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Effect of sorbitol and boron on the growth and seed quality of faba bean (*Vicia faba* L.)

Walaa S. Elbatrawy[1]*; Enas E. Yousif[2] and Hend A. Ghannam[3]

Address:

[1]*Department of Seed Technology Research, Field crops institute, Agriculture Research Centre, Giza, Egypt.*

[2]*Department of Soil Fertility and Plant Nutrition Research Soil & Water and Environment Research Institute, Agriculture Research Centre, Giza, Egypt.*

[3]*Food Legumes Research Department, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt.*

*Corresponding author***: Walaa S. Elbatrawy**, *e-mail: dr.walaa.elbatrawy@gmail.com*

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ABSTRACT

Since ancient times, many edible crops have been planted in Egyptian lands that have become an essential part of daily eating habits; faba bean (Vicia faba L.) became one of these crops and also became the most important food legume crop in Egypt. This experiment was carried out in the two winter seasons (2020/2021 and 2021/2022) at Tag El-Ezz Research Station using two varieties of faba bean (Giza 843 and Nubaria 5) and adding sorbitol (sugar alcohol) and boron, individually or combined via seed soaking and foliar application, to investigate the ability to improve seed yield and quality. A split-plot design was used where faba bean varieties were in the main plots while sorbitol and boron treatments were in sub-plots. Results indicated that the Giza 843 variety was better. Pronounced differently, differences among studied treatments are either combinations or singles. The best performance was recorded with the soaked Giza 843 variety with treatments (sorbitol at 10.0 g L-1 and boron at 10.0 mg L-1) and simultaneously foliar application with the same rates during plant life. Generally, it can be concluded that the seed soaking and foliar application of sorbitol and boron were successful ways to improve field emergence and optimize seed yield (quality and quantity) of both faba bean (*Vicia faba* L.) varieties Giza 843 and Nubaria 5.

Keywords: Sorbitol, boron element and faba bean.

INTRODUCTION

Faba bean (*Vicia faba* L.) is a primary source of vegetable protein and carbohydrates in human food and animal feed. Faba bean is the most important legumes crop in Egypt. The cultivated area with faba bean in Egypt in the eighties, used to exceed 360,000 feddans and has been gradually decreasing to become only about 125,000 feddans in the 2020/2021 season (Sheha *et al.,* 2022). Self-sufficiency in the past was achieved, and now the government import large quantities of the faba bean (Soliman and El Sherpiny, 2021). The Egyptian market demands no less than 450 thousand tons annually, while the production of the last season was about 190 thousand tons, and therefore there is a large gap between production and consumption of up to 60% that made the self-sufficiency rate little (does not exceed 40%) despite an increase in the average productivity, where the feddan is almost doubled, from 0.868 tons / feddan to 1.6 tons / feddan (Adam *et al.,* 2022). Vertical expansion by continuing to develop new varieties of faba bean, which are characterized by high yield and early maturity, in addition to their ability to resist foliar diseases, has become necessity to reduce the gap between production and consumption (Waly *et al*., 2021). Sugar alcohol is a new generation of foliar nutrients for plants (Moing, 2000). Sugar alcohol is a carbohydrate and one of the distinctive products of the photosynthesis process as they move freely in the plant and help the sugar alcohol to obtain strong and abundant growth and work on the development and growth of the plant (Jain *et al.,* 2010). Sugar alcohol is not just a fertilizer that contains small elements and normal formulations or chelates, but it is a new system for delivering microelements to the places where they are manufactured in the plant (Ma *et al.,* 2022). Sorbitol, a six-carbon sugar alcohol, less commonly known as glucitol ($C_6H_{14}O_6$) is a sugar alcohol with a sweet taste. Most sorbitol is made from potato starch, but it is also found in nature, for example in apples, pears, peaches, and prunes. It is converted to fructose by sorbitol-6-phosphate 2-dehydrogenase (Li *et al.,*

2020). Sorbitol is one of the most frequently found polyols in higher plants. It is a direct product of photosynthesis in mature plant leaves (Issa *et al.,* 2020; Li et al., 2020), in parallel with sucrose, and both serve similar functions, like translocation of carbon skeletons and energy between sources and sink organs (AL-Taee, *et al.,* 2022). Boron is one of the essential microelements that play in plants a role in the formation of cell walls, and in the transmission of sugars in the plant (El-Agrodi *et al.,* 2016). Using borax was effective in improving germination, early seedling growth and yield (Iqbal *et al*., 2017). Results showed significant superiority of boron within the plant high, number of main branches per plant, leaves area and total yield (Mosleh and Abdul Rasool 2019). Sugar is easily transported through cell membranes after its union with boron, and it is necessary for cell division, bark formation, the transmission of some hormones, and pollen germination, and controls the speed of plant water absorption (Al-Hasany *et al.,* 2020). Its presence increases plant resistance to drought and has a great relationship with plant hormones that affect the growth of the developing tops of the market and roots and has a relationship in regulating calcium absorption (Li et al., 2020; Kadhim, 2022). Therefore, the current work aimed to assess the response of different varieties of faba bean plant to sorbitol as a sugar alcohol and boron via soaking and foliar application.

MATERIALS AND METHODS

1. Experimental Site:

The field experiment of the present study was carried out at Tag El-Ezz Research Station, Agriculture Research Center (ARC), (31°31' 47.64" N latitude and 30°56' 12.88" E longitude), Temi El-Amdid District, El-Dakahlia Governorate, Egypt during 2020/2021, 2021/2022 seasons.

2. Soil Sampling and Analysis:

The characteristics of the initial soil are presented in Table 1, where all soil analyses were done according to Sparks *et al.* (2020) and Dane and Topp (2020). The soil samples were taken at a depth of (0-30 cm).

Table 1. Characteristics of the initial soil.

Properties	Values
Physical characteristics	
Sand (%)	16.52
Silt (%)	34.18
Clay (%)	49.30
Texture class	clay
Chemical characteristics	
EC_w, dS m^{-1}	2.95
pH (1:2.5 soil suspension)	8.00
Organic matter (%)	1.25
Available N, mg kg^{-1}	45.5
Available P, mg kg^{-1}	6.20
Available K, mg kg^{-1}	245

3. Experimental Setup:

The field experiment was executed during the two successive winter seasons (2020/2021-2021/2022). Two diverse faba bean (*Vicia faba* L.) varieties were used (Giza 843 and Nubaria 5) for the sake of studying the influence of both sorbitol and boron via seed soaking and foliar application methods at different rates in a split plot design with three replicates. Faba bean varieties represented the main plots, while the treatments of both boron elements and sorbitol were devoted to sub-plots. Each plot contained five ridges whose length was 3.5 m and were 60 cm apart. Seeds were sown on one side of the ridge at a distance of 20 cm; the plot area was 10.5 m2. Sowing took place in mid-November. The treatments were as follows: T1: Control, without addition (dry); T2: Control, without addition (distilled water); T3: Sorbitol at a rate of 5.0 g L-1; T4: Sorbitol at a rate of 10.0 g L-1; T5: boron as boric acid at rate of 5.0 mg L-1, T6: boron as boric acid at rate of 10.0 mg L-1, T7: Combined treatment (T3+ T5) and T8: Combined treatment (T4+ T6).

4. Measurement traits:

4.1: At a period of 14 days from sowing seeds, field emergence percentages were determined after planting 24 seeds at area of a square meter.

4.2: At a period of 75 days from sowing faba bean seeds, some growth criteria and chemical constituents were determined. Ten plants were randomly chosen from the central ridges of each plot to estimate foliage fresh and dry weights gm per plant. The determined photosynthetic pigment was total chlorophyll, using fresh samples

according to Sumanta *et al.* (2014) chlorophyll (a & b) were determined, accurately (0.5g) of fresh cutting parts was weighted and homogenized with 10 ml of methanol extractant solvent at 4°C in presence traces of sodium bicarbonate into the test tube covered by aluminum foil (AOAC, 2000). Green color tincture concentration was spectrophotometrically measured at (665.2nm) chlorophyll a and (652.4nm) chlorophyll b wavelength. The oven-dried faba bean leaves were ground and wet digested by a mixture of perchloric and sulfuric acids (1:1) as described by Peterburgski, (1968). Determined nutrients were nitrogen, which was estimated using Kjeldahl method, while phosphorus was determined using spectrophotometer and potassium was determined using flam photometer as described by Walinga *et al.,* (2013). Boron was determined in clear digested solution by colorimetric method as mentioned by Bingham (1982).

4.3: At harvesting, Plant height (cm), Number of branches plant^{-1}, Number of pods plant^{-1}, Number of seeds plant^{-1}, Seed yield plant^{-1} (g), Seed yield (ard. fed) and 100-seed weight (g).

5. Agricultural practices:

Faba bean (*Vicia faba* L.) was preceded by rice crop. The experimental sites were prepared as recommended by the ministry of Agriculture and reclaimed land. Mineral fertilizers were applied as ammonium sulfate 15 kg per feddan, calcium dihydrogen phosphate at 120 kg per feddan and potassium sulfate 50 kg per feddan. Organic fertilizer and all other agricultural practices for growing and serving faba bean plants were applied as recommended.

Table 2. Meteorological data of experimental site during 2020/2021 and 2021/2022 growing faba bean seasons

	Air Temp °C				Relative humidity	
	2020/2021		2021/2022		2020/2021	2021/2022
	Min	Max	Min	Max	Average	Average
Nov.	15.52	25.54	16.47	28.68	64.94	66.14
Dec.	11.71	23.46	10.85	20.28	65.02	71.63
Jan.	9.95	22.05	6.96	17.60	67.07	71.22
Feb.	9.73	22.24	7.97	19.89	68.2	70.13
Mar.	10.30	23.36	8.73	21.39	65.64	59.13
April.	12.08	29.84	13.47	31.533	56.22	51.87
May.	17.86	37.14	16.79	33.87	46.37	51.22

Sources: Climate Change Information Center & Renewable Energy-CCICRE

Seeds of both faba bean varieties were obtained from Food Legumes Research Department, Field Crops Research Institute, Agricultural Research Center, El-Gama St., Giza, Egypt. Both boron elements as boric acid and sorbitol crud materials were carried out from Department of Soil Fertility and Plant Nutrition Research Soil & Water and Environment Research Institute, Agriculture Research Centre, El-Gama St., Giza, Egypt. Faba bean seeds were sown at recommended rate of 60 kg per feddan. The air temperature during both growing seasons is shown in Table 2.

6. Statistical Analysis:

All obtained data were subjected to statistical analysis according to the technique of analysis of variance (ANOVA) of split plot design for the field experiment, as described by Gomez and Gomez (1984).

RESULTS

According to the following data, the differences between the response of both studied faba bean varieties and the treatments were highly significantly different. Treating the faba beans seeds with soaking before sowing in solutions of sorbitol, boron and mix at different rates with each other foliar application of sorbitol, boron and mix at the same rates during faba bean plant life significantly affected field emergence after 14 days from sowing and growth criteria of faba bean plants at the period of 75 days from sowing (Table 3). Also, the studied treatments significantly affected chemical constituents and chlorophyll content in leaves of faba bean plants at a period of 75 days from sowing (Tables 4 and 5) as well as seed yield and its components at harvest stage (Tables 6 and 7) and chemical and quality traits (Tables 8 and 9).

1. Growth performance:

Data in Table 3 showed that Nubaria 5 variety was nearly better than Giza 843 variety for field emergence (%), plant height (cm). But the results were reversed later, where Giza 843 variety showed a modest superiority in branches number per plant, fresh weight gm per plant and dry weight gm per plant. Data in Table 4 showed that the Giza 843 variety possessed the highest values of chemical constituents in leaves *i.e.,* N, P, K (%), B (mg kg^{-1}) and chlorophyll (mg g^{-1} F.W), compared to Nubaria 5 variety. The same trend was found during both studied seasons.

Regarding the effect of sorbitol and boron on the growth performance parameters, tables 3, 4 and 5 elucidated pronounced differences among studied treatments. Mixed treatments outperformed both single treatments and control treatments. The combined treatment of sorbitol at rate of 10.0 g L^{-1} and boron at rate of 10.0 mg L^{-1} gave the highest, while the combined treatment of sorbitol at rate of 5.0 g L^{-1} and boron as boric acid at rate of 5.0 mg L^{-1} came in the second order. Also, the high studied rate of either sorbitol or boron was effective compared to the low high studied rate of both substances. On the other hand, the control treatment [without addition, (dry)] came in the last order. Generally, the sequence order of studied treatments regarding the most studied characteristics from the most effective to the less was as follows; $T_8 > T_7 > T_6 > T_4 > T_5 > T_3 > T_2 > T_1$. The same trend was found during the two seasons.

Concerning interaction effect the highest values of all aforementioned traits were recorded with Giza 843 variety soaked as a pre-sowing treatment in both solutions of sorbitol and boron element together as combined treatments (sorbitol at a rate of 10.0 g L^{-1} and boron as boric acid at a rate of 10.0 mg L^{-1}) and simultaneously foliar application of sorbitol and boron element at the same rates during faba bean plant life. The same trend was found during the two studied seasons (2020/2021-2021/2022).

Table 3. Effect of sorbitol and boron element on the field emergence a period of 14 days from sowing as well as the growth parameters of faba bean plants a period of 75 days from sowing during (2020/2021-2021/2022) seasons.

Treatments		Field emergence, %		Fresh weight, g plant^{-1}		Dry weight, g plant^{-1}	
		1st	2nd	1st	2nd	1st	2nd
Varieties							
Nubaria 5		97.08	97.50	127.35	129.52	19.89	20.24
Giza 843		97.04	97.50	130.22	132.74	20.86	21.25
LSD at 5%		N.S	N.S	1.43	0.14	0.10	0.71
Treatments							
T_1		90.17	90.83	111.84	114.00	15.18	15.49
T_2		94.33	94.50	114.11	116.09	15.80	16.07
T_3		98.00	98.33	130.56	132.91	21.11	21.48
T_4		98.83	99.17	135.17	137.87	22.30	22.76
T_5		97.50	98.67	128.53	130.80	20.53	20.85
T_6		98.50	99.33	132.83	135.37	21.71	22.06
T_7		99.33	99.67	137.51	139.84	22.90	23.27
T_8		99.83	99.50	139.73	142.18	23.46	23.97
LSD at 5%		1.09	1.24	1.44	2.23	0.35	0.24
Interaction							
Nubaria 5	T_1	89.00	90.00	109.63	111.73	14.72	15.06
	T_2	94.67	95.67	111.99	113.72	15.36	15.58
	T_3	98.00	97.67	129.38	131.44	20.61	20.93
	T_4	99.00	99.33	133.95	136.34	21.78	22.23
	T_5	97.67	99.33	127.39	129.29	20.05	20.36
	T_6	98.67	99.33	131.67	134.11	21.23	21.56
	T_7	99.33	99.67	136.20	138.61	22.43	22.82
	T_8	100.00	99.00	138.55	140.92	22.93	23.36
Giza 843	T_1	91.33	91.67	114.05	116.28	15.63	15.92
	T_2	94.00	93.33	116.23	118.46	16.24	16.55
	T_3	98.00	99.00	131.73	134.37	21.60	22.04
	T_4	98.67	99.00	136.39	139.40	22.81	23.29
	T_5	97.33	98.00	129.67	132.30	21.01	21.34
	T_6	98.33	99.33	133.98	136.62	22.19	22.56
	T_7	99.33	99.67	138.81	141.06	23.37	23.72
	T_8	99.67	100.00	140.91	143.45	23.98	24.59
LSD at 5%		1.54	1.76	2.03	3.16	0.50	0.37

T_1: Control, without addition, (dry), T_2: Control, without addition, (distilled water), T_3:Sorbitol at rate of 5.0 g L^{-1}, T_4: Sorbitol at rate of 10.0 g L^{-1}, T_5: boron as boric acid at rate of 5.0 mg L^{-1}, T_6: boron as boric acid at rate of 10.0 mg L^{-1}, T_7: Combined treatment (T_3+ T_5) and T_8: Combined treatment (T_4+ T_6).

Table 4. Effect of sorbitol and boron element on the chemical constituents (N, P and K%) in leaves of faba bean (*Vicia faba* L.) plants at period of 75 days from sowing during (2020/2021-2021/2022) seasons.

Treatments		N %		P %		K %	
		1st	2nd	1st	2nd	1st	2nd
Varieties							
Nubaria 5		3.22	3.27	0.140	0.146	1.69	1.72
Giza 843		3.38	3.44	0.150	0.155	1.81	1.84
LSD at 5%		0.02	0.01	0.001	0.001	0.01	0.03
Treatments							
T_1		2.74	2.78	0.128	0.132	1.54	1.58
T_2		2.77	2.82	0.134	0.138	1.58	1.61
T_3		3.10	3.16	0.141	0.146	1.72	1.75
T_4		3.51	3.56	0.154	0.160	1.88	1.91
T_5		2.94	2.99	0.136	0.142	1.62	1.66
T_6		3.30	3.35	0.149	0.155	1.81	1.84
T_7		3.99	4.06	0.157	0.163	1.90	1.93
T_8		4.06	4.12	0.163	0.169	1.96	1.98
LSD at 5%		0.02	0.07	0.002	0.001	0.03	0.05
Interaction							
Nubaria 5	T_1	2.71	2.75	0.126	0.131	1.53	1.56
	T_2	2.76	2.80	0.130	0.135	1.55	1.58
	T_3	2.97	3.02	0.136	0.139	1.62	1.65
	T_4	3.35	3.40	0.149	0.154	1.81	1.84
	T_5	2.83	2.88	0.132	0.136	1.57	1.60
	T_6	3.16	3.21	0.142	0.149	1.72	1.76
	T_7	3.97	4.03	0.151	0.157	1.83	1.86
	T_8	4.01	4.07	0.158	0.165	1.90	1.92
Giza 843	T_1	2.76	2.82	0.129	0.133	1.54	1.59
	T_2	2.79	2.85	0.138	0.140	1.60	1.63
	T_3	3.23	3.30	0.146	0.152	1.82	1.85
	T_4	3.66	3.73	0.160	0.166	1.94	1.98
	T_5	3.05	3.10	0.140	0.147	1.67	1.71
	T_6	3.43	3.48	0.156	0.161	1.89	1.92
	T_7	4.00	4.09	0.163	0.169	1.96	2.00
	T_8	4.11	4.17	0.167	0.174	2.01	2.05
LSD at 5%		0.03	0.10	0.004	0.001	0.04	0.07

T_1: Control, without addition, (dry), T_2: Control, without addition, (distilled water), T_3: Sorbitol at rate of 5.0 g L^{-1}, T_4: Sorbitol at rate of 10.0 g L^{-1}, T_5: boron as boric acid at rate of 5.0 mg L^{-1}, T_6: boron as boric acid at rate of 10.0 mg L^{-1}, T_7: Combined treatment (T_3+ T_5) and T_8: Combined treatment (T_4+ T_6).

Table 5. Effect of sorbitol and boron element on boron and chlorophyll contents in leaves of faba bean (*Vicia faba* L.) plants at period of 75 days from sowing during (2020/2021-2021/2022) seasons.

Treatments		Boron (mg kg^{-1})		Chlorophyll (mg g^{-1} F.W)	
		1st	2nd	1st	2nd
Varieties					
Nubaria 5		19.14	19.44	0.824	0.839
Giza 843		20.11	20.42	0.880	0.896
LSD at 5%		0.11	0.11	0.032	0.031
Treatments					
T_1		4.54	4.59	0.646	0.659
T_2		4.42	4.49	0.799	0.814
T_3		17.74	17.99	0.853	0.866
T_4		21.28	21.44	0.908	0.925
T_5		25.11	25.67	0.803	0.818
T_6		29.21	29.72	0.896	0.914
T_7		25.59	26.03	0.953	0.971
T_8		29.11	29.51	0.959	0.975
LSD at 5%		0.11	0.40	0.023	0.003
Interaction					
Nubaria 5	T_1	4.48	4.54	0.660	0.674
	T_2	4.36	4.43	0.768	0.782
	T_3	17.02	17.22	0.832	0.851
	T_4	20.17	20.46	0.849	0.866
	T_5	25.00	25.41	0.770	0.783
	T_6	28.48	29.03	0.844	0.861
	T_7	25.05	25.41	0.929	0.946
	T_8	28.53	28.99	0.939	0.953
Giza 843	T_1	4.60	4.63	0.632	0.644
	T_2	4.48	4.55	0.830	0.846
	T_3	18.46	18.75	0.873	0.882
	T_4	22.38	22.42	0.966	0.984
	T_5	25.21	25.93	0.836	0.852
	T_6	29.95	30.42	0.949	0.966
	T_7	26.13	26.65	0.976	0.996
	T_8	29.69	30.03	0.978	0.997
LSD at 5%		0.15	0.56	0.032	0.004

T_1: Control, without addition, (dry), T_2: Control, without addition, (distilled water), T_3: Sorbitol at rate of 5.0 g L^{-1}, T_4: Sorbitol at rate of 10.0 g L^{-1}, T_5: boron as boric acid at rate of 5.0 mg L^{-1}, T_6: boron as boric acid at rate of 10.0 mg L^{-1}, T_7: Combined treatment (T_3+ T_5) and T_8: Combined treatment (T_4+ T_6).

2. Yield and Seed Quality:

It was cleared from data illustrated in Tables 6, 7, 8 and 9 that seed yield and its components *i.e.,* seeds number per pod, pods number per plant, seeds number per plant, dry weight of 100 seeds (g), seed weight per plant (g) and seed yield (Ard. per fed) as well as chemical characteristics *i.e.,* N, P, K (%) and B (mg kg^{-1}) and biochemical characteristics *i.e.,* crude protein and carbohydrates (%) were significantly affected as a result of studied treatments.

The same Tables illustrated that the highest values of seeds number per pod, pods number per plant, seeds number per plant, dry weight of 100 seeds (g), seed weight per plant (g), seed yield (Ard. per fed.), N, P, K (%), B (mg kg^{-1}), crude protein and carbohydrates (%) were realized with the Giza 843 variety compared to Nubaria 5 variety. The same trend was found during both studied seasons.

Sorbitol, boron and mix, tables elucidated that pronouncedly differences among treatments. Pronounced promotional effect due to treatments on the growth criteria had reflected in the yield and its components. In other words, same trend of yield and its components same trend of growth performance. Combined treatments outperformed both single treatments and control treatments. Mixed treatment of sorbitol at

rate of 10.0 g L^{-1} and boron as boric acid at rate of 10.0 mg L^{-1} came in the first order, while the combined treatment of sorbitol at rate of 5.0 g L^{-1} and boron as boric acid at rate of 5.0 mg L^{-1} came in the second order. Also, the high studied rate of either sorbitol or boron was effective compared to the low high studied rate of both substances. On the other hand, the control treatment [without addition, (dry)] came in the last order.

Generally, the highest values of most aforementioned traits were realized with T_8 treatment followed by T_7 then T_6, T_4, T_5, T_3, T_2 and T_1, respectively. The same trend was found during the two studied seasons (2020/2021-2021/2022).

Concerning interaction effect, highest values of seeds number per pod, pods number per plant, seeds number per plant, dry weight of 100 seeds (g), seed weight per plant (g), seed yield (Ard. per fed.), N, P, K (%), B (mg kg^{-1}), crude protein and carbohydrates (%) were realized with Giza 843 verity soaked before sowing in both solutions of sorbitol and boron element together as combined treatments (sorbitol at a rate of 10.0 g L^{-1} and boron as boric acid at a rate of 10.0 mg L^{-1}) and simultaneously foliar application of sorbitol and boron element at the same rates during faba bean plant life. The same trend was found during the two studied seasons (2020/2021-2021/2022).

Table 6. Effect of sorbitol and boron element on plant height, number of branches and number of pods per plant of faba bean (*Vicia faba* L.) seeds during the (2020/2021-2021/2022) seasons

Treatments		Plant height (cm)		Number of branches (number per plant)		Number of pods (number per plant)	
		1st	2nd	1st	2nd	1st	2nd
Varieties							
Nubaria 5		158.25	162.79	5.04	5.79	47.67	49.71
Giza 843		157.33	162.29	6.08	6.88	51.00	52.96
LSD at 5%		N.S	N.S	0.64	0.35	0.35	N.S
Treatments							
T_1		136.33	139.17	3.00	3.33	35.50	36.67
T_2		143.50	147.83	3.67	4.33	38.33	41.00
T_3		155.50	160.50	5.17	6.50b	49.33	51.00
T_4		161.83	166.83	6.17	7.17	52.67	54.50
T_5		153.17	158.00	5.00	5.83	48.00	49.83
T_6		159.83	165.33	6.00	6.83	51.83	54.33
T_7		174.33	179.83	7.33	8.00	58.50	60.67
T_8		177.83	182.83	8.17	8.67	60.50	62.67
LSD at 5%		1.77	3.86	0.63	0.81	1.01	2.69
Interaction							
Nubaria 5	T_1	140.33	143.67	3.00	3.33	36.33	37.67
	T_2	145.00	149.67	3.67	4.33	39.67	44.33
	T_3	156.33	160.67	5.67	7.00	52.33	52.67
	T_4	161.00	166.00	6.67	7.67	55.00	57.33
	T_5	155.33	160.67	5.67	6.33	51.67	52.33
	T_6	159.33	165.00	6.67	7.33	54.00	56.33
	T_7	169.00	174.67	8.33	9.33	58.67	60.33
	T_8	172.33	178.00	9.00	9.67	60.33	62.67
Giza 843	T_1	132.33	134.67	3.00	3.33	34.67	35.67
	T_2	142.00	146.00	3.67	4.33	37.00	37.67
	T_3	154.67	160.33	4.67	6.00	46.33	49.33
	T_4	162.67	167.67	5.67	6.67	50.33	51.67
	T_5	151.00	155.33	4.33	5.33	44.33	47.33
	T_6	160.33	165.67	5.33	6.33	49.67	52.33
	T_7	179.67	185.00	6.33	6.67	58.33	61.00
	T_8	183.33	187.67	7.33	7.67	60.67	62.67
LSD at 5%		2.51	5.46	0.89	1.14	1.04	3.80

T_1: Control without addition, (dry), T_2: Control, without addition, (distilled water), T_3: Sorbitol at rate of 5.0 g L^{-1}, T_4: sorbitol at rate of 10.0 g L^{-1}, T_5: boron as boric acid at rate of 5.0 mg L^{-1}, T_6: boron as boric acid at rate of 10.0 mg L^{-1}, T_7: Combined treatment (T_3+ T_5) and T_8: Combined treatment (T_4+ T_6).

Table 7. Effect of sorbitol and boron element on yield and yield components of faba bean (*Vicia faba* L.) seeds during the (2020/2021-2021/2022) seasons.

Treatments		Number of seeds (number per plant)		Seed yield (g per plant)		Seed yield (Ard. per fed.)		100-seed weight (g)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Varieties									
Nubaria 5		194.4	201.42	174.3	177.5	8.80	8.98	87.17	90.04
Giza 843		209.7	217.17	224.2	228.2	12.26	12.49	105.08	108.79
LSD at 5%		0.47	1.73	2.52	0.59	0.12	0.03	2.02	1.42
Treatments									
T1		140.83	145.83	115.3	117.6	4.36	4.44	86.33	89.33
T2		154.33	160.00	125.4	127.5	4.80	4.90	87.50	90.33
T3		184.67	191.33	192.4	195.4	10.04	10.22	95.33	98.33
T4		217.83	225.33	212.3	216.3	11.95	12.15	98.83	102.83
T5		170.83	176.83	174.0	177.1	8.67	8.82	94.33	97.33
T6		207.83	215.33	202.0	205.6	10.55	10.78	97.67	101.33
T7		265.83	274.33	275.5	280.4	14.40	13.74	102.17	105.00
T8		274.33	285.33	297.1	302.8	16.42	15.83	106.83	110.83
LSD at 5%		5.62	4.99	2.37	2.98	0.13	0.07	1.88	2.07
Interaction									
Nubaria 5	T1	149.67	155.00	89.92	91.67	3.74	3.79	73.00	76.00
	T2	159.00	165.00	93.52	95.05	4.33	4.41	75.33	77.00
	T3	177.00	183.67	187.2	190.2	9.86	10.09	87.33	90.00
	T4	220.00	228.00	197.9	201.5	10.42	10.68	90.67	94.67
	T5	162.00	168.00	168.0	171.1	7.30	7.46	87.00	89.00
	T6	212.00	219.00	190.0	193.7	8.98	9.18	89.67	93.00
	T7	231.67	238.67	223.9	228.5	14.58	13.81	95.33	98.00
	T8	244.00	254.00	243.8	248.2	15.12	15.43	99.00	102.67
Giza 843	T1	132.00	136.67	140.7	143.6	5.01	5.08	99.67	102.67
	T2	149.67	155.00	157.3	160.0	5.29	5.39	99.67	103.67
	T3	192.33	199.00	197.6	200.6	10.22	10.37	103.33	106.67
	T4	215.67	222.67	226.6	231.2	13.47	13.65	107.00	111.00
	T5	179.67	185.67	180.0	182.9	10.04	10.19	101.67	105.67
	T6	203.67	211.67	214.0	217.5	12.15	12.36	105.67	109.67
	T7	300.00	310.00	327.0	332.3	16.23	14.67	109.00	112.00
	T8	304.67	316.67	350.4	357.4	18.70	17.21	114.67	119.00
LSD at 5%		7.95	7.07	3.35	4.22	0.19	0.11	2.66	2.93

T_1: Control without addition, (dry), T_2: Control, without addition, (distilled water), T_3: Sorbitol at rate of 5.0 g L^{-1}, T_4: sorbitol at rate of 10.0 g L^{-1}, T_5: boron as boric acid at rate of 5.0 mg L^{-1}, T_6: boron as boric acid at rate of 10.0 mg L^{-1}, T_7: Combined treatment (T_3+ T_5) and T_8: Combined treatment (T_4+ T_6).

Table 8. Effect of sorbitol and boron element on the chemical and quality traits of faba bean (*Vicia faba* L.) seeds during (2020/2021-2021/2022) seasons.

Treatments		N %		P %		K %	
		1st	2nd	1st	2nd	1st	2nd
Varieties							
Nubaria 5		3.46	3.50	0.215	0.219	2.05	2.08
Giza 843		3.63	3.70	0.236	0.244	2.23	2.27
LSD at 5%		0.03	0.02	0.004	0.001	0.01	0.04
Treatments							
T_1		2.89	2.92	0.183	0.188	1.87	1.90
T_2		3.00	3.05	0.198	0.202	1.92	1.96
T_3		3.54	3.59	0.216	0.221	2.07	2.10
T_4		3.81	3.86	0.248	0.256	2.31	2.34
T_5		3.33	3.36	0.202	0.207	1.98	2.01
T_6		3.70	3.76	0.237	0.243	2.19	2.23
T_7		4.03	4.08	0.253	0.259	2.35	2.39
T_8		4.11	4.17	0.265	0.274	2.45	2.49
LSD at 5%		0.04	0.10	0.002	0.001	0.03	0.05
Interaction							
Nubaria 5	T_1	2.82	2.85	0.181	0.184	1.85	1.89
	T_2	2.97	3.01	0.193	0.195	1.89	1.93
	T_3	3.40	3.43	0.201	0.203	1.96	1.99
	T_4	3.72	3.75	0.237	0.242	2.15	2.19
	T_5	3.21	3.21	0.192	0.197	1.93	1.96
	T_6	3.61	3.65	0.220	0.223	2.07	2.11
	T_7	3.97	4.02	0.242	0.247	2.23	2.26
	T_8	4.01	4.06	0.253	0.261	2.34	2.36
Giza 843	T_1	2.95	3.00	0.185	0.192	1.88	1.92
	T_2	3.03	3.09	0.204	0.209	1.95	1.99
	T_3	3.68	3.74	0.231	0.240	2.18	2.21
	T_4	3.89	3.97	0.260	0.271	2.46	2.49
	T_5	3.45	3.52	0.211	0.216	2.03	2.06
	T_6	3.79	3.86	0.254	0.263	2.31	2.35
	T_7	4.08	4.15	0.263	0.271	2.48	2.53
	T_8	4.20	4.28	0.276	0.287	2.56	2.62
LSD at 5%		0.06	0.14	0.004	0.002	0.04	0.07

T_1: Control, without addition, (dry), T_2: Control, without addition, (distilled water), T_3: Sorbitol at rate of 5.0 g L^{-1}, T_4: Sorbitol at rate of 10.0 g L^{-1}, T_5: boron as boric acid at rate of 5.0 mg L^{-1}, T_6: boron as boric acid at rate of 10.0 mg L^{-1}, T_7: Combined treatment (T_3+ T_5) and T_8: Combined treatment (T_4+ T_6).

Table 9. Effect of sorbitol and boron element on the chemical and quality traits of faba bean (*Vicia faba* L.) seeds during (2020/2021-2021/2022) seasons.

Treatments		B (mg kg^{-1})		Protein (%)		Carbohydrates (%)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Varieties							
Nubaria 5		6.46	6.57	21.65	21.89	56.18	57.18
Giza 843		7.05	7.17	22.71	23.13	57.38	58.36
LSD at 5%		0.03	0.01	0.16	0.01	0.23	0.13
Treatments							
T_1		4.18	4.24	18.03	18.26	52.95	53.92
T_2		4.27	4.34	18.74	19.05	54.14	54.98
T_3		6.28	6.38	22.12	22.41	56.69	57.60
T_4		6.85	6.97	23.79	24.13	57.91	58.96
T_5		7.63	7.76	20.80	21.14	55.48	56.49
T_6		8.51	8.64	23.16	23.49	57.18	58.13
T_7		7.73	7.88	25.17	25.52	59.49	60.60
T_8		8.59	8.72	25.63	26.06	60.41	61.47
LSD at 5%		0.05	0.10	0.22	0.60	0.17	0.28
Interaction							
Nubaria 5	T_1	3.55	3.61	17.63	17.79	52.49	53.44
	T_2	3.63	3.69	18.57	18.81	53.61	54.46
	T_3	6.15	6.25	21.25	21.44	55.57	56.46
	T_4	6.62	6.74	23.27	23.46	57.07	58.11
	T_5	7.46	7.59	20.06	20.29	54.82	55.87
	T_6	8.32	8.44	22.56	22.83	56.56	57.58
	T_7	7.54	7.68	24.81	25.11	59.26	60.35
	T_8	8.41	8.53	25.06	25.36	60.06	61.14
Giza 843	T_1	4.80	4.87	18.44	18.73	53.41	54.39
	T_2	4.92	5.00	18.92	19.29	54.67	55.49
	T_3	6.40	6.51	22.98	23.38	57.81	58.75
	T_4	7.08	7.21	24.31	24.79	58.75	59.81
	T_5	7.79	7.92	21.54	21.98	56.13	57.11
	T_6	8.70	8.85	23.75	24.15	57.79	58.68
	T_7	7.92	8.07	25.52	25.94	59.73	60.85
	T_8	8.77	8.90	26.19	26.75	60.75	61.80
LSD at 5%		0.07	0.15	0.31	0.85	0.23	0.40

T_1: Control, without addition, (dry), T_2: Control, without addition, (distilled water), T_3: Sorbitol at rate of 5.0 g L^{-1}, T_4: Sorbitol at rate of 10.0 g L^{-1}, T_5: boron as boric acid at rate of 5.0 mg L^{-1}, T_6: boron as boric acid at rate of 10.0 mg L^{-1}, T_7: Combined treatment (T_3+ T_5) and T_8: Combined treatment (T_4+ T_6).

DISCUSSION

Ebadah *et al.* (2006) and Rizk (2011) mentioned that Giza 843 is the lowest susceptible to aphid infestation. Abou-El-Seba *et al.,* (2016) mentioned that the superiority of the Giza 843 variety may be due to its resistance to broomrapes (Orobanche spp.) and tolerance to leaves diseases. Ibrahim (2016) reported that Giza 843 was one of the highest cultivars for maturity, plant height, number of branches, number of pods, number of seeds per pod, 100-seed weight and total seed production. A catalytic role that appeared for sorbitol may be attributed that the sugar alcohols can find different ways of being absorbed through the leaf through open stomata or pores as mentioned by Moing, (2000) and Jain *et al.,* (2010), who also stated that there are two main conductors within the plant for water and nutrients, which are wood and phloem. And through them, the basic elements of the metabolic channels are connected, but the problem is that the main entrance to the wood is the growing tops of the roots, not the leaves. As for the bark, the main artery for transporting elements, nothing is allowed to enter it. When using the usual leaf fertilizers, the plant is forced to spend energy and time to dissolve and break these nutrients, and in the end, a very small part passes into the plant. The plant sees the unique mixture of sugar alcohols as a natural ingredient, which allows it to pass through the bark easily, delivering more nutrients and better (Li *et al.,* 2020). Once inside the bark, the sorbitol may carry nutrients to the active metabolic channels in the required

quantity. There is no other delivery system that delivers nutrients with such efficiency. Once the nutrients are accepted within the bark, it becomes possible to carry those nutrients to any of the active metabolic channels (Issa *et al.,* 2020). It must not be overlooked that the unique composition of sorbitol, characterized by small molecules, may have improved the absorption of nutrients through the open stomata and foliar pores. In the production stage, sugar alcohols delivered nutrients to flowers, and grains, which improved the quality and productivity of the faba bean crop (Ma *et al.,* 2022). The findings are in accordance with those of AL-Taee, *et al.,* (2022). Regarding the superiority of boron treatments, it may be activated some enzymes in the faba bean plant, especially those responsible for the production of phenolic compounds. Also, the superiority of boron treatments may be attributed to their major role in protein representation (Ati and Ali, 2011). Also, it is known that boron regulates the ratio between calcium and potassium in the plant and has a role in cell division and plant growth in addition to its importance for the growth of the pollen tube of flowers and the completion of the process of pollination and fertilization as mentioned by El-Agrodi *et al.,* (2016). Boron is important for the process of holding the formation of seeds inside the pods and the representation of lignin, therefore it has a role in building cell walls (Jasim and Obaid, 2014). The boron treatments led to increase in the seed quality parameters and this may be due to its ability in playing a vital role in the formation of cell walls and facilitating the movement and transfer of photosynthetic products from leaves to the pods such as the transfer of sugars and carbohydrates (Hellal *et al.,* 2015). The findings are in harmony with those of (El-Yazied and Mady, 2012). Seed priming with boron, especially at low concentrations, has potential to boost germination rate and seedling growth of wheat. Metabolic processes involved in early phases of germination are stimulated by seed priming thus seedlings produced from primed seeds with B emerged earlier and produced healthy seedlings (Iqbal *et al*., 2017). Increasing yield may be due to the formation of hormones for flowering that increases the percentage of flowering and increases the vitality of the pollen grains due to the role of boron in pollination and the pollen tube growth, and possibly due to the role of alcohol sugars in transport nutrients to the seeds quickly and then increase the weight of seeds as a result of the accumulation of elements in the form of proteins and carbohydrates (Mosleh and Abdul Rasool 2019). Interaction between (*Vicia faba* L.) and boron at the concentration of 200 mg/liter gave the highest average for all studied traits (plant height, No. of branches plant^{-1}, the content of total chlorophyll in the leaves, pod length, No. of pods plant^{-1}, pod weight, No. of seeds pod^{-1}, the average weight of 100 seeds and total seed yield ton ha^{-1}) as concluded by Kadhim (2022). The combination of boron and sorbitol was better than the single treatments of both boron and sorbitol and this may be due to that when the foliar application of boron as a single treatment, it is not possible to guarantee access to the places of its manufacture in the plant, but with the foliar spraying system with sugar alcohols (sorbitol), the performance is different due to the small particles of sorbitol, and thus sorbitol works to reach a large amount of boron through the main transporting vessels represented in the bark and thus achieve greater benefit from boron.

CONCLUSION

The findings increase our knowledge concerning the efficacy of both sorbitol and boron in optimizing the productivity of faba bean plants. It can be concluded that soaking faba bean Giza 843 varity seeds as a pre-sowing treatment side by side with foliar application of sorbitol and boron together as a combined treatment was a successful way to improve field emergence and optimize seed yield of faba bean. And finally, all studied rates of sorbitol and boron help in providing a conducive atmosphere for better faba bean growth and this leads to increase seed yield and quality.

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تأثير السوربيتول والبورون علي نمو وجودة محصول الفول البلدي

ولاء سامي البطراوى*[1] , ايناس السعيد محمد يوسف[2] و هند ابو الفتوح رمضان غنام[3]

[1]. قسم بحوث تكنولوجيا البذور, معهد بحوث المحاصيل الحقلية , مركز البحوث الزراعية
[2]. قسم بحوث خصوبة الأراضي وتغذية النبات , معهد بحوث الأراضي والمياه والبيئة مركز البحوث الزراعية
[3]. قسم بحوث المحاصيل البقولية , معهد بحوث المحاصيل الحقلية , مركز البحوث الزراعية
* بريد المؤلف المراسل dr.walaa.elbatrawy@gmail.com

منذ القدم، تم زراعة العديد من المحاصيل الصالحة للأكل في الأراضي المصرية والتي أصبحت جزءًا أساسيًا من عادات الأكل اليومية ؛ أصبح الفول البلدى أحد هذه المحاصيل كما أصبح أهم محصول بقولي غذائي في مصر. أجريت هذه التجربة خلال موسمى (2021/2020 و 2022/2021) بمحطة بحوث تاج العز – مركز البحوث الزراعية باستخدام صنفين من الفول البلدى (جيزة 843 والنوبارية 5) مع إضافة السوربيتول (سكر كحولى) وبورون فردي أو مخلوط. عن طريق نقع البذور والرش على الأوراق لدراسة قدرتها على تحسين محصول البذور وجودتها. تم استخدام تصميم القطعة المنشقة حيث كانت أصناف الفول في القطع الرئيسية ، بينما كانت معاملات السوربيتول والبورون في القطع الفرعية. أشارت النتائج إلى أن صنف جيزة 843 كان الأفضل. الاختلافات بين المعاملات تحت الدراسة سواء مفردة أو مخلوطة كانت واضحة بشكل ملحوظ. تم تسجيل أفضل أداء أثناء نقع بذور صنف جيزة 843 مع المعاملات (السوربيتول عند 10.0 جم لكل لتر والبورون 10.0 مجم لكل لتر) والاضافة الورقية في نفس الوقت بنفس المعدلات أثناء فترة نمو النبات. بشكل عام ، يمكن الاستنتاج أن نقع البذور والاستخدام الورقي للسوربيتول والبورون كان وسيلة ناجحة لتحسين أداء ومحصول البذور (الجودة والكمية) لكلا صنفي الفول البلدي.

الكلمات المفتاحية: الفول البلدي، السوربيتول، البورون.