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المجلة العراقية لبحوث السوق وحماية المستهلك

RESPONSE OF FABA BEAN TO PLANTING DISTANCE BETWEEN PLANTS AND SPRAYING WITH NANO AND TRADITIONAL BORON

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ABSTRACT

A field experiment was conducted during winter season of 2021 at a research station of college of agricultural engineering sciences, university of Baghdad to determine the response of active fertility percentage and seed yield and its components of faba bean (*Vicia faba* L. cv. Aguadulce) to distance between plants and spraying of nano and traditional boron. A Randomized Complete Block Design according to split-plots arrangement was used at three replicates. The main plots were three distances between plants (25, 35 and 45 cm), while the sub plots including spraying of distilled water only (control treatment), spraying of boron at a 100 mg L^{-1} and spraying of nano boron at two concentrations (10 and 15 mg L^{-1}). The results showed that the 25 cm distance between plants was significantly superiority and gave a highest mean of seed yield (4.968 ton ha^{-1}), whereas the 45 cm distance between plants was significantly superiority and gave highest means of number of branches (10.83 branch $plant^{-1}$), number of flowers (400.4 flower $plant^{-1}$), number of pods (28.36 pod $plant^{-1}$), active fertility percentage (7.10%) and umber of seeds (6.66 seed pod^{-1}). The spraying of nano boron at a 10 mg L^{-1} was significantly superior and gave the highest means of number of pods (26.91 pod $plant^{-1}$), active fertility percentage (7.01%), number of seeds (6.23 seed pod^{-1}) and seed yield (4.334 ton ha^{-1}), while the spraying of nano boron at a 15 mg L^{-1} was significantly superior and gave the highest means of number of branches (9.83 branch $plant^{-1}$) and number of flowers (400.0 flower $plant^{-1}$). The interaction between two factors had significant effect on the most studied traits.

Keywords: *Vicia faba* L., intra-rows, boron forms, flowers abscission, pods setting.

استجابة الباقلاء لمسافة الزراعة بين النباتات ورش البورون النانوي والاعتيادي

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الخلاصة

نفذت تجربة حقلية خلال الموسم الشتوي لعام 2021 في المحطة البحثية التابعة لكلية علوم الهندسة الزراعية/ جامعة بغداد لتحديد استجابة نسبة الخصب الفعال وحاصل البذور ومكوناته للباقلاء صنف Aguadulce لمسافة الزراعة بين النباتات ورش البورون بشكليه النانوي والاعتيادي، طبقت التجربة بترتيب الألواح المنشقة وفق تصميم القطاعات الكاملة المعشاة وبثلاثة مكررات، إذ مثلت الألواح الرئيسة ثلاث مسافات زراعة بين النباتات (25 و35 و45 سم)، في حين مثلت الألواح الثانوية رش الماء المقطر فقط (معاملة المقارنة) ورش البورون الاعتيادي بالتركيز 100 ملغم لتر$^{-1}$ ورش البورون النانوي بالتركيزين 10 و15 ملغم لتر$^{-1}$. أظهرت النتائج أن المسافة 25 سم بين النباتات تفوقت معنويا بأعلى متوسط لحاصل البذور (4.968 طن هـ$^{-1}$)، وتفوقت المسافة 45 بين النباتات معنويا بأعلى متوسط لعدد الافرع (10.83 فرع نبات$^{-1}$) وعدد الأزهار (400.4 زهرة نبات$^{-1}$) وعدد القرنات (28.36 قرنة نبات$^{-1}$) ونسبة الخصب الفعال (7.10%) وعدد البذور (6.66 بذرة قرنة$^{-1}$). كذلك تفوق رش البورون النانوي بالتركيز 10 ملغم لتر$^{-1}$ معنويا بأعلى متوسط لعدد القرنات (26.91 قرنة نبات$^{-1}$) ونسبة الخصب الفعال (7.01%) وعدد البذور (6.23 بذرة قرنة$^{-1}$) وحاصل البذور (4.334 طن هـ$^{-1}$)، في حين تفوق رش البورون النانوي بالتركيز 15 ملغم لتر$^{-1}$ معنويا بتحقيقه أعلى متوسط لعدد الأفرع (9.83 فرع نبات$^{-1}$) وعدد الأزهار (400.0 زهرة نبات$^{-1}$). كان تأثير التداخل بين عاملي الدراسة معنويا في أغلب الصفات المدروسة.

الكلمات المفتاحية: الباقلاء، المسافة بين نبات وأخر، أشكال البورون، تساقط الأزهار، عقد القرنات.

INTRODUCTION

The low active fertility percentage is still a major reason for the low productivity of faba bean, despite the application of many means aimed at reducing its negative impact on the economic yield of this crop, which requires finding appropriate scientific solutions and application the agricultural technologies that reduce the impact of this problem, especially the technologies that are directly related to its occurrence. There are many reasons of the low active fertility percentage, including competition between plants and plant parts on the growth factors **(Arathi *et al*., 1999)**, thus the control of competition among plants on the necessary requirements of plant growth and development through changing the planting distance between plants (intra-rows) is one of the technologies that could be improvement the active fertility percentage and enhancing plant productivity **(Bakry *et al*., 2011)**, as the changing of distance between plants means that plants differ in the efficiency of their use of water, nutrients and solar radiation, which will negatively or positively affect the genetic energy of the variety and its physiological ability, which will be reflected on the efficiency of the photosynthesis process and their metabolic compounds and their impact on the plant growth and pods setting **(Khalil *et al*., 2010)**. Also, the low availability of some nutrients in the soil, such as boron, is one of the factors affecting the processes of pollination and fertilization **(Van Doorn & Stead, 1997)**. The high pH in Iraqi soil reduces the availability of boron duo its exposure to fixation and deposition processes, as a result, its absorption decreases and the plant doesn't benefit from it in sufficient amount. Therefore, the foliar nutrient with boron is an effective technology in providing the plant’s requirements of this element, especially in critical stages of growth **(Ali *et al*., 2014; Nasser, 2019)**. Faba beans need to boron, especially at the reproductive stage, as a result of its physiological effectiveness in increasing the pollen germination and pollen tube growth as well as improving the stability of pollen tubes, which will positively affect the active fertility percentage and economic yield **(Gupta, 2007)**. In order to an increase the plant’s benefit from this element, the thought came to use the nano-shape of this element beacuse of the distinctive characteristics of its particles as a result of its small particles diameter, which increases its chemical efficiency and provides more area for metabolic reactions as well as its ease of dissolution, absorption and diffusion within plant tissues **(Veronica *et al*., 2015)**. Thus, the molecules that possess such properties are considered an intelligent transfer system by exploiting the nano-porous surfaces of plant parts, which increases the efficiency of their use as well as reduces the use of traditional fertilizers and environmental pollution **(Nunez *et al*., 2018)**. This research was carried out to determine the response of active fertility percentage and seed yield and its components of faba bean to distance between plants and spraying of nano and traditional boron.

MATERIALS AND METHODS

A field experiment was conducted during winter season of 2021 at a research station of college of agricultural engineering sciences, university of Baghdad in a silt loam soil, to determine the response of active fertility percentage and seed yield and its components of faba bean (*Vicia faba* L. cv. Aguadulce) to distance between plants and spraying of nano and traditional boron. A randomized complete block design according to split-plots arrangement was used at three replicates. The main plots were three distances between plants (25, 35 and 45 cm) which symbolize D_1, D_2 and D_3 respectively, while the sub plots including spraying of distilled water only (control treatment), spraying of traditional boron at a 100 mg L^{-1} and spraying of nano boron at two concentrations (10 and 15 mg L^{-1}) which symbolize B_0, B_{100}, Bn_{10} and Bn_{15} respectively. The spraying was carried out three times (beginning emergence of flowering buds, 25 and 50% flowering) in the early morning using a 10 liter dorsal sprinkler until the leaves were completely wet **(Alzubaidy, 2014)**.

Soil management were carried out, and then the experiment land was divided into 36 experimental units, each experimental unit included 4 rows, 75 cm apart, to reach a plant density of 53333, 38095 and 29629 plants ha^{-1} for the 25, 35 and 45 cm distances between plants respectively. Phosphorous fertilizer was added with an average 35 Kg P ha^{-1} as a triple super phosphate (46% P_2O_5) at one dose before the planting, while the nitrogen fertilizer was added with an average 50 kg N ha^{-1} as a urea (46% N) at two equal doses, the first at the planting time, while the second at the flowering stage **(Al-Jubouri, 1985)**. The seeds faba bean were sown on the 4 November 2020 by 3 seeds per hill, and then thinned to one seedling after emergence. Crop management was carried out as needed, and the plants were harvested after the appearance of maturity signs.

Studied traits

1. Number of branches per plant:

The number of main lateral branches of five plants was randomly taken from each experimental unit at the harvest stage was calculated and their mean was extracted.

2. Number of flowers per plant:

The number of flowers of five randomly taught plants was calculated from each experimental unit from the beginning of their emergence until harvesting, at a rate of three times a week, and then its mean was extracted.

3. Number of pods per plant:

The number of pods per five plants was randomly taken from each experimental unit at the harvest stage was calculated their mean was extracted.

4. Active fertility percentage (%):

It was calculated at the harvest stage by the following equation:

$$\text{Active fertility (\%)} = \frac{\text{No. of total pods per plant}}{\text{No. of total flowers per plant}} \times 100$$

5. Number of seeds per pod:

The number of seeds per ten pods was randomly taken from each experimental unit at the harvest stage was calculated and their mean was extracted.

6. Weight of 100 seeds (g):

One hundred seed were randomly taken from the grain yield of each experimental unit, weighed and the mean of 100 seeds weight was extracted.

7. Seed yield (t ha^{-1}):

It was calculated at the harvest stage by the following equation:

$$\text{Seed yield (ton ha}^{-1}) = \frac{\text{Plant seed yield (g plant}^{-1}) \times \text{Plant density (plant ha}^{-1})}{10^6}$$

The data were statistically analyzed using Genstat program and least significant difference (LSD) test at 0.05 probability level was used to comparison between means **(Steel & Torrie, 1960)**.

RESULTS AND DISCUSSION

Number of branches per plant

The results in (Table 1) indicate that the number of branches per plant was significantly differed by the effect of distance between plants, the D_3 (45 cm between plants) achieved a highest mean (10.83 branch plant^{-1}) compared with D_1 (25 cm between plants) which achieved a lowest mean (6.08 branch plant^{-1}). The reason of increasing may be attributed to an increase the penetration of solar radiation when increase the distance between plants, which may led to the oxidation of auxin due to an increase the activity of IAA-oxidase enzyme and reduce the auxin concentration transmitted to the lateral buds of the plant associated with the lack of competition between plants on the growth factors which facilitated the flow of nutrients and water to the lateral buds as and then increased their emergence and growth **(Attiya & Jadoaa, 1999)**. However, **Abd-Elaziz *et al*. (2019)** and **Hailu & Ayle (2019)** indicated that the increasing of distance between faba bean plants led to a significant increase in the number of branches per plant. Also, data in Table 1 show that the spraying of nano boron at a 15 mg L^{-1} (Bn_{15}) was significantly superior and gave a highest mean of this trait (9.83 branch plant^{-1}) with non-significant difference with spraying of nano boron at a 10 mg L^{-1} (Bn_{10}) which gave 9.24 branch plant^{-1} but they significantly differed with spraying of traditional boron at a 100 mg L^{-1} (B_{100}) which gave 8.40 branch plant^{-1} and spraying of distilled water only (B_0) which gave a lowest mean (6.54 branch plant^{-1}). The reason of an increasing may be due to the characteristics of the nano boron fertilizer, which may have led to its rapid absorption and transmission through molecular transporters or internal cellular channels, as well as providing a large area for various metabolic reactions in the plant due to the small diameter of its particles **(Singh *et al*., 2015)**, which may have led to an increasing the efficiency of photosynthesis and its metabolic products transmitted to the active growth areas, as boron effectively contributes to facilitating the transmission of carbohydrates from the leaves to the meristemic parts, buds and storage tissues in the plant **(Mengel & Kirkby, 1982)**. In this regard, **Al-Hasany *et al*. (2020)** and **Huthily *et al*. (2021)** reported that the spraying of nano boron led to a significant increase in the number of branches per faba bean plants. The interaction between two factors had significant effect on this trait (Table 1), and the reason of interaction may be duo to difference of relative response of this trait to the effect of distance between plants in the different boron concentrations. The $D_3 \times Bn_{15}$ combination recoded a highest value (12.20 branch plant^{-1}) with non-significant difference with $D_3 \times B_{100}$ and $D_3 \times Bn_{10}$ combinations which recorded 11.58 and 11.11 branch plant^{-1} respectively, while the $D_1 \times B_0$ combination recorded a lowest value (4.52 branch plant^{-1}).

Table (1): Effect of distance between plants and spraying of nano and traditional boron on the number of branches per plant**.**

Distance between plants (cm)	Boron concentrations (mg L^{-1})				Mean
	B_0	B_{100}	Bn_{10}	Bn_{15}	
D_1	4.52	5.65	7.35	6.78	6.08
D_2	6.68	7.98	9.27	10.50	8.60
D_3	8.42	11.58	11.11	12.20	10.83
LSD 0.05	1.12				0.77
Mean	6.54	8.40	9.24	9.83	
LSD 0.05	0.65				

Number of flowers per plant

According to research data, the number of flowers per plant was significantly differed by the effect of distance between plants (Table 2), the D_3 achieved a highest mean (400.4 flower plant^{-1}) compared with D_1 which achieved a lowest mean (342.1 flower plant^{-1}). The reason of increasing may be due to the positive role of increasing the planting distance in reducing the competition between plants on the water and nutrients and increasing the interception of solar radiation, which led to an increase the number of branches per plant (Table 1), and then raising the efficiency of the photosynthesis process and increasing its metabolic products, which contributed to an increase stimulating the emergence and growth of flower buds and then increasing the flowering sites in the plant, as flower production is directly related with environmental potential and the plant's ability to produce sufficient carbohydrates to support the flowering process **(Force *et al*., 1988)**. Similar results were finding by **Gavusoglu & Azdemir (2019)** who indicated that the increasing of distance between faba bean plants led to a significant increase in the number of flower per plant. Also, data in (Table 2) indicate that the spraying of nano boron at a 15 mg L^{-1} (Bn_{15}) was significantly superior and gave a highest mean of this trait (400.0 flower plant^{-1}) compared with spraying of nano boron at a 10 mg L^{-1} (Bn_{10}) which gave 381.7 flower plant^{-1}, spraying of traditional boron at a 100 mg L^{-1} (B_{100}) which gave 372.6 flower plant^{-1} and spraying of distilled water only (B_0) which gave a lowest mean (341.8 flower plant^{-1}). The reason of increasing could be due to the positive role of spraying of nano boron at a 15 mg L^{-1} in increasing the number of branches per plant (Table 1). The interaction between two factors had significant effect on this trait (Table 2), and the reason of interaction may be duo to difference of relative response of this trait to studied factors. The D_3 x Bn_{15} combination recoded a highest value (438.0 flower plant^{-1}), while the D_1 x B_0 combination recorded a lowest value (314.0 flower plant^{-1}).

Table (2): Effect of distance between plants and spraying of nano and traditional boron on the number of flowers per plant.

Distance between plants (cm)	Boron concentrations (mg L^{-1})				Mean
	B_0	B_{100}	Bn_{10}	Bn_{15}	
D_1	314.0	347.3	333.0	374.0	342.1
D_2	346.0	376.0	408.0	388.0	379.5
D_3	365.3	394.3	404.0	438.0	400.4
LSD 0.05	17.7				12.8
Mean	341.8	372.6	381.7	400.0	
LSD 0.05	10.2				

Number of pods per plant

The results in (Table 3) indicate that the number of pods per plant was significantly differed by the effect of distance between plants, the D_3 gave a highest mean (28.36 pod plant^{-1}) compared with D_1 which gave a lowest mean (18.44 pod plant^{-1}). The reason of the superiority may be due to the role of increasing the distance between plants in securing the appropriate conditions for growth, which led to its superiority in the number of branches per plant (Table 1) and the number of flowers per plant (Table, 2) and then increasing the number of pods sites on the plant. These results are in agreement with **El-Kholy *et al*. (2019)** and **Hailu & Ayle (2019)** who indicated that the increasing of distance between faba bean plants led to a significant increase in the number of flowers per plant. Also, the results in Table 3 show that the spraying of nano boron at a 10 mg L^{-1} (Bn_{10}) was significantly superior and achieved a highest mean of this trait (26.91 pod plant^{-1}) with non-significant difference with spraying of nano boron at a 15 mg L^{-1} (Bn_{15}) which achieved 26.18 pod plant^{-1} but they significantly differed with spraying of traditional boron at a 100 mg L^{-1} (B_{100}) which achieved

23.57 pod plant^{-1} and spraying of distilled water only (B_0) which achieved a lowest mean (19.52 pod plant^{-1}). The reason of spraying nano boron superiority may be attributed to its characteristics due to the small diameter of its particles **(Servin *et al*., 2015)**, which led to an increase its quantitative effect, dissolution rate, absorption and diffusion speed compared with traditional boron **(Tanou *et al*., 2017)**, which was positively reflected on the increase its chemical and physiological activity in the plant (**Agrawal & Rathore, 2014**), as boron plays a positive role in the growth of callus in the cell walls of pollen tubes as a result of the formation of the callus complex borate, as well as it plays an important role in chemically directing of the growth of pollen tube towards the ovary **(Robbertse *et al*., 1990)**, and facilitates the transmission of metabolites from the leaves to the reproductive parts **(Leite *et al*., 2008)**. Similar results were finding by **Al-Hasany *et al*. (2020); Al-Khafagi *et al*. (2020); Huthily *et al*. (2021)** who reported that the spraying of nano boron led to a significant increase in the number of pods per faba bean plants. The interaction between two factors had significant effect on this trait (Table 3), and the reason of interaction may be duo to difference of relative response of this trait to studied factors. The D_3 x Bn_{10} combination had a highest value (32.44 pod plant^{-1}), whereas the D_1 x B_0 combination had a lowest value (14.54 pod plant^{-1}).

Table (3): Effect of distance between plants and spraying of nano and traditional boron on the number of pods per plant.

Distance between plants (cm)	**Boron concentrations (mg L^{-1})**				**Mean**
	B_0	**B_{100}**	**Bn_{10}**	**Bn_{15}**	
D_1	14.54	17.66	19.19	22.35	18.44
D_2	20.59	25.00	29.11	26.67	25.34
D_3	23.42	28.06	32.44	29.53	28.36
LSD 0.05	2.56				1.65
Mean	19.52	23.57	26.91	26.18	
LSD 0.05	1.48				

Active fertility percentage (%)

According to research data, the active fertility percentage was significantly differed by the effect of distance between plants (Table 4), the D_3 achieved a highest percentage (7.10%) compared with D_1 which achieved a lowest percentage (5.42%). The reason of superiority may be due to the positive role of increasing the distance between plants in increasing the number of flowers per plant (Table 2) and number of pods per plant (Table 3). These results are in agreement with **Abd-Elaziz *et al*. (2019)** who indicated that the active fertility percentage was significant increase when increasing the distance between faba bean plants. Also, the results in Table 4 indicate that the spraying of nano boron at a 10 mg L^{-1} (Bn_{10}) was significantly superior and gave a highest percentage (7.01%) compared with spraying of nano boron at a 15 mg L^{-1} (Bn_{15}) which gave 6.56%, spraying of traditional boron at a 100 mg L^{-1} (B_{100}) which gave 6.33% and spraying of distilled water only (B_0) which gave a lowest percentage (5.69%). The reason of spraying nano boron at a 10 mg L^{-1} superiority may be attributed to its role when sprayed at an appropriate concentration in stimulating pollen germination and growth of the pollen tube and improving the stability of pollen tubes, which reduces the flowers abscission and ovaries abortion **(Gupta, 2007)** and increase the number of pods per plant (Table 3) and then increase the active fertility percentage. The interaction between two factors had significant effect on this trait (Table 4), and the reason of interaction could be duo to difference of relative response of this trait to studied factors. The D_3 x Bn_{10} combination recoded a highest value (8.06%), while the D_1 x B_0 combination recorded a lowest value (4.72%).

Table (4): Effect of distance between plants and spraying of nano and traditional boron on the active fertility percentage (%).

Distance between plants (cm)	Boron concentrations (mg L^{-1})				Mean
	B_0	B_{100}	Bn_{10}	Bn_{15}	
D_1	4.72	5.14	5.81	6.00	5.42
D_2	5.91	6.68	7.16	6.93	6.67
D_3	6.42	7.17	8.06	6.75	7.10
LSD 0.05	0.62				0.39
Mean	5.69	6.33	7.01	6.56	
LSD 0.05	0.36				

Number of seeds per pod

The results in (Table 5) show that the number of seeds per pod was significantly differed by the effect of distance between plants, the D_3 achieved a highest mean (6.66 seed pod^{-1}) compared with D_1 which achieved a lowest mean (4.69 seed pod^{-1}). The reason of increasing could be attributed to the lack of competition between plants on the growth factors as a result of an increase the distance between plants, which led to an increase the efficiency of the photosynthesis process and its metabolic products which led to supply the ovules with necessary nutrients for their growth and prevention of abortion and then increasing the number of seeds per pod **(Gezahegen *et al*., 2016)**. This indicates that the planting at a greater distance was more efficient in partitioning the metabolites between sinks, which led to an increase the number of seeds per pod. These results are in agreement with **Hailu & Ayle (2019)** who stated that the number of seeds per pod was significant increase when increasing the distance between faba bean plants. Also, data in Table 5 reveal that the spraying of nano boron at a 10 mg L^{-1} (Bn_{10}) was significantly superior and achieved a highest mean of this trait (6.23 seed pod^{-1}) with non-significant difference with spraying of nano boron at a 15 mg L^{-1} (Bn_{15}) which achieved 6.07 seed pod^{-1} but they significantly differed with spraying of traditional boron at a 100 mg L^{-1} (B_{100}) which achieved 5.61 seed pod^{-1} and spraying of distilled water only (B_0) which achieved a lowest mean (5.20 seed pod^{-1}). The reason of increasing when spraying nano boron could be arributed to its chemical activity due to the small diameter of its particles (**Tanou *et al*., 2017**), as well as its physiological activity in facilitating the transmission of metabolites from the leaves to the emerging seeds when combined with hydroxyl radical in the sugars to form a complex esters of boric acid which can easily pass through cell membranes to the plant storage parts than the passage of polarized sugar molecules alone **(Leite *et al*., 2008)**. The interaction between two factors had significant effect on this trait (Table 5), and the reason of interaction may be duo to difference of relative response of this trait to studied factors. The D_3 x Bn_{10} combination had a highest value (7.10 seed pod^{-1}) with non-significant difference with D_3 x Bn_{15} combination which had 6.93 seed pod^{-1}, while the D_1 x B_0 combination had a lowest value (4.07 seed pod^{-1}).

Table (5): Effect of distance between plants and spraying of nano and traditional boron on the number of seeds per pod.

Distance between plants (cm)	Boron concentrations (mg L^{-1})				Mean
	B_0	B_{100}	Bn_{10}	Bn_{15}	
D_1	4.07	4.57	4.83	5.20	4.69
D_2	5.40	5.83	6.67	6.07	5.98
D_3	6.13	6.47	7.10	6.93	6.66
LSD 0.05	0.30				0.25
Mean	5.20	5.61	6.23	6.07	
LSD 0.05	0.17				

Weight of 100 seeds (g)

The results in (Table 6) indicate that there was non-significant effect of planting distance between plants, spraying of boron concentrations and the interaction between the two studied factors on the weight of 100 seeds.

Table (6): Effect of distance between plants and spraying of nano and traditional boron on the weight of 100 seeds (g).

Distance between plants (cm)	**Boron concentrations (mg L^{-1})**				**Mean**
	B_0	**B_{100}**	**Bn_{10}**	**Bn_{15}**	
25	139.83	141.80	137.73	143.60	140.74
35	148.07	146.67	145.90	140.37	145.25
45	146.40	143.37	137.23	144.77	142.94
LSD 0.05	N.S				N.S
Mean	144.77	143.94	140.29	142.91	
LSD 0.05	N.S				

Seed yield (ton ha^{-1})

According to research data, the seed yield was significantly differed by the effect of distance between plants (Table 7), the D_1 gave a highest mean (4.968 ton ha^{-1}) compared with D_3 which gave a lowest mean (3.018 ton ha^{-1}). The reason of the superiority when planting at a 25 cm between plants may be due to an increase the number of plants per unit area that compensated the decrease in the yield components **(Tawfiq, 2019)**. Similar results were finding by **El-Kholy *et al*. (2019)** and **Hailu & Ayle (2019)** who stated that the seed yield of faba bean was significant increase when decreasing the distance between plants. Also, the results in (Table 7) reveal that the spraying of nano boron at a 10 mg L^{-1} (Bn_{10}) was significantly superior and achieved a highest mean of this trait (4.334 ton ha^{-1}) compared with spraying of nano boron at a 15 mg L^{-1} (Bn_{15}) which achieved 4.186 ton ha^{-1}, spraying of traditional boron at a 100 mg L^{-1} (B_{100}) which achieved 3.970 ton ha^{-1} and spraying of distilled water only (B_0) which achieved a lowest mean (3.464 ton ha^{-1}). The reason of increasing the seed yield when spraying of nano boron at a 10 mg L^{-1} may have been due to the superiority of the same concentration in two components of the seed yield, i.e. the number of pods per plant and the number of seeds per pod (Table 3 and 5). These results are in agreement with **Al-Hasany *et al*. (2020)**; **Al-Khafagi *et al*. (2020); Huthily *et al*. (2021)** who reported that the spraying of nano boron led to a significant increase in the seed yield of faba bean. The interaction between two factors had significant effect on this trait (Table 7). The reason of interaction may be duo to difference of relative response of this trait to studied factors. The D_1 x Bn_{15} combination had a highest value (5.398 ton ha^{-1}), while the D_3 x B_0 combination had a lowest value (2.508 ton ha^{-1}).

Table (7): Effect of distance between plants and spraying of nano and traditional boron on the seed yield (ton ha^{-1}).

Distance between plants (cm)	**Boron concentrations (mg L^{-1})**				**Mean**
	B_0	**B_{100}**	**Bn_{10}**	**Bn_{15}**	
D_1	4.424	4.997	5.144	5.398	4.968
D_2	3.460	3.885	4.453	4.119	3.979
D_3	2.508	3.118	3.405	3.039	3.018
LSD 0.05	0.217				0.187
Mean	3.464	3.970	4.334	4.186	
LSD 0.05	0.125				

CONCLUSION

We can concluded that planting at a 45 cm between plants led to an increase the number of flowers and pods per plant, which was positively reflected on the increase the active fertility percentage as well as an increase the number of seeds per pod. However, planting at a 25 cm between plants achieved a highest seed yield per unit area due to an increase the number of plants per unit area. Also, the spraying of nano boron showed a higher chemical and physiological effectiveness than the traditional boron, which led to its superiority in most studied characteristics, especially when sprayed at a 10 mg L^{-1}, while both forms of boron were more efficient than control treatment (spraying of distilled water only). Spraying nano boron at a 15 mg L^{-1} gave highest results of the number of branches and flowers per plant, but spraying it at a 10 mg L^{-1} reduced the flowers abscission and increased the active fertility percentage, fertilized ovules percentage and seed yield per unit area.

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