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Effect of spacing and *Rhizobium* inoculum on the yield and quality of faba bean (*Vicia faba* L.)

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ABSTRACT

An experiment was conducted at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh to evaluate the effect of spacing and *Rhizobium* inoculum level on the yield and quality of faba bean. The experiment comprised of four spacings viz., 30 cm × 30 cm, 30 cm × 25 cm, 30 cm × 20 cm and 30 cm × 15 cm, and four levels of *Rhizobium* inoculum viz., 0, 40, 80 and 120 g kg^{-1} seed. The experiment was laid out in a randomized complete block design with three replications. It was observed that the highest seed yield (1.23 t ha^{-1}) was recorded at spacing 30 cm × 20 cm which was as good as the yield (1.14 t ha^{-1}) at 30 cm × 15 cm spacing. The highest crude fat (3.16%) and ash (4.79%) were recorded at spacing 30 cm × 20 cm while the highest crude protein (33.62%) and fibre (15.49%) were recorded at 30 cm × 25 cm and 30 cm × 30 cm spacing, respectively. In case of *Rhizobium* inoculum, the highest seed yield (1.04 t ha^{-1}) and stover yield (1.75 t ha^{-1}) were obtained in *Rhizobium* inoculum 80 g kg^{-1} seed. The highest crude protein (33.54%) and crude fat (2.82%) were recorded at *Rhizobium* inoculum 120 g kg^{-1} seed while the highest ash (4.88%) and fibre (15.28%) was recorded at *Rhizobium* inoculum 80 g kg^{-1} and *Rhizobium* inoculum 40 g kg^{-1} seed, respectively. In case of interaction, the highest seed yield (1.46 t ha^{-1}) and stover yield (2.53 t ha^{-1}) were obtained at 30 cm × 20 cm spacing with *Rhizobium* inoculum 80 g kg^{-1} seed. The highest amount of protein (35.73%) and ash (5.63%) were found at 30 cm × 25 cm spacing with *Rhizobium* inoculum 80 g kg^{-1} seed while the highest crude fat (4.48%) and fibre (18.04%) were recorded at 30 cm × 20 cm spacing with *Rhizobium* inoculum 120 g kg^{-1} seed and spacing 30 cm × 30 cm with control treatment of *Rhizobium*, respectively. Based on these results it can be concluded that spacing 30 cm × 20 cm coupled with *Rhizobium* inoculum 80 g kg^{-1} seed appears as the promising combination in respect of seed yield of faba bean.

Introduction

Faba bean (*Vicia faba* L.) is an important legume crop which is used as food for human consumption and as animal feed (Gasim *et al*., 2015). It is the fourth important pulse crop in the world next to dry bean, dry peas, and chickpeas (Kumari and Van Leur, 2011). Its value as a food and feed crop lies in its high lysine- rich protein, vitamins, minerals, and carbohydrates (Crepon *et al*., 2010). It contains L-DOPA which is the precursor of dopamine to be pharmacologically active on patients with Parkinson's disease (Ramírez-Moreno *et al*., 2015). Faba bean is grown in some limited locality of Bangladesh with common names as *Kalimotor*, *Baklakalai* and *Bhograkalai* in various places. It can be grown in low fertile soils with less agricultural inputs compared to other pulse crops. It cannot only be grown on diverse agro-climatic conditions successfully, but it can also be produced on residual soil moisture, relatively more tolerant to biotic and abiotic stress, with minimum input (Singh and Bhatt, 2012). Faba bean production is affected by different factors such climatic conditions soil fertility, water supply, varieties or genotypes and plant population

density. Plant population density of faba bean is an important factor where plant competition for environmental resources is affected by the spatial arrangement of those plants; this may be affected by the plant density, by the distance between rows and plants. Concerning the effect of row spacing or plant population densities reveled that increasing seed yield as row spacing decreased. Yield components and yield of faba bean influenced by plant densities were reported elsewhere (Amer *et al*., 1992; Stutzel and Aufhammer, 1992 and Frade and Valenciano, 2005.). Some organisms like *Rhizobium*, *Bradyrhizobium* etc. have been identified to use as biological agent for fixing nitrogen by symbiosis process with legume crops and make the nutrients available to the plants. The use of *Rhizobium* inoculants in legume crop production can play a very crucial role in improving soil environment and sustainable agriculture. Bangladesh Institute of Nuclear Agriculture isolated some *Rhizobium*/ *Bradyrhizobium* strains for some pulse crops as a

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substitute of nitrogenous fertilizers. However, not yet any Rhizobium strains isolated specifically for faba bean in Bangladesh. Inoculation with *Rhizobium* increased effective nodule, dry matter production, grain and stover yields over uninoculated control in other legumes crops. To reduce the production cost and to fulfill the demand, more pulse production could be achieved through seed inoculation with *Rhizobium* strains, which is known to influence on nodulation, nitrogen fixation, growth, yield and quality of pulses. Considering the above point of view, the present study was undertaken to find out the optimum plant spacing and check the effectiveness of one available *Rhizobium* strains for faba bean.

Materials and Methods

Experimental site

The research work was conducted at the Agronomy Field laboratory, Bangladesh Agricultural University, Mymensingh located at 24.75^0 N latitude and 90.50^0 E longitude at an altitude of 18m. The soil belongs to the Old Brahmaputra Alluvium Soil under Agro-ecological Zone 9 (AEZ-9). The experimental field was a medium high land with silt loam texture with pH 6.81.

Experimentation and crop husbandry

The experiment comprised of four spacing viz., 30 cm × 30 cm, 30 cm × 25 cm, 30 cm × 20 cm and 30 cm × 15 cm, and four levels of *Rhizobium* inoculum viz., 0, 40, 80 and 120 g kg^{-1} seed. The experiment was laid out in a randomized complete block design with three replications. Each replication had 16 unit plots to which the treatment combinations were assigned at random. The unit plot size was 2.5 m × 2.0 m. Faba bean seeds were collected from Dhamrai, Savar upazilla, Dhaka district. *Rhizobium leguminosarum bv. viciae* strain (Host: lentil) from BINA was used. The experimental land was opened with a power tiller on 20 October 2017. Ploughing and cross ploughing were done with country plough followed by laddering. Land preparation was completed on 5 November and was ready for sowing seeds. TSP, MoP and Gypsum were applied at final land preparation at the rate of 60, 50 and 45 kg ha^{-1}, respectively.

Seeds were taken in three medium size pots and then the required rate of *Rhizobium* inoculum was mixed with the seed where molasses was used as additive. Seeds were sown maintaining selected spacing with two seeds per hole on 14 November 2017. Weeding was done twice at 20 days after sowing (DAS) and 40 DAS. Thinning was done during first weeding. Some plants were attacked by rust that was successfully controlled by spraying Hemoxy 50WP fungicide.

Harvesting and data collection

At the time when 80% of the pods turned brown color, the crop was assessed to attain maturity. The crop was harvested at 105 DAS from prefixed 1.0 m × 1.0 m area in each plot, respectively. Before harvesting five plants were selected randomly from each plot excluding border rows and central 1.0 m × 1.0 m area and uprooted for data recording. The harvested crop was bundled plot-wise, tagged and brought to the threshing floor and sun dried for 3 days. Seeds were separated from the plants by beating the bundles with bamboo sticks. Manually the seeds of the pods were separated from the plants of 1 m^{-2} area were sun dried to a constant weight. Plants of whole individual plot were collected and sun dried. Then weight was taken in an electrical balance, and the yield was converted to ton ha^{-1}. Harvest index was calculated using the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Seed yield}}{\text{Seed yield + Stover yield}} \times 100$$

Chemical analysis

The crude protein (Kjeldahl N × 6.25), crude fat (solvent extraction), crude fibre and ash were analyzed following standard method (AOAC, 2000; Mortuza *et al*., 2009).

Statistical analysis

The collected data were analyzed statistically using the 'Analysis of Variance' technique with the help of computer package M-STAT and mean differences were adjudged by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Results and Discussion

Effects on growth and yield

Effect of spacing

The highest number of branches $plant^{-1}$ (8.96), total pods $plant^{-1}$ (63.87) and filled pods $plant^{-1}$ (55.58) were obtained at spacing 30 cm × 30 cm followed by spacing 30 cm × 25 cm, which was at par with spacing 30 cm × 20 cm and the lowest number of branches $plant^{-1}$ (7.56) and total pods $plant^{-1}$ (57.49) were obtained at spacing 30 cm × 15 cm (Table 1). These results are in agreement with that of Bakry *et al*. (2011) who stated that branches $plant^{-1}$ and pods $plant^{-1}$ decreased with increasing the plant population density. Stutzel and Aufhammer (1992) noticed that increase in the number of pods $plant^{-1}$ with increasing plant spacing may be due to increase in the number of pods per node as the result of higher net assimilation rates and reduction of competition in wider spacing. Numerically, the highest number of unfilled pods $plant^{-1}$ (9.55) was obtained from spacing 30 cm × 15 cm and the lowest number of unfilled pods $plant^{-1}$ (8.75) was obtained at spacing 30 cm × 25 cm (Table 1). Aborted seed-bearing pod formation takes place due to decreasing plant spacing. Similar findings were reported by Stutzel and Aufhammer (1992). The number of seeds pod^{-1} was not significantly affected by plant spacing. The influence of spacing on seed yield was significant. Among the studied four spacings, 30 cm × 20 cm gave the highest seed yield (1.23 t ha^{-1}) which was at par with the spacing 30 cm × 15 cm while the lowest seed yield

(0.65 t ha^{-1}) was produced by 30 cm × 25 cm spacing (Fig. 1). Sprent *et al.* (1977) explained that the prime effect of increasing density more likely to be due to altered competition within adjacent plants than mutual shading. The highest number of plants m^{-2}, highest number of seeds $pods^{-1}$, and the highest 1000-seed weight contributed to higher seed yield at 30 cm × 20 cm spacing under present experimental situation and it was probably due to comparatively higher yield potential as well as having higher yield attributes over other spacing. Supporting evidence was found by Shalaby and Mohamed (1978) that increasing plant spacing gave the highest seed yield. Stover yield also showed similar trend as seed yield (Fig. 4) where relatively closer spacing showed higher stover yield due to highest plant population $unit^{-1}$ area. The highest harvest index (41.19%) was obtained from spacing 30 cm × 15 cm which was at par with spacing 30 cm × 30 cm, while the lowest harvest index (29.13%) was obtained from spacing 30 cm × 25 cm (Table 1).

Table 1. Effect of spacing and *Rhizobium* inoculum level on crop characters, yield components and yield of faba bean

	Number of branches $plant^{-1}$	Number of total pods $plant^{-1}$	Number of filled pods $plant^{-1}$	Number of unfilled pods $plant^{-1}$	Number of seeds pod^{-1}	1000- seed weight (g)	Harvest index (%)
Spacing (cm × cm)							
30 × 30	8.96a	63.87a	55.58a	8.78	3.64	100.7	41.05a
30 × 25	8.19b	61.04b	51.05b	8.75	3.65	101.0	29.13c
30 × 20	8.41b	60.22bc	50.48b	9.33	3.71	102.5	39.81b
30 × 15	7.56c	57.49c	49.63b	9.55	3.65	101.8	41.19a
Sig. level	**	**	**	NS	NS	NS	**
Rhizobium inoculum level (g kg^{-1} seed)							
0	7.86b	61.11c	50.73c	9.16	3.41	102.2	32.94d
40	8.07a	61.43b	52.15b	8.68	3.41	102.1	35.95b
80	8.35a	62.56a	54.53a	8.85	3.53	102.2	37.28a
120	8.31a	61.64ab	51.77bc	8.71	3.34	102.6	34.87c
Sig. level	**	*	**	NS	NS	NS	NS
CV (%)	7.84	6.28	5.41	23.55	5.17	0.69	5.15

Figures in a column under each factor of treatment having the same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); **= Significant at 1% level of probability, *= Significant at 5% level of probability, NS = Not Significant

Effect of Rhizobium inoculum level

The highest number of branches $plant^{-1}$ (8.35) and total pods $plant^{-1}$ (62.56) were obtained at *Rhizobium* inoculum 80 g kg^{-1} seed which was at par with 120 g kg^{-1} seeds and 40 g kg^{-1} seed while the lowest branches $plant^{-1}$ (7.86) was obtained at control treatment (Table 1). The highest number of filled pods $plant^{-1}$ (54.53) was obtained at *Rhizobium* inoculum 80 g kg^{-1} seed followed by inoculum 40, 120 g kg^{-1} seed while the lowest number of filled pods $plant^{-1}$ (50.73) was obtained at control treatment. Number of seeds pod^{-1} was not significantly affected due to application of *Rhizobium* inoculum. Application of *Rhizobium* inoculum 80 g kg^{-1} seed produced the highest seed yield (1.04 t ha^{-1}) followed by *Rhizobium* inoculum 120, 40 g kg^{-1} seed while the lowest seed yield (0.83 ha^{-1}) was obtained at control treatment of *Rhizobium* inoculum (Fig. 2). The highest stover yield (1.75 t ha^{-1}) was obtained from application of *Rhizobium* inoculum 80 g kg^{-1} seed followed by inoculum 120 g kg^{-1} seed while the lowest stover yield (1.55 t ha^{-1}) was obtained from application of *Rhizobium* inoculum 40 g kg^{-1} seed (Fig. 5). *Rhizobium* inoculum level exerted significant effect on harvest index. It was found that application *Rhizobium* inoculum 80 g kg^{-1} seed gave the highest harvest index (37.28%) followed by at *Rhizobium* inoculum 40 g kg^{-1} (35.95%) seed while the lowest harvest index (32.94%) was found at control (Table 1) treatment of *Rhizobium* (Rhizobium inoculum 0 g kg^{-1} seed).

Effect of interaction

The highest number of branches $plant^{-1}$ (9.91), was obtained at spacing 30 cm × 30 cm with *Rhizobium* inoculum 80 g kg^{-1} seed which was statistically identical to spacing 30 cm × 30 cm with *Rhizobium* inoculum 40 g kg^{-1} seed and spacing 30 cm × 30 cm with inoculum 120 g kg^{-1} seed while the lowest number of branches $plant^{-1}$ (6.33) was obtained at spacing 30 cm × 20 cm with control treatment (Table 2). Apparently, the highest number of total pods $plant^{-1}$ (63.53) was obtained at spacing 30 cm × 30 cm with *Rhizobium* inoculum 80 g kg^{-1} seed combination while the lowest number of pods $plant^{-1}$ (55.14) was obtained at spacing 30 cm × 15 cm with *Rhizobium* inoculum 40 g kg^{-1} seed combinations (Table 2). Interaction between spacing 30 cm × 30 cm with *Rhizobium* inoculum 80 g kg^{-1} produced the highest filled pods (55.67) and the lowest number of filled pods $plant^{-1}$ (45.17) was found from the spacing 30 cm × 15 cm with *Rhizobium* inoculum 120 g kg^{-1} seed (Table 2). Apparently, the highest number of unfilled pods $plant^{-1}$ (11.13) was obtained at spacing 30 cm × 15 cm and *Rhizobium* inoculum 80 g kg^{-1} seed combination. On the other hand, the minimum number of unfilled pods $plant^{-1}$ (7.53) was obtained at spacing 30 cm × 25 cm with *Rhizobium* inoculum 80 g kg^{-1} seed combination (Table 2). The highest number of seeds pod^{-1} (4.17) was produced at spacing 30 cm × 20 cm with *Rhizobium* inoculum 80 g kg^{-1} seed (Table 2) while number of seeds pod^{-1} produced at other interaction of spacing and *Rhizobium* inoculum is statistically identical. Numerically, the highest 1000-seed weight (106.2 g) was produced at spacing 30 cm × 20 cm with *Rhizobium* inoculum 80 g kg^{-1} seed followed by spacing 30 cm × 20 cm with *Rhizobium* inoculum 120 g kg^{-1} seed and the lowest 1000-seed weight (99.67 g) was produced at spacing 30 cm × 30 cm with *Rhizobium* inoculum 120 g kg^{-1} seed (Table 2). Spacing 30 cm × 20 cm gave the highest seed yield (1.46 t ha^{-1}) with the application of *Rhizobium* inoculum 80 g kg^{-1} seed followed by same spacing with the application of *Rhizobium* inoculum at 120 g kg^{-1} seed while the lowest seed yield (0.48 t ha^{-1}) was obtained from spacing 30 cm × 25 cm with the application of *Rhizobium* inoculum at 40 g kg^{-1} seed (Fig. 3). Spacing 30 cm × 20 cm with the application of *Rhizobium* inoculum 80 g kg^{-1} seed produced the maximum stover yield (2.53 t ha^{-1}) which was statistically identical with spacing 30 cm × 20 cm with *Rhizobium* inoculum 120 g kg^{-1} seed while the lowest stover yield (0.88 t ha^{-1}) was obtained from the spacing 30 cm × 30 cm with *Rhizobium* inoculum 80 g kg^{-1} seed (Fig. 6). The highest harvest index (47.80 %) was found from the spacing 30 cm × 15 cm with application of *Rhizobium* inoculum 80 g kg^{-1} seed, which was at par with spacing 30 cm × 30 cm combined with *Rhizobium* inoculum 120 g kg^{-1} seed while the lowest harvest index (22.76%) was found in spacing 30 cm × 25 cm in combination with the application of *Rhizobium* inoculum 40 g kg^{-1} seed (Table 2).

Table 2. Effect of interaction between spacing and *Rhizobium* inoculum level on crop characters, yield components and yield of faba bean

Interaction (Spacing × *Rhizobium* inoculum level)	Number of branches plant^{-1}	Number of pods plant^{-1}	Number of filled pods plant^{-1}	Number of unfilled pods plant^{-1}	Number of seeds pod^{-1}	1000- seed weight (g)	Harvest index (%)
$S_1 \times R_1$	9.27b	61.47	51.79bcd	10.67	3.66b	102.8	37.51e
$S_1 \times R_2$	9.07ab	60.26	53.70bc	8.067	3.72b	102.6	39.23de
$S_1 \times R_3$	9.91a	63.53	55.67a	7.600	3.52b	100.23	41.59cd
$S_1 \times R_4$	8.88abc	61.00	49.53cde	8.800	3.69b	99.67	45.88ab
$S_2 \times R_1$	8.20bcde	62.20	54.53a	8.067	3.61b	100.5	32.01f
$S_2 \times R_2$	7.43efg	59.00	47.83de	10.07	3.67b	102.4	22.76g
$S_2 \times R_3$	8.78bc	56.90	45.23e	7.533	3.71b	103.8	30.88f
$S_2 \times R_4$	7.47efg	61.07	50.60bcd	9.333	3.63b	102.4	30.88f
$S_3 \times R_1$	6.33g	60.50	51.60bcd	9.667	3.69b	100.5	29.38f
$S_3 \times R_2$	7.42efg	62.33	51.97bcd	7.867	3.43b	101.3	29.16f
$S_3 \times R_3$	7.38efg	61.93	54.06b	9.133	4.17a	106.2	36.59e
$S_3 \times R_4$	7.60def	62.00	47.88de	10.67	3.58b	104.8	35.11e
$S_4 \times R_1$	8.70bcd	59.87	51.77bcd	8.267	3.65b	101.8	35.85e
$S_4 \times R_2$	7.18efg	55.14	49.87cde	8.733	3.71b	102.0	36.87e
$S_4 \times R_3$	7.77cdef	58.47	49.77cde	11.13	3.65b	104.3	47.80a
$S_4 \times R_4$	6.60fg	56.50	45.17 e	10.07	3.61b	104.1	43.42bc
Sig. level	**	NS	**	NS	**	NS	**
CV (%)	7.84	6.28	5.41	23.55	5.17	3.79	5.15

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); **= Significant at 1% level of probability, NS = Not Significant; S_1= 30 cm × 30 cm, S_2= 30 cm × 25 cm, S_3= 30 cm × 20 cm, S_4= 30 cm × 15 cm; R_1= 0 g kg^{-1} seed, R_2= 40 g kg^{-1} seed, R_3= 80 g kg^{-1} seed, R_4= 120 g kg^{-1} seed

Quality character (proximate components)

Effect of spacing

The highest crude protein (33.62%) was obtained from spacing 30 cm × 25 cm followed by spacing 30 cm × 20 cm while the lowest crude protein (31.36%) was obtained from spacing 30 cm × 30 cm. The highest crude fat (3.16%) was obtained from spacing 30 cm × 20 cm followed by spacing 30 cm × 15 cm while the lowest crude fat (1.98%) was obtained from spacing 30 cm × 30 cm (Table 3). The highest ash (4.81%) was obtained from spacing 30 cm × 15 cm, while the lowest ash content (4.23%) was obtained from wider spacing 30 cm × 30 cm (Table 3). The highest crude fibre (15.49%) was obtained from spacing 30 cm × 30 cm followed by spacing 30 cm × 20 cm while the lowest crude fibre (14.10%) was obtained from closer spacing 30 cm × 15 cm (Table 3).

Effect of Rhizobium inoculum level

Inoculation of *Rhizobium* significantly increased crude protein content in faba bean seeds compared to un-inoculated control plants (Table 3). *Rhizobium* inoculum applied at 120 g kg^{-1} seed *Rhizobium* produced the highest crude protein (33.54%) followed by inoculum at 40 g kg^{-1} seed while the lowest crude protein (32.03%) was obtained from control treatment (*Rhizobium* inoculum not applied). This result in accordance with that of Rugheim and Abdelgani (2012) and Arafa *et al.* (2018). The highest crude fat (2.82%) was obtained in *Rhizobium* inoculum 120 g kg^{-1} seed followed by inoculum at 80 g kg^{-1} seed while the lowest crude fat (2.17%) was obtained from *Rhizobium* inoculum 40 g kg-^{1} seed (Table 3). *Rhizobium* inoculation showed an increasing trend of crude seed fat content beginning 80 g kg^{-1} seed onward and reached the highest at 120 g kg^{-1} seed. This is due to application of biological fertilization with *Rhizobium leguminosarum bv. viceae*. Similar findings were reported by Elsheikh and Elzidany (1997). *Rhizobium* inoculum significantly increases ash content. Application of *Rhizobium* inoculum at 80 g kg^{-1} produced the highest ash content (4.88%) which was at par with inoculum level 120 g kg^{-1} seed while the lowest ash content (4.25%) was obtained from *Rhizobium* inoculum at 40 g kg^{-1} seed. This corroborates with the findings of Rugheim and Abdelgani (2012). In case of inoculation the highest fibre content (15.28%) was obtained from application of *Rhizobium* inoculum 40 g kg^{-1} seed followed by control treatment while the lowest fibre content (13.64%) was obtained in *Rhizobium* inoculum 80 g kg^{-1} seed (Table 3).

Interaction effect

The highest crude protein content (35.73%) was found from the spacing 30 cm × 30 cm combined with *Rhizobium* inoculum 120 g kg^{-1} seed which was similar to the spacing 30 cm × 25 cm combined with *Rhizobium* inoculum 80 g kg^{-1} seed (Table 4) while the lowest protein content (26.64%) was found from the spacing 30 cm × 30 cm in combination with the control treatment (*Rhizobium* not applied) (Table 4). The highest seed fat content (4.48%) was obtained at spacing 30 cm × 20 cm combined with *Rhizobium* inoculum 120 g kg^{-1} seed followed by interaction between spacing 30 cm × 20 cm with *Rhizobium* inoculum 80 g kg^{-1} seed while the lowest seed fat content (1.86%) was found in spacing 30 cm × 30 cm combined with *Rhizobium* inoculum 40 g kg^{-1} seed (Table 4). Spacing 30 cm × 25 cm along with *Rhizobium* inoculum 80 g kg^{-1} gave the highest ash content (5.63%) followed by spacing 30 cm × 15 cm with inoculum 120 g kg^{-1} seed while the lowest ash content (3.86%) was found from the spacing 30 cm × 25 cm with the *Rhizobium* inoculum 40 g kg^{-1} seed (Table 4). Spacing 30 cm × 30 cm along with the application of *Rhizobium* inoculum 0 g kg^{-1}gave the highest seed fibre content (18.04%) followed by interaction between spacing 30 cm × 20 cm and 40 g kg^{-1} seed while the lowest seed fibre content (12.47%) was found from the spacing 30 cm × 30 cm combined with the *Rhizobium* inoculum 80 g kg^{-1} seed (Table 4).

Table 3. Effect of spacing and *Rhizobium* inoculum level on quality of faba bean

Treatments	Crude protein (%)	Crude fat (%)	Ash (%)	Fibre (%)
Spacing (cm × cm)				
30 × 30	31.36d	1.98d	4.23c	15.49a
30 × 25	33.62a	2.36c	4.65b	14.24c
30 × 20	33.07b	3.16a	4.79a	15.01b
30 × 15	32.75c	2.84b	4.81a	14.10d
Rhizobium inoculum level (g kg^{-1} seed)				
0	32.03d	2.58c	4.51b	15.04b
40	33.02b	2.17d	4.25c	15.28a
80	32.21c	2.77b	4.88a	13.64d
120	33.54a	2.82a	4.85a	14.88c
Level of Significance	**	**	**	**
CV (%)	0.50	2.17	1.31	0.57

Table 4. Effect of interaction between spacing and *Rhizobium* inoculum level on quality of faba bean

Interaction (Spacing × *Rhizobium*)	Crude Protein (%)	Crude fat (%)	Ash (%)	Fiber (%)
$S_1 \times R_1$	26.64k	2.03ij	4.40f	18.04a
$S_1 \times R_2$	33.65d	1.86l	4.08g	16.02c
$S_1 \times R_3$	29.43j	2.11hi	4.14g	12.47l
$S_1 \times R_4$	35.73a	1.90 kl	4.31f	15.42d
$S_2 \times R_1$	34.99b	2.57e	4.55e	14.00h
$S_2 \times R_2$	30.81i	2.22g	3.86h	14.44g
$S_2 \times R_3$	35.73a	2.18gh	5.63a	13.60i
$S_2 \times R_4$	32.93f	2.45 f	4.55e	14.92f
$S_3 \times R_1$	35.00b	1.99 jk	4.38f	15.25e
$S_3 \times R_2$	34.30c	2.15gh	4.42f	17.56b
$S_3 \times R_3$	30.79i	4.02b	5.15c	13.12j
$S_3 \times R_4$	32.20g	4.48a	5.21bc	14.13h
$S_4 \times R_1$	31.50h	3.73c	4.69d	12.88k
$S_4 \times R_2$	33.30e	2.43f	4.64de	13.11j
$S_4 \times R_3$	32.90f	2.77d	4.61de	15.35de
$S_4 \times R_4$	33.30e	2.44f	5.31b	15.04f
Level of Significance	**	**	**	**
CV (%)	0.50	2.17	1.31	0.57

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); **= Significant at 1% level of probability; S_1=30 cm × 30 cm, S_2= 30 cm × 25 cm, S_3= 30 cm × 20 cm, S_4= 30 cm × 15 cm and R_1= 0 g kg^{-1} seed, R_2= 40 g kg^{-1} seed, R_3 = 80 g kg^{-1} seed, R_4= 120 g kg^{-1} seed

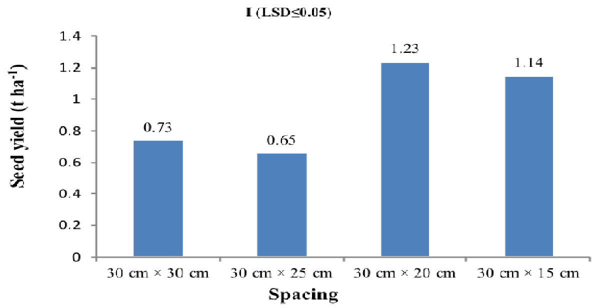

Fig. 1. Effect of spacing on seed yield of faba bean

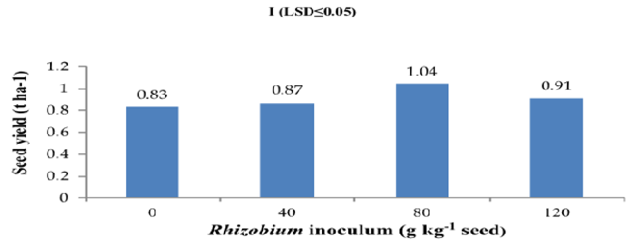

Fig. 2. Effect of *Rhizobium* inoculum level on seed yield of faba bean

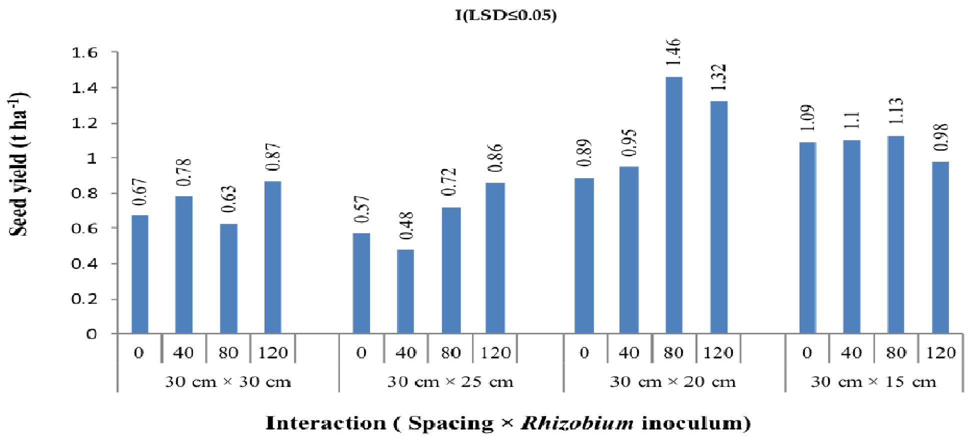

Fig. 3. Interaction effect of spacing and *Rhizobium* inoculum level on seed yield of faba bean

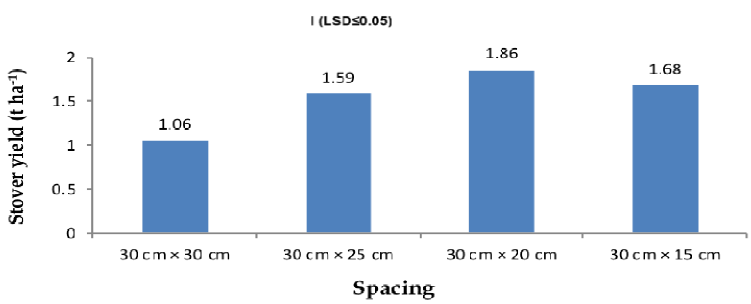

Fig. 4. Effect of spacing on stover yield of faba bean

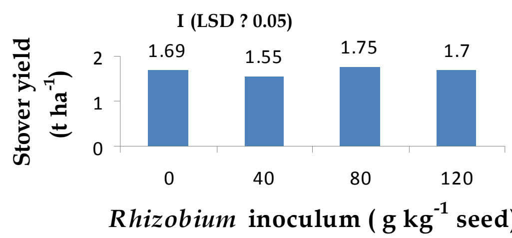

Fig. 5. Effect of *Rhizobium* inoculum level on stover yield of faba bean

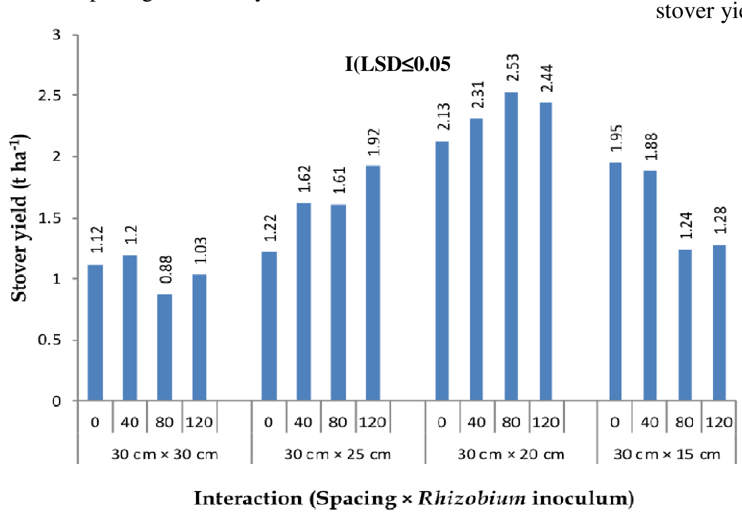

Fig. 6. Interaction effect of spacing and *Rhizobium* inoculum level on stover yield of faba bean

Conclusion

The highest seed yield, seed crude fat and ash were recorded at spacing 30 cm × 20 cm while the highest seed crude protein and seed fibre were recorded at 30 cm × 25 cm and 30 cm × 30 cm spacing, respectively. In case of *Rhizobium* inoculum, the highest seed yield and stover yield were obtained in *Rhizobium* inoculum 80 g kg^{-1} seed. The highest seed crude protein, crude fat and ash were recorded at *Rhizobium* inoculum 120 g kg^{-1} seed while the highest seed fibre was recorded at *Rhizobium* inoculum 40 g kg^{-1} seed. In case of interaction, the highest seed yield and stover yield were obtained at 30 cm × 20 cm spacing combined with *Rhizobium* inoculum 80 g kg^{-1} seed while the highest protein and ash were found at 30 cm × 25 cm spacing combined with *Rhizobium* inoculum 80 g kg^{-1} seed whereas the highest crude fat and fibre were recorded at 30 cm × 20 cm spacing with *Rhizobium* inoculum 120 g kg^{-1} seed and spacing 30 cm × 30 cm with control treatment of *Rhizobium*, respectively. Based on the findings of the study it can be concluded that spacing 30 cm × 20 cm coupled with *Rhizobium* inoculum 80 g kg^{-1} seed appears as the promising combination in respect of seed yield of faba bean.

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