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Impacts of Row Spacing on Faba Bean L. Growth under Mediterranean Rainfed Conditions

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Abstract: The effects of row spacing on faba bean L. growth was investigated during the two growing seasons 2003-2005 at two locations under Mediterranean rainfed conditions of Jordan. Five row spacing (30, 40, 50, 60 and 70 cm) were used in a Randomized Complete Block Design (RCBD) with four replications. The results showed that higher row spacing (50-70 cm) resulted in the greatest yield with a reduction at the narrow spacing. The increase in the characters studied were: (~50%) for grain, (53-100%) for nodule dry weight, (77%) for nodule number and (34%) for root dry weight. The behavior of faba bean under various spacing with respect to vegetative growth and root growth varied according to the location. This indicates that under different environments the vegetative growth is affected more than root growth. High significant positive correlation was found between vegetative growth and yield (r = 0.60 and 0.63), nodule dry weight (r = 0.44 and 0.67), nodules no/plant (r = 0.42 and 0.75) and root dry weight (r = 0.46 and 0.85). The same was found for the root growth (root dry weight) which was highly correlated with yield (r = 0.38 and 0.89), nodule dry weight (r = 0.86 and 0.80) and nodules no/plant (r = 0.30 and 0.59) at the two locations during the two seasons. This prominent association between vegetative and root growths and nodules traits illustrated the importance of leguminous crops in fixing atmospheric N_2 which is highly demanded by the plant for it's growth. This study demonstrated good prospects for faba bean improvements under rainfed conditions. Moreover, it revealed the importance of leguminous crops in nitrogen fixation which is entirely reflected on the performance of the crop and on ecology.

Key words: *Vicia faba*, faba bean, sowing rate, terrestrial, rhizobial, symbioses, ecosystem, mediterranean region

INTRODUCTION

Biological Nitrogen Fixation (BNF) is an efficient source of nitrogen. The total annual terrestrial inputs of N from BNF has given range from 139 to 175 million tones of N, with symbiotic associations growing in arable land accounting for 25 to 30% (35 to 44 million tons of N) and permanent pasture accounting for another 30% (45 million tons of N) (Peoples *et al*., 1995a; Paul, 1988). This illustrated the relative importance of BNF in cropping and pasture systems and the magnitude of the task necessary if BNF is to be improved to replace a proportion of the 80 to 90 million tones of N-fertilizer expected to be applied annually to agricultural land by the end of the decade. BNF can play a key role in land remediation. An examination of the history of BNF shows that interest generally has focused on the symbiotic system of leguminous plants and rhizobia, because these associations have the greatest quantitative impact on the nitrogen cycle. A tremendous potential for contribution of fixed nitrogen to soil ecosystems exists among the legumes (Brockwell *et al*., 1995; Peoples *et al*., 1995a, b; Tate, 1995). Estimates showed that the rhizobial symbioses with the somewhat greater than 100 agriculturally important legumes contribute nearly half the annual quantity of BNF entering soil ecosystems (Tate, 1995). Legumes are very important both ecologically and agriculturally because they are responsible for a substantial part of the global flux of nitrogen from atmospheric N_2 to fixed forms such as ammonia, nitrate and organic nitrogen. Atmospheric N_2 fixed symbiotically by the association between *Rhizobium* species and legumes represents a renewable source of N for agriculture. Values estimated for various legume crops and pasture species are often impressive, commonly falling in the range of 200 to 300 kg of N/ha/year (Peoples *et al*., 1995a). Yield increases of crops planted after harvesting of legumes are often equivalent to those expected from application of 30-80 kg of N-fertilizer/ha (Peoples *et al*., 1995b). One of the most important leguminous crop is faba bean. Faba bean (*Vicia faba* L.) is the fourth most important pulse crop in the world. It occupies the greatest area planted to legumes in the Arab countries (Amin, 1988). Cultivated faba bean is used as human food in developing countries and as animal feed, mainly for pigs, horses, poultry and pigeons in industrialized countries. It can be used as a vegetable, either green or dried, fresh or canned. The most popular dishes of faba bean are Medamis (stewed beans), Falafel (deep fried cotyledon paste with some vegetables and spices), Bissara (cotyledon paste poured onto plates) and Nabet soup (boiled germinated beans) (Jambunathan *et al*., 1994). Feeding value of faba bean is high and is considered in some areas to be superior to field peas or other legumes. It is one of the most important winter crops for human consumption in the Middle East. Faba bean has been considered as a meat extender or substitute and as a skim-milk substitute. Sometimes grown for green manure, but more generally for stock feed. Large-seeded cultivars are used as vegetable. Roasted seeds are eaten like peanuts in India (Duke, 1981). The straw can also be used for brick making and as a fuel in parts of Sudan and Ethiopia. As traditional medicinal uses it is used as folk medicine, diuretic, expectorant, or tonic (Williams *et al*., 1988). Faba bean (*Vicia faba* L.) is a valuable food legume rich in proteins and carbohydrate for the people of Middle East and North Africa (Karamanos *et al*., 1994). In Jordan the crop is mainly grown under irrigation for fresh pod utilization. However, considerable areas of the crop are grown under rainfed for dry seed production. Faba bean fits well with cereals in the rotation. Dantuma and Thompson (1983) reported that optimum growing conditions of faba bean yield more than 6 tons ha^{-1} of dry seed with high profits for the grower. Low yield of faba bean in Jordan was attributed to several factors, in which the poor cultural practices was the most critical (Tawaha and Turk, 2001). One of the most important cultural practices was planting density. In general the effect of plant population depend largely on the available soil moisture. When soil moisture is adequate and irrigation is provided, increasing row spacing resulted in a significant yield increase on the other hand, a lower density was found to result in greater yield of faba bean when grown under rain fed conditions) (Salih, 1985). Earlier studies have shown that seeding rate or planting density is an important factor affecting yield of grain legumes. Therefore, yield response of seed legumes to seeding rates were discussed by several workers and different relative values between hay and seed yield with seeding rate were found (Murray and Slinkard, 1969; McEwen *et al*., 1988; Martin *et al*., 1994; Noffsinger and Santen, 1995; Tawaha and Turk, 2001; Turk and Tawaha, 2002). Increasing plant population from 10 to 50 plants m^{-2} increased seed yield from 4.59 to 5.23 tons ha^{-1} (Bianchi, 1979; Caballero, 1987; Al-Rifaee, 1999). The optimum faba bean yield was obtained at a plant population of 25 plants m^{-2} (Comarovschi, 1974 Rebillard and Lelièvre, 1980; Stringi *et al*., 1986; Haddad and Thalji, 1988) whereas, the highest yields was obtained at 40 and 85 plants m^{-2}, respectively (Christensen, 1974; Bonari and Macchia, 1975). However, Turk and Tawaha (2002) reported high yields for faba bean (*Vicia faba* L.) using the local cultivar cv. *Minor*, by high seeding rate (100 plant m^{-2}) under rainfed conditions of Jordan conditions.

The objectives of this study are:

- To investigate the direct influence of row spacing on the nodules characteristics of faba bean under rainfed conditions of Jordan.
- To investigate the association between the nodules characteristics and yield and other agronomical characters under different row spacing.
- To develop recommendations for faba bean production under rainfed conditions in the Mediterranean region.

MATERIALS AND METHODS

The study was conducted to determine the proper row spacing for faba bean production under rainfed conditions of Jordan during the 2003-2005 growing seasons. A local faba bean cultivar (Giza 1) was used. The experiment was conducted at two locations namely: Jubeiha and Rajib. Jubeiha is located at about 32 North Latitude and 35 East longitude with an elevation of 980 m. Whereas Rajib is located at 32 North Latitude and 35 East Longitude with an elevation of 640 m. Soil texture in both locations is clay with pH around 8. The two areas are considered to represent the areas in Jordan where major field crops are grown. Average rainfall received at the two locations during the two growing seasons were 550.7 and 713.8 mm (Table 1). In the experiment, five between row spacing were tested (Table 2). Randomized Complete

Table 1: Monthly rainfall (mm) distribution in the two locations when the experiments were conducted

Rajib		Jubeiha		
2004/2005	2003/2004	2004/2005	2003/2004	Month
6.8	4.6	3.0	1.2	Oct.
162.6	58.0	134.3	46.0	Nov.
56.8	126.6	34.8	107.8	Dec.
168.4	86.8	146.0	70.4	Jan.
126.2	252.6	67.7	246.1	Feb.
62.8	192.4	28.0	179.9	Mar.
42.6	32.2	4.3	29.0	Apr.
26.8	21.4	2.8	-	May.
653	774.6	420.9	680.4	Total
713.8		550.7		Average

Table 2: Planting row spacing used in the study

Plant population (Plant m^{-2})	Row spacing (cm)
75	30
44	40
31	50
24	60
20	70

Block Design (RCBD) was employed with four replications. At flowering, 20 plants were sampled at random from each plot to study nodule number and dry weight, plant height and root dry weight. At maturity, the two outside rows from each plot were excluded as a border and the remaining central rows were harvested. Data on grain yield and yield components were measured. The experiment plot was 5 m long and consisted of 18, 12, 9, 7 and 6 rows according to the row spacing used. Seedbed prepared by chiseling, followed by rotovating. Furrows were opened by labour and seeding was done by hand . A fertilizer treatment of 40 kg ha^{-1} of P_2O_5 was applied and mixed to soil prior to planting.

RESULTS AND DISCUSSION

Effect of row spacing on nodules and some plant characters: Effect of row spacing on some plant characters are represented in Table 3. In the first season and in both locations row spacing did not affect significantly the characters studied except for nodule dry weight in Jubeiha location where significant differences were obtained. This may be due to less rainfall in Jubeiha as compared to Rajib location. Less competition between plants was behind no significant differences between various spacing in Rajib for the characters under investigation, where better results obtained under higher spacing. This is rather expected with less moisture availability for plant growth and thus more competition was under narrow spacing.

Similar results were obtained in the following growing season, where row spacing affected nodules dry weight in both locations and more dry weight produced under higher row spacing. This season was characterized by low rainfall as compared to the previous season in both locations, but still Rajib received more rainfall as compared to Jubeiha. The behavior of faba bean to different spacing with respect to the other traits was varied according to the location. For instance, vegetative growth (plant height) and nodule number were affected significantly by row spacing in Jubeiha. In contrast, only root growth (root dry weight) was affected significantly by row spacing in Rajib. This indicates that under less moisture content the vegetative growth is more affected than root growth and. This is true since more competition is prevailing between plants under low moisture conditions. In the first season at Jubeiha higher spacing (50 and 70 cm) showed the heaviest nodule dry weight as compared to the low spacing with significant differences. The increase in nodule dry weight under these spacing was (53%). In the second season at Jubeiha higher row spacing (70 cm) showed the heaviest nodule dry weight as compared to other spacing with significant differences. The increase in nodule dry weight under this spacing was (48%). The same trend was found in the second season at Rajib where, higher row spacing (50 cm) exhibited the heaviest nodule dry weight as compared to other spacing. However, other spacing showed no significant differences. The increase in nodule dry weight under this spacing was double (100 %). In the second season at Jubeiha higher row spacing (70 cm^2) produced the highest vegetative growth(plant height) with significant differences as compared to narrow spacing. The increase in nodule dry weight under these spacing was (15%). For the nodule number the same result was obtained, where the higher row spacing (50-70 cm) gave more nodules and

Table 3: Effect of row spacing on nodules weight and number and on some other characters at the two locations and the two growing seasons

Rajib (2003/2004) (rainfall = 774.6 mm)				Jubeiha (2003/2004) (rainfall = 680.4 mm)				
Nodule dry wt (g)	Nodule No.	Root dry wt (g)	Plant height (cm)	Nodule dry wt (g)	Nodule No.	Root dry wt (g)	Plant height(cm)	Row spacing (cm)
0.61a	91.4a	1.36a	35.7a	0.45b	53.2a	1.71a	42.8a	30
0.55a	86.6a	1.38a	36.5a	0.38b	54.2a	1.39a	44.2a	40
0.60a	93.0a	1.25a	36.0a	0.69a	54.1a	1.84a	42.0a	50
0.61a	87.8a	1.38a	37.0a	0.40b	56.8a	1.34a	45.4a	60
0.62a	90.8a	1.42a	34.2a	0.54ab	52.8a	1.59a	42.4a	70
(rainfall = 653mm) (Rajib (2004/2005				Jubeiha(2004/2005) (rainfall = 420.9mm)				
0.20b	44.6a	1.61b	40.4a	0.52c	52.7c	1.20a	33.8b	30
30ab	47.7a	1.68b	42.4a	0.58bc	66.9bc	1.22a	35.0b	40
0.40a	47.3a	2.15a	43.5a	0.72b	84.2ab	1.14a	38.9a	50
0.30ab	55.1a	2.15a	40.9a	0.63bc	93.4a	0.95a	38.3a	60
0.23ab	50.6a	1.76ab	40.7a	0.92a	90.5a	0.95a	38.2a	70

*: Means within each column, followed by the same letter are not significantly different at the 5% probability level according to Duncan's Multiple Range Test

the increase in number was (77%). At Rajib, the plants have the same behavior with respect to root growth under the same spacing and gave a (34%) increase in dry weight.

Effect of row spacing on yield and yield components: The effect of row spacing on yield and some of the yield components are presented in Table 4.

The grain yield produced was seriously affected by the row spacing. At both locations and during the first season, higher row spacing (50-70 cm) gave a substantial yield increase over that produced by narrow spacing. The increase in grain yield under these spacing were (52%) and (50%) for Jubeiha and Rajib, respectively. However, in the second season the effect of row spacing was not so clear on the pod number/plant at Jubeiha. And the same result was obtained but for the grain yield at Rajib. It seems to be the effect of row spacing was predominant on seed size more than pod number/plant. The effect row spacing on grain yield, however, seems to result from the production of heavier seeds at the higher row spacing (50-70 cm). This is rather expected since pod initiation usually start early in the growing season before any moisture stress. Therefore, moisture stress which resulted from low rainfall or moisture depletion due to high plant competition, will be more pronounced at the end of the growing season, which coincide with seed filling stage, thus affect seed weight. Also the advantage resulted from the extended period of vegetative growth, which resulted in the improvement of several agronomical character contributing to yield such as plant height, number of pods produced and number of nodules, nodule dry weight and root dry weight. As a general result faba bean yield increased up to a row spacing of 50 cm^2, further decrease in spacing did not increase yield due to competition. These results agreed the results obtained by (Stringi *et al*., 1986, Bianchi, 1979; Comarovschi, 1974; Rebillard and Lelièvre, 1980; Caballero, 1987; Haddad and Thalji, 1988; Al-Rifaee, 1999) where, low plant population produced higher yields. However, these results came in contrast to Christensen (1974), Bonari and Macchia (1975) and Turk and Tawaha (2002), who reported high yields for faba bean at higher planting density.

Phenotypic association between the characters studied: Simple phenotypic correlation coefficient (r) between the studied characters are presented in Table 5. Correlation coefficient were affected by location and season. High significant positive correlation was found between vegetative growth and yield (r = 0.60 and 0.63), nodule dry weight (r = 0.44 and 0.67), nodules no/plant (r = 0.42 and 0.75) and root dry weight (r = 0.46 and 0.85) for the two locations, respectively. Similar results were obtained were obtained for the root growth (root dry weight) which was highly correlated with yield (r = 0.38 and 0.89), nodule dry weight (r = 0.86 and 0.80) and nodules no/plant (r = 0.30 and 0.59) for the two locations, respectively. The prominent and significant association between vegetative and root growths and nodules traits illustrated the importance of leguminous crops in fixing atmospheric N_2 which is highly demanded by the plant for it's growth. Therefore, nitrogen fixed by plant supported a strong vegetative up ground and down ground growths which is directly and indirectly supported the yield. This illustrated the relative importance of BNF in cropping and pasture systems as indicated by (Peoples *et al.* 1995a, b; Tate, 1995).

Table 4: Faba bean yield (kg ha^{-1}) and yield components as affected by row spacing grown under rain fed conditions of Jordan during 2003/2004 and 2004/2005 seasons

Rajib			Jubeiha			
Grain yield (kg ha^{-1}) (2004/2005)	Grain yield (kg ha^{-1}) (2003/2004)	Pod No. plant	Grain yield (kg ha^{-1}) (2004/2005)	Pod No. plant	Grain yield (kg ha^{-1}) (2003/2004)	Row spacing (cm)
177a	609c	3.0b	230a	6.5a	767c	30
194a	736c	3.4b	182a	6.1a	955b	40
202a	827ab	5.3a	211a	5.8a	1085ab	50
247a	812ab	3.4b	204a	6.5a	1165a	60
209a	913a	2.9b	194a	5.8a	1056ab	70

Means within each column, followed by the same letter(s) are not significantly different at 5% probability level according to Duncan's Multiple Range Test

Table 5: Correlation coefficients (r) between characters of faba beans, grown under rain fed conditions of Jordan at two locations during 2003-2005 seasons

Root dry wt. (2)	Root dry wt (1)	Nodules No./plant (2)	Nodules No./plant (1)	Nodule dry wt (2)	Nodule dry wt (1)	Yield (2)	Yield (1)	Characters
0.85**	0.46**	0.75*	0.42**	0.67*	0.44**	0.63*	0.60**	Plant height
-	-	0.59**	0.30*	0.80**	0.86**	0.89**	0.38**	Root dry wt
0.34	0.45**	0.08	0.42**	0.86**	0.37**	0.16	0.35**	Pod No.
0-.53	0.10	0.04	0.00	0.31	0.14	0.66**	0.22	100-seed wt
-	-	-	-	0.53**	0.42**	0.27*	0.47**	Nodules No/plant
-	-	-	-	-	-	0.42**	0.55**	Nodules dry wt.

*,**: Significant at 5 and 1% probability, respectively. (1) Jubeiha 2003/2004 and 2004/2005, (2) Rajib 2003/2004 and 2004/2005

Pod number/plant was highly associated only with nodule dry weight (r = 0.37 and 0.86) at both locations during the two seasons. However, it was strongly associated with nodules no/plant (r = 0.42) and with root dry weight (r = 0.45) only at Rajib location during the two seasons. Seed size (100 seed wt.) had a strong association with yield (r = 0.66)only at Rajib location. This was due to the favorable conditions prevailed at the vegetative and reproductive phases. Whereas, no significant correlation was found with other characters.

Nodules no. plant was highly correlated with yield (r = 0.47 and 0.27)and nodule dry weight (r = 0.42 and 0.53) at both locations during the two seasons. Also strong correlation was found between nodules dry weight and yield (r = 0.55 and 0.42) at the two locations.

CONCLUSIONS

- Higher row spacing (50-70 cm^2) resulted in a positive impacts on nodules traits and yield performance of faba beans.
- The study proved the possibility for faba bean improvements under rainfed conditions of Jordan as well as Mediterranean region.
- The study revealed strong association between nodule traits and vegetative and root growths. This indicated the importance of leguminous crops in nitrogen fixation which supported strong vegetative up ground and down ground growths, which is entirely reflected on the yield performance of faba bean. This illustrated the relative importance of BNF in cropping systems.

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