic analysis, after considering the cost of cauliflower seedling and boron spray application as well as field operating and irrigation system cost, the incomes from cauliflower yield was used (CIMMYT, 1988) according to the formulas:

Net Income = value of obtained yield –production costs;

Statistical Analysis

Analysis of data was done, using SAS program for statistical analysis. The differences among means for all traits were tested for significance at 5 % level according to Waller and Duncan (1969).

Results and Discussions

Vegetative growth characteristics

Data in Table 2 show that the highest vegetative growth was obtained by plant spacing 0.50 m during the both seasons. Using 0.30 m plant spacing led to decrease of all vegetative growth characteristics. The same trend was obtained during the second growing season. Referring to the effect of boron spray application, data in Table (2) illustrate that increase the concentration of boron led to significantly increased plant height, number of leaves per plant, foliage fresh and dry weight significantly during the two seasons. The highest plant height, number of leaves per plant, foliage fresh and dry weight were obtained by 200 ppm followed by 100 ppm; 50ppm boron came in the third option. There was no significant difference between boron concentration treatments in terms of stem diameter of cauliflower plant; all boron foliar sprays were significantly higher than control treatment. While the lowest plant height, number of leaves per plant, foliage fresh and dry weight was obtained by 50 ppm. the interaction effect between plant spacing and boron spray revealed the highest plant height, number of leaves per plant, foliage fresh and dry weight were obtained by 0.50 m plant spacing combined with 200 ppm boron spray followed by 0.50 m plant spacing combined with 100 ppm boron spray; the lowest plant height, number of leaves per plant, foliage fresh and dry weight were obtained by 0.30 m plant spacing combined with control treatment. The same results were obtained by Hossain *et al*. (2015) who concluded that proper plant spacing is essential for crop production due to sufficient utilization of light, nutrients and water by the plants. High plant population significantly affects plant growth. So, it is important to maintain sufficient plant spacing for maximum seed yield of cauliflower. However, foliar application of boron gave the highest fresh weight, the same results was obtained by Brown and Hu, (1997) who mentioned that boron application increased plant height, fresh and dry weight for plants. Naresh-Babu (2002) showed that foliar application of B at rates from 50 to 300 ppm on tomatoes had a positive effect on vegetative growth of the plants. Jafari-Jood *et al*., (2013) showed that spraying of boron significantly improved growth parameters of plants (plant height, leaves per plant and shoot weight) as compared with control (without spray).

Yield

Data in Table (3) show that the highest curd weight per plant was obtained by plant spacing 0.50 m followed by plant spacing 0.30m during the both seasons. The productivity of curds per Feddan took another trend, using 0.30 m plant

spacing gave the highest curds weight during the both seasons due to higher plant density and then higher number of curds per Feddan. The curd diameter and curd volume took the same trend as the cauliflower yield per plant during the both seasons. The 0.50 m gave a higher curd diameter than 0.30m during the two seasons.

Regarding the foliar spray application of boron on yield of cauliflower plant, data in Table (3) show that increasing the concentration of boron increases cauliflower yield during the both seasons. The highest cauliflower productivity was obtained by 200 ppm boron, followed by 100 ppm during the both seasons. The lowest cauliflower yield was obtained by control treatment. The curd diameter and curd volume took the same trend as the cauliflower yield per plant during the both seasons.

Referring to the interaction effect data indicated that the highest yield per plant were obtained by plant spacing 0.5m combined with 200 ppm boron followed by plant spacing 0.50 m combined with 100 ppm boron; while the lowest yield per plant was obtained by plant spacing 0.30 m combined with control. The yield per feddan took another trend, the highest yield feddan was obtained by 0.30m plant spacing combined with 200 ppm boron followed by 0.30 m plant spacing combined with 100 ppm boron during the both seasons. The lowest yield per square meter was obtained by 0.30 m plant spacing combined with control treatment. The same results was obtained by Keng *et al*. (2004) who concluded that high density planting increased the seed yield per unit area without significant effect on quality significantly. Hossain *et al*. (2015) the high plant density obtained higher cauliflower per land unit. Bacha *et al*. (2017) stated that wider plant spacing produces heads of larger size and narrow row spacing produces smaller heads. As for boron foliar application enhanced yield of cauliflower, the same results

El-Said (2009) who showed that foliar application of boron at 100 ppm and fertilization with 75% mineral nitrogen fertilizer + 25% organic nitrogen resulted significant increase of plant height, number of branches, fresh and dry weight, total yield per feddan and N, P and K contents in sweet pepper plants leaves. El-Mahdy, (2007) showed that foliar spray of B increased pepper vegetative growth parameters and yield.

Nutrient percentage

Data in Table 4 show that plant spacing affected the nutrient percentages, the highest nutrient percentages were obtained by 0.5 m plant spacing. N, P, K, Ca and Mg were lower under 0.3 m plant spacing than 0.5m.

Regarding the boron spray, obtained data show that 200 ppm of foliar spray of boron led to increased boron content of cauliflower leaves followed by 100 ppm, while the lowest B content was obtained by control treatment. The boron application increased the N, P, K, Ca and Mg percentages, the highest N, P, K, Ca and Mg were obtained by 200 ppm followed by 100 ppm while the control treatment had the lowest N, P, K, Ca and Mg percentages during the both seasons. These results agreed with Keng *et al*. (2004) who concluded that higher plant density led to reduced nutrient content in plants due to higher competition between plants of water and nutrients. These obtained results in terms of boron foliar application agreed with Arisha *et al*. (1999) who concluded that foliar spray of B at rates 12.5, 25 and 50 ppm as boric acid with recommended doses of NPK increased number of leaves per tomato plant, dry weight of plant, concentration and total uptake of N, P and K. another possibility, the optimum amount of boron stimulated the phosphorus uptake by plant roots and promoted plant growth with higher yield (Day, 2000). On the other hand, boron helps in the absorption of water and carbohydrate metabolism (Haque *et al*., 2011), translocation of carbohydrates in plants, DNA synthesis in meristems, cell division and elongation, active salt absorption, fertilization, water relation and photosynthesis and involves indirectly in metabolism of nitrogen, phosphorous, fat and hormones. Furthermore, application of B possesses a typical ‘starter effect’. Boron deficiency may markedly inhibit nutrient uptake and growth of the trees, whereas severe deficiency of B may result in the death of the trees even though the supply of other nutrient elements is adequate (Meng *et al*., 2008).

Economic analysis

Operating costs of producing one feddan of cauliflower using two different distances 0.3 and 0.5 m were estimated including the seasonal cost such as labor, irrigation, fertilization, etc. (Table 5). Cauliflower production not according to weight but per number of heads. The price of cauliflower head was according to head diameter. The average of curd diameter during the two tested seasons was considered in the economic analysis. The price of curd was categorized according to head diameter.

The plant spacing treatment had high economic impacts due to the effect of plant spacing on curd diameter (Table 3). The highest net profit per feddan was obtained by 0.50 m plant spacing compared to 0.30 m. Despite the 0.30 m plant spacing had a higher number of curd heads per feddan; the net profit of 0.50 m plant spacing was higher due to the price of curd was determined according to the curd diameter. According to the economic analysis using 0.5 cm plant spacing had higher net profit than 0.30m (Figure 1).

Regarding the boron application, the economic impact was effective due to the effect of boron foliar application on curd diameter. The 200 ppm boron application gave the highest net profit per feddan followed by 100 ppm; while the lowest net profit per feddan was obtained by control treatment (Figure 2). We can conclude that the highest net profit per feddan was obtained by 0.50 m plant spacing combined with 200 ppm boron foliar application followed by 0.30 m plant spacing combined with 200 ppm boron foliar application. The lowest net profit was obtained by 0.30 m plant spacing combined with control treatment.

Conclusion

In the experiment plant spacing 50 cm treatment gave higher curd yield per plant but plant spacing 30 cm treatment gave the highest curd yield per area unit (feddan).

Micronutrients boron foliar spray application was more effective than control. The results of the investigation suggest that the highest cauliflower curd yield per plant can be obtained, in plant spacing 0.5m combined with 200 ppm boron. While, the production from land units increased by using 0.3 m in-row plant spacing combined with 200 ppm boron.

Table 1 : Climate data during the experiment duration for Dokki area.

	AIR TEMP		RH%	PRECIPITATION	WIND SPEED	SOIL TEMP TEMPTTEMP.	ET_o
	max °C	min °C	avg	sum mm	avg m/s	avg °C	avg mm
				1st season			
Nov. 2019	28.9	10.8	57.9	11.6	0.3	21.7	3.2
Dec. 2019	21.6	6.6	56.5	10.7	0.5	16.5	2.6
Jan. 2020	17.8	4.2	59.6	3.2	0.5	13.4	2.1
Feb. 2020	19.6	5.7	57.2	6.9	0.4	15.2	2.4
Mar. 2020	22.6	7.2	56.2	4.6	0.7	16.8	3.1
				2nd season			
Nov. 2020	27.6	10.3	58.2	7.4	0.4	20.2	3.1
Dec. 2020	23.1	8.8	58.8	6.0	0.3	16.8	2.8
Jan. 2021	18.3	5.5	58.8	3.8	0.4	16.4	2.2
Feb. 2021	20.9	5.5	57.8	1.6	0.5	16.6	2.5
Mar. 2020	21.9	6.9	56.9	3.4	0.6	16.8	2.9

Air Temp = air temperature RH% = relative humidity percentage.
Soil Temp = Soil temperature ETo = reference evapotranspiration

Table 2 : Effect of in-row plant spacing and boron foliar spray on plant height, number of leaves per plant, stem diameter, fresh and dry weight of leaves and stem during 2019/2020 and 2020/2021 seasons in Dokki farm

plant spacing	2019/ 2020					2020/ 2021				
	Foliar application									
	plant height (cm)									
	Control	**B1**	**B2**	**B3**	**Mean**	**Control**	**B1**	**B2**	**B3**	**Mean**
30 Cm	61.5 e	68.2 d	70.0 cd	71.5 cd	67.8 B	58.5 g	65.2 f	66.2 ef	67.4 de	64.3 B
50 Cm	72.2 bc	73.4 ab	75.3 ab	76.4 a	74.3 A	69.2 cd	70.7 c	72.9 b	76.0 a	72.2 A
Mean	66.9 C	70.8 B	72.7 AB	74.0 A		63.8 D	67.9 C	69.5 B	71.7 A	
	Number of leaves									
30 Cm	15.4 c	16.3 bc	16.8 b	18.2 a	16.7 B	15.7 c	17.0 bc	17.7 bc	18.3 ab	17.2 B
50 Cm	16.8 b	16.8 b	18.2 a	19.1 a	17.7 A	17.3 bc	17.0 bc	19.0 ab	20.3 a	18.4 A
Mean	16.1 C	16.6 C	17.5 B	18.7 A		16.5 C	17.0 BC	18.3 AB	19.3 A	
	Stem diameter (cm)									
30 Cm	3.9 b	4.4	4.5 ab	4.6 ab	4.3 B	3.6 d	4.1 cd	4.3 bc	4.3 bc	4.1 B
50 Cm	4.4 ab	4.8 ab	4.5 ab	5.0 a	4.7 A	4.2 bcd	5.1 a	4.1 bcd	4.8 ab	4.5 A
Mean	4.2 B	4.5 AB	4.5 AB	4.8 A		3.9 B	4.6 A	4.2 AB	4.5 A	
	Canopy fresh weight (Kg)									
30 Cm	3.1 f	3.3 ef	3.4 de	3.6 cd	3.3 B	3.2 e	3.4 de	3.6 cd	3.8 bc	3.5 B
50 Cm	3.2 ef	3.7 bc	4.1 a	4.0 ab	3.8 A	3.5 cd	4.0 ab	4.3 a	4.2 a	4.0 A
Mean	3.1 C	3.5 B	3.8 A	3.8 A		3.3 C	3.7 B	3.9 A	4.0 A	
	Canopy dry weight (g)									
30 Cm	261 d	279 d	304 c	331 b	294.4 B	267 d	288 d	328 bcd	304 cd	297 B
50 Cm	287 cd	348 b	392 a	392 a	355.2 A	325 bcd	383 abc	396 ab	429 a	383 A
Mean	274 D	314 C	348 B	362 A		296 B	335 AB	362 A	366 A	

Table 3 : Effect of in-row plant spacing and boron foliar spray on yield per plant, yield per square meter, curd diameter and curd density during 2019/2020 and 2020/2021 seasons in Dokki farm

plant spacing	2019/ 2020					2020/ 2021				
	Foliar application									
	Curd weight (Kg/plant)									
	control	**B2**	**B3**	**B4**	**Mean**	**Control**	**B1**	**B2**	**B3**	**Mean**
30 Cm	0.89 e	1.15 d	1.15 d	1.27 cd	1.11 B	0.94 e	1.22 d	1.24 c	1.38 c	1.19 B
50 Cm	1.47 bc	1.50 bc	1.64 ab	1.74 a	1.59 A	1.56 b	1.56 b	1.65 b	1.81 a	1.65 A
Mean	1.18 C	1.32 BC	1.39 AB	1.51 A		1.25 D	1.39 C	1.45 B	1.59 A	
	Yield (Ton/Fadden)									
30 Cm	10.2 e	13.2 abc	13.2 ab	14.6 a	12.8 A	10.8 d	14.1 b	14.3 b	15.8 a	13.7 A
50 Cm	10.3 e	10.5 de	11.5 cde	12.2 bc	11.1 B	10.9 d	10.9 d	11.6 cd	12.7 c	11.5 B
Mean	10.2 C	11.8 B	12.4 AB	13.4 A		10.8 D	12.5 C	12.9 B	14.2 A	
	Curd diameter (cm)									
30 Cm	13.6 e	16.3 d	17.0 d	17.5 d	16.1 B	14.8 d	15.8 cd	16.8 cd	17.9 c	16.3 B
50 Cm	22.5c	23.6 bc	24.5 ab	25.6 a	24.1 A	25.0 b	25.5 ab	26.3 ab	27.5 a	26.1 A
Mean	18.1 D	20.0 C	20.7 B	21.5 A		19.9 C	20.7 BC	21.6 B	22.7 A	
	Volume (L/curd)									
30 Cm	0.37 d	0.48 d	0.69 c	0.73 bc	0.57 B	0.35 d	0.46 d	0.65 c	0.69 bc	0.54 B
50 Cm	0.77 bc	0.81 bc	0.86 b	1.03 a	0.87 A	0.73 bc	0.77 bc	0.78 b	1.09 a	0.84 A
Mean	0.57 C	0.65 C	0.77B	0.88 A		0.54 D	0.61 C	0.72 B	0.89 A	

Table 4 : Effect of in-row plant spacing and boron foliar spray on N, P, K, and B during 2019/2020 and 2020/2021 seasons in Dokki farm

plant spacing	2019/ 2020					2020/ 2021				
	Foliar application									
	N (%)									
	Control	B1	B2	B3	Mean	Control	B1	B2	B3	Mean
30 Cm	2.65 b	2.69 ab	2.73 ab	2.75 ab	2.71 B	2.51 a	2.60 a	2.66 a	2.74 a	2.63 A
50 Cm	2.70 ab	2.76 ab	2.78 ab	2.83 a	2.77 A	2.64 a	2.78 a	2.90 a	3.01 a	2.83 A
Mean	2.68 B	2.73 AB	2.76 AB	2.79 A		2.57 B	2.69 AB	2.78 AB	2.87 A	
	P (%)									
30 Cm	0.22 d	0.31 bc	0.31 bc	0.37 ab	0.30 B	0.23 e	0.27 de	0.29 d	0.36 bc	0.29 B
50 Cm	0.26 cd	0.32 bc	0.33 b	0.40 a	0.33 A	0.27 de	0.31 cd	0.37 ab	0.41 a	0.34 A
Mean	0.24 C	0.31 B	0.32 B	0.39 A		0.25 D	0.29 C	0.33 B	0.39 A	
	K (%)									
30 Cm	2.33 e	2.54 cd	2.56 cd	2.74 ab	2.54 A	2.30 e	2.49 cde	2.54 bcd	2.70 ab	2.51 A
50 Cm	2.36 de	2.59 bc	2.70 abc	2.82 a	2.62 A	2.36 de	2.53 bcde	2.67 abc	2.81 a	2.59 A
Mean	2.35 C	2.56 B	2.63 B	2.78 A		2.33 C	2.51 B	2.60 B	2.76 A	
	B (ppm)									
30 Cm	38.2 d	42.8 c	44.0 bc	47.5 ab	43.1 A	38.5 d	42.2 c	46.6 ab	48.2 ab	43.9 A
50 Cm	38.4 d	42.5 c	44.8 abc	48.0 a	43.4 A	38.9 d	42.6 c	45.7 b	48.7 a	44.0 A
Mean	38.3 C	42.7 B	44.4 B	47.8 A		38.7 D	42.4 C	46.1 B	48.4 A	

Table 5 : Average economic analysis for producing cauliflower under different plant spacing and boron foliar application during 2019/2020 and 2020/2021 seasons in Dokki farm

plant spacing	Boron application	Number Seedling	Total seedling cost	Boron application cost	Others cost (irrigation, fertilizer…)	Total production costs	Average curd diameter	Price per curd	Total return	Net profit
		Per feddan	L.E./Feddan				cm	L.E./Feddan		
0.30 m	control	11500	2875	25	13805	16705	14.2	2.5	28750	12045
	B1	11500	2875	50	13805	16730	16.1	2.6	29900	13170
	B2	11500	2875	100	13805	16780	16.9	2.7	31050	14270
	B3	11500	2875	200	13805	16880	17.7	2.8	32200	15320
0.50 m	control	7000	1750	25	8895	10670	23.8	3.5	24500	13830
	B1	7000	1750	50	8895	10695	24.6	3.6	25200	14505
	B2	7000	1750	100	8895	10745	25.4	3.7	25900	15155
	B3	7000	1750	200	8895	10845	26.6	3.8	26600	15755

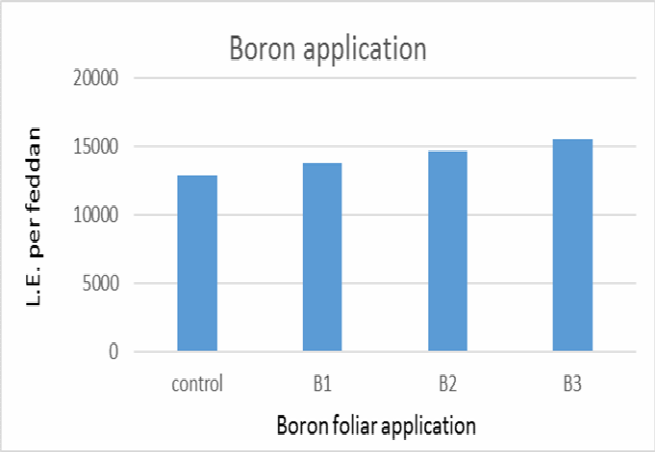

Fig. 1: Effect of boron application on average net profit per feddan during 2019/2020 and 2020/2021 seasons in Dokki farm

Fig. 1: Effect of plant spacing on average net profit per feddan during 2019/2020 and 2020/2021 seasons in Dokki farm

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