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OPTIMAL INTRA-ROW SPACING FOR PRODUCTION OF LOCAL FABA BEAN (*VICIA FABA* L. MAJOR) CULTIVARS IN THE MEDITERRANEAN CONDITIONS

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Abstract

This research was carried out to evaluate the effects of 4 different local faba bean cultivars (LARA, YERLI, SAKIZ and SEVILLE) and intra-row spacing (5, 10, 15 and 20 cm) on the yield and yield components under the Mediterranean-type conditions of Turkey, during the two growing seasons of 2009/2010 and 2010/2011. All examined traits, except first pod height, were influenced by growing season and these parameters were higher in the second growing season compared with the first due to higher rainfall in the second growing season. However, there were no differences among cultivars in terms of seed yield and some yield components because of the similar characters of the seeds that were used in the research. Between 10 and 12 cm intra-row spacing were found to be the optimum for highest seed yield of faba beans grown in the Mediterranean conditions.

Introduction

The term "pulse", as used by the Food and Agricultural Organization (FAO), is reserved for crops harvested solely for the dry seed. Pulses are important due to their high protein and essential amino acid content. Due to recent recommendations to reduce meat and increase legume consumption, the latter have received increased interest as a human foodstuff in developing countries. Faba bean (*Vicia faba* L.) is the fourth most important pulse crop in the world with 4.316.371 tons produced (Anon., 2010), and widely used in the Mediterranean region as a source of protein in both human and animal nutrition, either fresh or dried (Larralde, 1982). It contains a large amount of proteins, carbohydrates, B-group vitamins and minerals. The protein content (29.57-31.83%), carbohydrate (52.96-54.60%), ash (3.37-3.47%), fat (0.81-1.24%) and fibre (10.88-11.96%) of faba beans depends on the variety (Sarah *et al*., 2009). Faba beans play a key role in crop rotation due to their ability to fix nitrogen, and the beans are able to provide a significant level of nitrogen from the soil air using a symbiotic relationship with Rhizobium bacteria.

The main aim objective of when growing the crop is to obtain the highest yield. However, there are several factors that affect the production such as sowing time, soil fertility, and varieties or genotypes. According to many studies carried out in faba bean, there are significant differences among varieties concerning yield and yield components (Bakry *et al*., 2011; Osman *et al*., 2010; Daur *et al*., 2010; Karadavut *et al*., 2010; Alan & Geren, 2006; Pekşen *et al*., 2006; Iyad *et al*., 2004). Another factor is seeding rate or planting density, which affect the growth, development and grain productivity per unit area in almost all agricultural crops, including faba bean, and is not stable for one variety due to different climate conditions. Low plant density may result in low yield, more weed infestation and poor radiation-use efficiency; however, high plant density can cause lodging, less light penetration in the crop canopy, reduced photosynthetic efficiency and can reduce the yield drastically (Vassilev, 1998; Jettner *et al*., 1998a 1998b; Lemerle *et al*., 2004; Lemerle *et al*., 2006). Earlier studies have shown that yield and its components are affected by planting densities (Turk & Tawaha, 2002; Bakry *et al*., 2011; Thalji, 2006 & 2010; Khalil *et al*., 2011). Therefore, the present research was conducted to evaluate response of different local faba bean cultivars and planting densities on the yield and yield components under the Mediterranean-type conditions of Turkey.

Materials and Methods

Experiments were carried out at the Research Area of Department of Field Crops of Cukurova University in Adana (35^o 18' E, 37^o 01' N; 23 m above sea level) during the winter seasons of 2009/2010 and 2010/2011. A randomised complete block design (RCBD) with three replicates was used to conduct treatments. Four cultivars named LARA, YERLI, SAKIZ and SEVILLE, obtained from local markets, were randomly assigned for the main plots. The four intra-row spacing of 5, 10, 15 and 20cm were randomly assigned to 7.2 m^2 sub-plots and consisted of 44.5, 22, 15 and 11 seeds per square metre according to the intra-row spacing used. Each sub-plot consisted of four rows of 4 m length that were 45 cm apart. Prior to sowing, plants were fertilised with equivalent to 40 kg ha^{-1} N, and 40 kg ha^{-1} P_2O_5 in both growing seasons. Sowings were carried out on December 6 2009, and December 10 2010. Emergence, flowering and podding dates were recorded when 50% of plants had emerged (January 1-5 2010, and January 6-10 2011), flowered (February 16 2010, and March 1 2011) and podded (March 10-14 2010, and March 15-19 2011) in each sub-plot. All plants were harvested at the end of June during both growing seasons. The following measurements were recorded from five randomly selected plants from mid-row of each plot: plant height (PH: cm), first pot height (FPH: cm), branch number (BN: number per plant), pod number (PN: number per plant), seed number (SN: number per plant), and seed weight (SW: g per plant). During both seasons, blackish-brown and dried plants were harvested in late June. After harvest, 100-SW (100-SW: g) was determined by mixing the whole sample, and then 100 seeds were randomly counted and weighed. For seed yields (SY: kg ha^{-1}), all rows were harvested, threshed, cleaned, weighed and converted into kg ha^{-1}. The area under consideration research region has a Mediterranean climate with wet winters and hot dry summers. According to the long-term average from four decades of records, there is early total precipitation of 625 mm and mean temperature 18.7°C. Mean temperature and total precipitation of the growing seasons during 2009-2010 and 2010-2011 are shown in Figs. 1 & 2. The soil of the research area is clay that has a pH of 6.7, 1.2% organic matter, 23.6% $CaCO_3$ and 0.09% salt content. All data for each trait were statistically analysed separately and combine the experimental years, and comparisons between means were made using least significant differences (LSD) at 0.05 probability level. Correlation coefficients were used to determined relationships among traits. Regression analysis was also performed between seed yield and plant densities. All statistical analyses were performed using the SAS program (Anon., 1999).

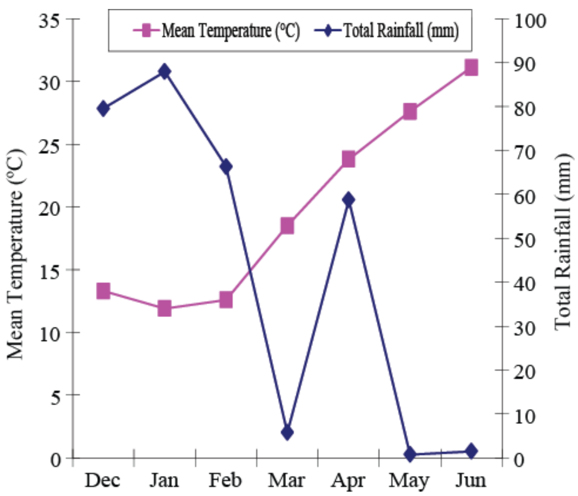

Fig. 1. Mean temperature (°C) and total rainfall (mm) in 2009-2010 growing seasons.

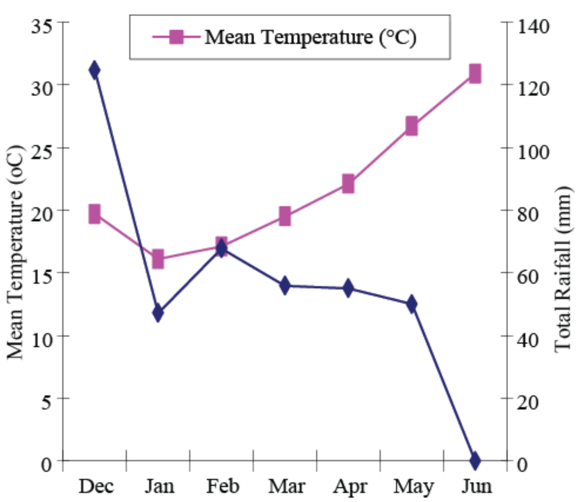

Fig. 2. Mean temperature (°C) and total rainfall (mm) in 2010-2011 growing seasons.

Results and Discussion

Plant height (cm) was influenced by growing seasons. The second growing season resulted in taller plant heights than the first growing season, in which average plant heights were 79.2cm and 67.8, respectively. Total precipitation and mean temperature of the second growing season was higher than that of the first growing season; this may explain the higher plant height obtained from the second growing season. These results are in agreement with those obtained by Al-Rifaee (2004) who reported that water stress affected the plant height. According to Table 1, results of statistical analysis indicated that cultivars significantly affect the plant height. The SEVILLE cultivar recorded the highest value with significant differences in comparison to other cultivars. Similar results are in agreement with those obtained by Bakry *et al*., (2011), Pekşen *et al*., (2006), Alan & Geren (2006), Pekşen & Gülümser (2007). On the other hand, plant height had no significant effect on cultivars during the second growing season. These results confirm the data findings of by Dahmardeh *et al*., (2010) and Osman *et al*., (2010) who have reported that there were no differences among genotypes in terms of plant height. The plant density had a significant effect on plant height in both growing seasons, and the highest plant height was obtained from 5cm intra-row spacing (Table 1). Furthermore, with the increase of the plant densities the plant height was decreased (Table 1). This is probably due to competition of plants in higher densities for light, resulting in taller plants. Similar findings were achieved by Khalil *et al*., (2010), Turk *et al*., (2002) and Thalji (2010), who indicated that the denser plant population increased the plant height due to competition among plants.

First pod height (cm) reflects the ability of the cultivars to be mechanically harvested. Significant differences were obtained from cultivars in the first growing season, but not in the second growing season (Table 1). In the first growing season, the highest first pod height was obtained from the SAKIZ cultivar (Table 2). Similarly, Peksen *et al*., (2006) and Peksen & Gülümser (2007) revealed that there might be differences among genotypes in terms of first pod height. Plant density in both growing seasons had significant effects on first pod height (Table 1). The highest first pod height was obtained from the highest plant density and gradually decreased with intra-row spacing from 5 to 20cm. Higher total precipitation during the second growing season improved plants and resulted in higher plants and first pod heights. Further, as seen in Table 3, plant height was positively and significantly correlated with first pod height. Interaction between faba bean cultivars and intra-row spacing had a significant effect on first pod height in the second growing season. In terms of the mentioned trait, the highest value was recorded from the YERLI and SAKIZ cultivars with 5 cm intra-row spacing and the SEVILLE cultivar in both 5 and 10 cm intra-row spacing. However, the YERLI cultivar gave the lowest value in the 20cm intra-row spacing.

Table 1. Plant height (cm), first pot height (cm), branch number (number per plant) and, pod number (number per plant) of faba bean as affected by cultivars and plan density.

Cultivars	Plant height (cm)		First pot height (cm)		Branch number (number per plant)		Pod number (number per plant)	
	2009/10	2010/11	2009/10	2010/11	2009/10	2010/11	2009/10	2010/11
LARA	68.0	77.5 B	25.4 B	24.3	2.3 C	3.1 AB	3.6	7.8 B
YERLI	63.9	71.8 B	24.2 B	22.5	2.7 AB	3.3 A	4.0	9.8 A
SAKIZ	71.8	78.9 B	30.3 A	26.8	2.4 BC	2.8 B	3.9	8.6 B
SEVILLE	67.6	88.7 A	24.8 B	28.0	2.8 A	3.1 A	3.5	8.4 B
LSD (p<0.05)	NS	7.14	3.53	NS	3.38	0.30	NS	0.88
	Intra-row spacing (cm)							
5	72.3 A	86.2 A	31.3 A	30.9 A	1.9 D	2.5 B	2.2 C	5.4 C
10	69.2 A	79.6 B	27.6 B	24.6 B	2.2 C	3.1 A	3.2 B	8.6 B
15	65.2 B	78.7 B	23.8 C	24.1 B	2.9 B	3.3 A	4.8 A	9.4 B
20	64.6 B	72.2 C	22.1 C	22.1 C	3.3 A	3.5 A	4.8 A	11.1 A
LSD (p<0.05)	3.89	4.72	2.14	1.67	0.21	0.41	0.53	0.99

LSD; Least significant difference (p = 0.05); NS not significant

Table 2. Seed number (number per plant), seed weight (g per plant), 100-sw (g) and seed yields (kg ha^{-1}) of faba bean as affected by cultivars and plan density.

Cultivars	Seed number (number per plant)		Seed weight (g per plant)		100-SW (g)		Seed yield (kg ha^{-1})	
	2009/10	2010/11	2009/10	2010/11	2009/10	2010/11	2009/10	2010/11
LARA	14.3	28.2	16.3	36.5	100.4 A	137. 5 A	1822.9	4859.4
YERLI	12.5	30.9	12.2	33.1	72.8 B	120.2 B	1495.4	3907.9
SAKIZ	14.5	30.1	14.7	36.1	92.0 AB	134.0 A	1803.3	4523.7
SEVILLE	12.7	20.7	12.9	36.2	105.4 A	135.8 A	1183.1	4511.6
LSD (p<0.05)	NS	NS	NS	NS	19.30	9.63	NS	NS
	Intra-row spacing (cm)							
5	7.2 C	20.0 C	6.9 D	23.6 D	87.4 B	130.9 B	1510.4 AB	4350.7 B
10	11.6 B	29.9 B	11.6 C	33.3 C	90.4 B	127.9 B	1659.7 A	5070.9A
15	16.8 A	32.9 AB	14.9 B	39.4 B	95.4 A	129.3 B	1712.2 A	4567.1 B
20	18.4 A	37.1 A	22.8 A	45.6 A	97.4 A	139.5 A	1422.3 B	3813.8 C
LSD (p<0.05)	2.31	4.49	2.93	4.91	4.06	5.41	218.3	418.9

LSD; Least significant difference (p = 0.05); NS not significant

Table 3. Correlation among examined traits during 2009-2011 years (n=96).

	PH	FPH	BN	PN	SN	SW	100 SW
First pod height	0.4916	1.0000					
Branch number	-0.0822	-0.6240	1.0000				
Pod number	0.2282	-0.4468	0.7040	1.0000			
Seed number	0.3177	-0.3622	0.6679	0.9184	1.0000		
Seed weight	0.3682	-0.3558	0.6134	0.8771	0.8948	1.0000	
100 Seed weight	0.5661	-0.0483	0.3314	0.6346	0.6748	0.7733	1.0000
Seed yield	0.6399	0.0480	0.3038	0.6525	0.6742	0.7015	0.7942

Branch number (number per plant) was higher in the second growing season compared with the first growing season (average 3.1 and 2.6 numbers per plant, respectively). Branch number was affected by cultivar in both growing seasons. YERLI and SEVILLE cultivars produced significantly higher branch numbers compared with the other cultivars (Table 2). These results are in agreement with the study carried out by Osman *et al*., (2010) who found that branch number showed significant differences among cultivars. Plant density in both growing seasons had a significant effect on branch number. Results in Table 1 indicate that the number of branches was decreased by increasing the plant population; the lowest branch number was obtained from 5 cm intra-row spacing; this confirms the results of Bakry *et al*., (2011) and Turk & Tawaha (2002). This reduction in branch number could be attributed to less competition between plants in the same unit areas. Additionally, another reason behind the low branch number is the negative and significant correlation between plant height and branch number (Table 3). As seen in Table 1, the cultivars with the highest plant height had the lowest branch number in terms of plant densities.

Pod number (number per plant) was higher in the second growing season compared with the first growing season (average 8.6, and 3.7 numbers per plant, respectively). This may be attributed to many factors such as water and temperature stress. As seen in Fig. 1, during the podding and after the podding stage, total rainfall in the first growing season was lower in comparison with the second growing season. Further, fluctuation in temperature between 1^{o}C and 22^{o}C, while faba bean plants were at flowering stage, probably caused serious losses in faba bean production. The time from flowering to podding in the first growing season (30 days) was higher than in the second growing season (15-20 days). Higher rainfall in the second growing season during the podding stage resulted in higher pod numbers than that in the first growing season. These results indicate that this trait is greatly influenced by environmental factors such as temperature and precipitation. The effect of these factors during critical stages such as flowering and podding on faba bean growth has previously been described (Al-Rifaee *et al*., 2004; Bakry *et al*., 2011; Thalji, 2006). Cultivars had a significant effect on pod number, and the YERLI cultivar produced the highest pod number in the second growing season; however, there was no significant effect on pod number in the first growing season (Table 1). Many studies indicate that faba bean cultivars differ significantly in pod number (Bakry *et al*., 2011; Dahmardeh *et al*., 2010; Osman *et al*., 2010). According to Table 1, during both seasons, pod number per plant was affected by plant density. Intra-row spacing of 5 cm (the highest plant density) gave the lowest pod number in both growing seasons, and increasing intra-row spacing from 5 to 20cm generally increased the pod number. These results are in agreement with results from Khalil *et al*., (2010), Thalji, (2006), Bakry *et al*., (2011) and Turk *et al*., (2002) who reported that pod number decreased with increasing plant density. This increase in pod number could be related to branch number. As seen in Table 3, pod number was positively and significantly correlated with branch number. These results are in agreement with the study carried out by Pekşen *et al*., (2006). Cultivars and intra-row spacing interaction had a significant effect on pod number in the first growing season. YERLI and SAKIZ cultivars with intra-row spacing of 20 cm produced the highest pod number, followed by the SAKIZ cultivar with 15cm, LARA cultivar 20cm and SEVILLE cultivar with 15cm intra-row spacing, whereas the lowest pod number was obtained from the LARA, SAKIZ and SEVILLE cultivars with the lowest intra-row spacing (5cm).

Seed number (number per plant) was higher in the second growing season compared with the first growing season (average 30.0, and 13.5 numbers per plant, respectively). The podding stage is a highly critical stage for production of faba bean and is affected by environmental factors. Any climatic fluctuation in this critical stage may cause serious losses in faba bean production. These results agree with the results obtained by Al-Rifaee *et al*., (2004), where drought conditions affected the seed number. Differences between the 2 years in terms of seed number may be due to the higher pod number in the second growing season. Pod number positively and significantly correlated with seed number (Table 3). However, these results do not agree with the results obtained by Alan & Geren (2007), who reported that there were no significant correlations between pod number and seed number. As seen in Table 2, plant density had an effect in both season, in which 15 and 20 cm intra-row spacing gave the highest seed number; however, the lowest seed number was obtained from 5 cm intra-row spacing. Increasing intra-row spacing significantly increased seed number. Thus, less competition between plants at lower density for available resources such as water and light, increases the available assimilates per seed and increases seed number per plant. These results are in agreement with those obtained by Turk & Tawaha (2002), who reported that plant density was negatively related to seed number on faba bean. Interaction between cultivars and intra-row spacing in the first growing season revealed that the highest seed number was recorded from SAKIZ and LARA cultivars in 20cm intra-row spacing followed by the SAKIZ and YERLI cultivars in 15 cm intra-row spacing. All cultivars in 5cm intra-row spacing gave the lowest value with regard to seed number.

Seed weight (g per plant) was higher in the second growing season compared with the first growing season (average 35.5, and 14.0g per plant, respectively). Seed weight was affected by higher precipitation, and also pod number in the second year. The data presented in Table 2 shows that seed weight was significantly increased with increased intra-row spacing and reached the highest values at intra-row spacing of 20 cm in both growing seasons. These increases were due to decreased inter-plant competition, leading to increased plant capacity for utilising the environmental inputs in increasing its yield components. These results are in agreement with Turk & Tawaha (2002), and Dahmardeh *et al*., (2010). Further, similar results were obtained by Thalji (2010) and Bakry *et al*., (2011), who reported that the increase in seed weight might be attributed to the decreased number of plants per square metre, which in turn counters the increase in metabolite synthesis due to less competition between plants in the same unit area. In addition, due to the positive and significant correlation between seed weight and pod number and seed number, the highest values were obtained from 20 cm intra-row spacing in all three traits.

100-seed weight (g) was greater in the second growing season compared with the first (average weight 131.9 and 92.6 g, respectively). This could be attributed to periods of drought during the podding and filling of pods stages in the first growing season. Similarly, Al-Rifaee *et al*.,

(2004) indicated that periods of drought during faba bean development decreased 100-seed weight. Similar to 100-seed weight, significant differences between years were found for pod number, seed number and seed weight. Highly significant positive correlations between 100-seed weight and pod number, and seed number and seed weight illustrate the importance of these traits for 100-seed weight. These results show that selection based on pod number, seed number and seed weight increase 100-seed weight. 100-seed weight reflects the ability of the genotypes to partition its dry matter into seed. Small seeds develop rapidly, once the reproductive phase starts, and produce less dry matter in their seed. Due to decrease assimilates, small seeds produce less seed weight. The least 100-seed weight was obtained from the YERLI cultivar, which had a smaller seed size than that of the other cultivars in both growing season (Table 2). This could be due to less biomass production and limited seed weight in small seeds, during both growing seasons. According to Table 2, plant population had a significant effect on 100-seed weight in both growing seasons, in which the highest 100-seed weight was obtained from 15 and 20cm intra-row spacing in the first growing season, and 20cm intra-row spacing in the second growing season. The effect on intra-row spacing on 100-seed weight seems to result from the production of heavier seeds at higher intra-row spacing (15-20 cm). Khalil *et al*., (2011) reported that low plant density produced heavier grains compared with high density, which produced lighter grain. Similar results were reported by Turk & Tawaha (2002). On the other hand, Osman *et al*., (2010) and Al-Rifaee *et al*., (2004) reported that environments did not significantly affect 100-seed weight. Interaction between cultivars and intra-row spacing in the second growing season revealed that the SEVILLE cultivar with intra-row spacing of 20cm produced the highest 100-seed weight followed by the LARA cultivar with 20cm, the SAKIZ cultivar with 20cm, the SEVILLE cultivar with 15cm and the LARA cultivar with 15cm intra-row spacing, whereas the YERLI cultivar gave the lowest 100-seed weight in the 15 cm intra-row spacing.

Seed yield (kg ha^{-1}) was influenced by growing season (Table 2). It was higher in the second growing season compared with the first growing season (average 4450.6, and 1576.2 kg ha^{-1}, respectively). This could be related the adverse drought conditions and fluctuation of temperature during flowering, podding and filling of pods stages in the first growing season (Fig. 1). Nevertheless, higher moisture and extended period of vegetative growth during the podding stage in the second growing season resulted in the improvement of several agronomical characters contributing to seed yield such as plant height, branch number, pod number, seed number, seed weight and 100-seed weight. These results are in general agreement with those of Turk & Tawaha (2002), and Al-Rifaee *et al*., (2004), who reported that shorter growing period, reduced seed number 100-seed weight and also decreased seed weight which reduced seed yield. Furthermore, positive and significant relationships were found between seed yield and these traits in this study. These results are in accordance with those reported by Thalji (2006) and Chaieb *et al*., (2011). Results of the two growing seasons indicated that cultivars did not affect the seed yield (Table 2). This can be attributed to the fact that these cultivars can be grown widely in Mediterranean conditions and have similar seed characters such as plant height, seed number, pod number and seed weight etc., which can significantly affect the yield and its components. These results are in agreement with Dahmardeh *et al*., (2010). During both growing seasons, there were no differences among cultivars in terms of plant height, seed number and seed weight, as was the case in the seed yield. As seen in Table 3, effect of intra-row spacing on seed yield was significant in both growing seasons. According to data regarding seed yield of faba beans, the highest seed yield was obtained from 15 and 10 cm intra-row spacing followed by 5 cm intra-row spacing in the first growing season (1712, 1660 and 1510 kg ha^{-1}, respectively). During the second growing season, the highest seed yield was obtained from 10 cm intra-row spacing (5071 kg ha^{-1}). Using the regression equations of the combined two years in Fig. 3, between 10 and 12 cm intra-row spacing were found to be the optimum for highest seed yield of faba beans grown in the Mediterranean-type conditions; above or below this spacing distance, seed yield significantly decreased. Consequently, from an economic point of view, further increases in plant population result in additional input cost, but increasing plant density does not significantly return an increase in seed yield. These results are in agreement with Al-Rifaee *et al*., (2004) and Thalji (2006), where low plant density produced a higher yield. However, these results are in contrast with Khalil *et al*., (2010), Khalil *et al*., (2011) and Dahmardeh *et al*., (2010), who reported high yields of faba beans at higher planting density.

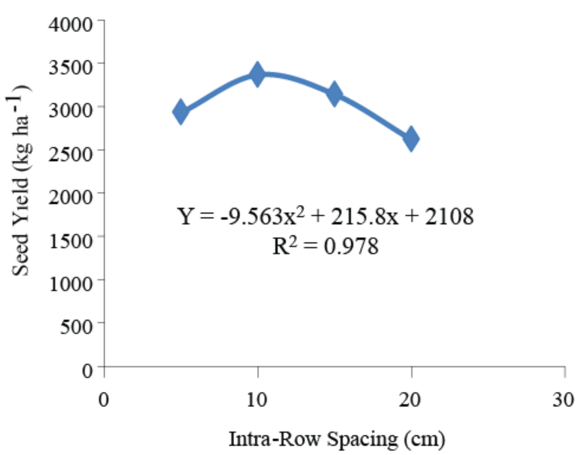

Fig. 3. Relationship between intra-row spacing and seed yield in combined of two years

Conclusions

From the above results and discussion, the cultivars had similar seed characters, which can significantly affect the yield and its components - as a result of this, there were no differences among genotypes in terms of yield and some yield components. Intra-row spacing of 12.5 cm may be suitable for faba beans grown in Mediterranean environmental conditions, and increasing plant density does not significantly return an increase in seed yield.

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