Optimum inter and intra row spacing for faba bean production under Fluvisols

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Abstract: **A field experiment was conducted at Haramaya university research site to determine optimum inter and intra row spacing for faba bean production under Fluvisol. Three inter row spacing (30, 40 and 50 cm) and three intra row spacing (8,10 and 12 cm) were arranged in 3 x 3 factorial combination in Randomized Complete Block Design (RCBD) with three replications. The results revealed that inter and intra row spacing had a significant effect on growth, yield and yield components of faba bean, except 100 seed weight. However, interaction effect of inter and intra row spacing was not significant. An increase in inter and intra row spacing significantly increased seed germination percentage, the number of branches per plant, pod length, number of pods per plant, number of seeds per pod and seed yield per plant. However, an increase in inter and intra row spacing reduced plant height, lodging, seed yield (kg ha-1) and dry matter yield (kg/ha). The highest seed yield of faba bean was obtained in 40 cm inter and 10 cm intra row spacing. Therefore, 40 cm inter and 10 cm intra row spacing is recommend for obtaining high yield of faba bean under Fluvisols.**

Keywords: Fluvisol, inter-row, intra-row, spacing, yield

I. INTRODUCTION

Faba bean ranks first in its production volume and cultivated land among pulse crops cultivated in Ethiopia and it is valuable as the cheap source of protein in most Ethiopian diet [1]. It plays an essential role in crop rotation due to their ability to fix nitrogen, and also able to provide a significant level of nitrogen from the soil air using a symbiotic relationship with Rhizobium bacteria [2]. According to Central Statistics Agency of Ethiopia 2012/13, Faba bean takes over 30% (nearly half a million hectares) of cultivated land with an average national productivity of 1.5 tons ha-1.

Ethiopia is considered as the secondary center of diversity and also one of the nine major agro-geographical production regions of faba bean. However, the productivity of faba bean in Ethiopia is still, far below its potential due to several constraints. Planting density, which affect the growth, development and grain productivity per unit area in almost all agricultural crops, including faba bean is one of the constraints. Plant density has a remarkable capacity to exploit the environment with varying competitive stresses. High plant density or narrower wider spacing may cause lodging, less light penetration in the crop canopy, reduced photosynthetic efficiency and can reduce the yield drastically; in contrast, low plant density or wider spacing may result in low yield, more weed infestation and poor radiation-use efficiency [3]. It has been reported that among various package of improved production technology proper plant population with appropriate adjustment of inter and intra row spacing play key role in enhancing faba bean production [4]. Optimum plant density differs from each variety and location, since different location has different soil type, soil moisture, soil fertility and relative humidity [5].

Fluvisol is a genetically young soil in alluvial deposits and it is a weekly developed soil. It is one of the major soil types in Eastern Ethiopia. Therefore, the present study aims to determine optimum inter and intra row spacing for faba bean production under Fluvisol.

II. MATERIALS AND METHODS

A. Experimental Site

The experiment was carried out during 2009 crop season at Rare, the research farm of Haramaya University. The site is located at a latitude of $9^o 26'$ N, a longitude of $42^o 03'$ E and an altitude of 1980 m asl. The rainy season of the area is bimodal with an average annual rainfall of 790 mm. The mean annual minimum and maximum temperatures are 8.25 and 23.4^0 C, respectively. The mean relative humidity is 50%, varying from 20 to 81%. The soil type of the experimental site is Fluvisol. The physical and chemical property of the soil is presented by Table I.

TABLE I: Initial Soil Properties of The Experimental Site

Soil properties		Value
pH		6.50
Total nitrogen (%)		0.13
Organic matter (%)		1.92
Available phosphorus(mg/kg)		9.80
CEC (cmol(+)/kg)		48.00
Soil texture	% Sand	49.60
	% Clay	28.40
	% Silt	22.00

B. Experimental Treatments and Design

The experiment was conducted by using 3 x 3 factorial combinations of inter-row (30 cm, 40 cm and 50 cm) and intra-row (8 cm, 10 cm, and 12 cm) spacing. The treatments were laid out in Randomized Complete Block Design (RCBD) with three replications. Details of treatment combinations and plant density are given in Table II. The plot size 6.0 m x 3.6 m (21.6 m^2) was used for all treatments. The number of rows per plot for the 30 cm, 40 cm and 50 cm inter row spacing were 12, 9 and 7, respectively, and the number of plants per row for the 8 cm, 10 cm and 12 cm intra-row spacing were 75, 60 and 50, respectively. The experimental material used for this study was the new faba bean variety called "*Gachena*". The variety was released by the Haramaya University. The variety has an indeterminate growth habit and grows well in the Hararghe highlands with an annual rainfall of 700-1000 mm.

TABLE II: Treatment Combinations and Corresponding Plant Population

Inter row	Intra row	Treatment	Plants ha^{-1}
30 cm	8 cm	T1	416,667
	10 cm	T2	333,333
	12 cm	T3	277,778
40 cm	8 cm	T4	312,500
	10 cm	T5	250,000
	12 cm	T6	208,333
50 cm	8 cm	T7	250,000
	10 cm	T8	200,000
	12 cm	T9	166,667

C. *Land Preparation, Planting And Data Collection*

The experimental field was ploughed and harrowed to a fine tilth using a tractor. The seeds were planted manually by placing two seed per hill on July 17, 2009. The plants were thinned to one plant per hill 10 days after emergence to maintain the prescribed intra- row population. At planting 18 kg/ha N and 46 kg /ha P_2O_5 was applied. The amount of fertilizer was based on the initial soil chemical properties (Table I) and crop requirement of N and P. The source of N and P_2O_5 were Diammonium Phosphate (DAP). Plots were regularly monitored and kept free from weeds and pests by manual weeding and pesticide application, respectively. Harvesting was done manually on November 27, 2009 at physiological maturity and samples were taken from a sample quadrat of 2 m x 2 m for each plot. Data such as, seed germination percentage, physiological maturity, lodging percentage, plant height, number of branches per plant, pod length, leaf area index at pod initiation, pod length, number of pods per plant, number of seeds per pod, hundred seed weight, seed yield per plant, seed yield, biomass yield, harvest index and disease score were collected.

D. *Statistical Analysis*

The SAS Statistical Software Package (Version 9.4) was used to perform an analysis of variance appropriate for factorial experiment in RCBD. The Least Significant Difference (LSD) was used for mean separation at 0.05% probability levels

III. RESULT AND DISCUSSION

Percentage of Seed Germination: The effect of inter and intra row spacing on percentage of seed germination was significant. However, the interaction effect of inter and intra row spacing was not significant. The highest percentage seed germination (92.6% and 93%) were observed in wider spacing (50 cm inter and 12 cm intra row spacing, respectively), while the lowest (86.6% and 87%) were observed in the narrowest spacing (30 cm inter and 8 cm intra row spacing, respectively). The trend noted was an increase in percentage of seed germination with decrease plant density (Table III). This result is in line with Tuarira and Moses [8] who reported the highest seed germination percentage on wider inter and intra row spacing.

Physiological Maturity: Inter and intra row spacing had a significant effect on physiological maturity of faba bean. However, the interaction effect of inter and intra row spacing was not significant (Table III). Plants grown in wider inter row spacing (50 cm) matured earlier (115 days) than the rest of the spacing. Similarly, plants grown in wider intra row spacing (12 and 10 cm) matured earlier than plants grown in narrow intra row spacing (8 cm). Increasing plant density considerably delayed maturity of faba bean. This might be due to lower canopy temperatures in the narrow rows which potentially reduced heat accumulation by plants and thereby prolonged maturity period. These results are in agreement with the findings of Lopez et al. [9] and Oad et al. [10] who reported that closer row spacing increased maturity days.

Leaf Area Index (LAI): LAI was significantly affected by inter and intra-row spacing, but not by interaction effect (Table III). The highest LAI (6.7) was obtained in the narrowest inter row spacing (30 cm) while the lowest (5.10) was for the widest spacing (50 cm). Likewise, the highest LAI (7.11) was obtained in narrowest intra row spacing (8 cm), while the lowest (4.44) was found in widest intra row spacing (12 cm). LAI was inversely related to an increase in inter and intra-row spacing. The rate of increase of leaf area determines the rate of increase in the photosynthetic capacity of the plant. This was probably due to decrease in ground area when inter and intra-row spacing was decreased. This is in line with Gezahegn et al. [4] who indicated that LAI was positively related with plant population.

Plant height (cm): Inter and intra row spacing had a significant effect on plant height of faba bean. However, the interaction effect of inter and intra row spacing was not significant on plant height of faba bean (Table III). The narrowest inter (30 cm) and intra (8 cm) row spacing gave significantly taller plants (104 cm) than the rest of the spacing. Furthermore, with the increase of the plant densities the plant height was increased. This was probably due to competition of plants in higher densities for light, resulting in taller plants. Similar findings were reported by Khalil et al. [11] and Singh et al. [12], who indicated that the denser plant population increased the plant height of faba bean due to competition among plants.

Number of branches per plant: There was a significant difference in the number of branches per plant as affected by inter and intra row (Table III). The widest inter (50 cm) and intra (12 cm) row spacing gave the highest number of branches per plant compare to other treatments. There were no significant difference (P>0.05) between 40 cm and 30 cm inter row spacing on number of branches per plant. Similarly, there were no significant difference (P>0.05) between 10 and 8 cm intra row spacing on number of branches per plant. The production of more branches at the wider spacing was attributed to low competition among plants for growth factors, which finally increased the number of effective branches. Moreover, wider plant spacing which intercepted more photosynthetically active radiation owing to better geometric situation that might have resulted in vigorous plant growth and more number of branches. The result is in line with Mekkei [13] who reported that the number of branches/plant was increased by increasing inter and intra row spacing.

Lodging (%): There was a significant difference in lodging of faba bean as affected by inter-and intra-row (Table III). However, there was no interaction effect on lodging of faba bean. The closest inter (30 cm) and intra (8 cm) row spacing resulted in higher lodging than the rest of the treatments. Furthermore, with the increase of the plant densities the lodging was increased.

TABLE III: Effect Of Inter and Intra-Row Spacing an Percentage af Seed Germination, Physiological Maturity, LAI , Plant Height, Number of Branch Per Plant and Lodging of Faba Bean

Treatment	percentage of seed germination (%)	Physiological maturity (Days)	LAI	Plant height (cm)	Number of branch per plant	Lodging (%)
Inter-row spacing (cm) (A)						
30	86.6b	120a	6.70a	104a	3.8b	3.49a
40	91.6a	117b	5.47b	98.8b	4.1b	2.45b
50	92.6a	115c	5.10b	92.7c	4.4a	1.81b
LSD (P≤0.05)	1.26	146	0.91	4.89	0.18	0.92
Intra-row spacing (cm) (B)						
8	87.3c	119a	7.11a	104a	4.0b	3.71a
10	90.3b	117b	5.71b	98.0b	4.2b	2.46b
12	93.0a	116b	4.44c	93.6b	4.3a	1.59b
LSD (P≤0. 05)	1.26	1.45	0.91	4.89	0.17	0.92
A x B	ns	ns	ns	ns	ns	ns

Means with different letter are significantly different at 5% probability level

Pod length (cm): Inter and intra row spacing had a significant effect on pod length of faba bean. However, the interaction effect of inter and intra row spacing was not significant (Table IV). The narrowest inter row spacing (30 cm) gave significantly lower pod length than wider intra-row spacing (50 and 40 cm) which gave similar pod length values. On the other hand, the three intra-row spacing gave significantly different pod length values in which pod length increased with an increase in intra row spacing. The reduction in pod length was associated with increasing plant density (decreasing inter and intra row spacing) which is in agreement with the report of Turk and Tawaha [14].

Number of pods per plant: The effect of inter and intra row spacing was significant on number of pods per plant (Table IV). The number of pods per plant was increased from 24.2 to 32.1 with increasing inter row spacing from 30 cm to 50 cm. Similarly, number of pods per plant increased from 25.2 to 30.2 with increasing intra row spacing fro 8 cm to 12 cm. This result may be due to wide spaces between the plants attributed to decreased inter plant competition that leads to increased plant capacity for utilizing the environmental inputs in building great amount of metabolites to be used in developing new tissues and increasing its yield components. This result is in agreement with Al-Suhaibani et al. [15] and Khalil et al. [6] and who found the highest number of pods per plant in low plant density.

TABLE IV: Effect of Inter and Intra Row Spacing on Pod Length, Number of Pods Per Plant, Number of Seeds Per Pod, Seed Yield Per Plant (G/Plant), 100 Seed Weight, Seed Yield (Kg Ha^{-1}), Dry Matter Yield(Kg Ha^{-1}) and Harvest Index (HI%) of Faba Bean

Treatment	Pod length (cm)	Number of pods per plant	Number of seeds per pod	Seed yield per plant	100 seed weight	Seed yield (kgha^{-}	Dry matter yield (kgha^{-1})	HI (%)
Inter-row spacing (cm) (A)								
30	6.45b	24.2b	2.47b	27.2b	61.1a	4008a	9258a	0.43b
40	6.83a	30.1a	2.73a	33.6a	63.6a	4222a	7952b	0.53a
50	6.86a	32.1a	2.79a	35.7a	63.4a	3138b	5988c	0.52a
LSD(P≤0.05)	0.31	2.89	0.2	6.02	ns	596	1243	0.05
Intra-row spacing (cm) (B)								
8	6.28c	25.2b	2.48b	27.9b	61.9a	3918a	7789ab	0.50a
10	6.66b	28.1ab	2.70a	34.2a	62.1a	4274a	8469a	0.50a
12	6.92a	30.1a	2.80a	34.4a	63.4a	3176b	6840b	0.47a
LSD(P≤0.05)	0.31	2.89	0.2	6.01	ns	596	1243	ns
A x B	ns	ns	ns	ns	ns	ns	ns	ns

Means with different letter are significantly different at the 5 % probability level

Number of seeds per pod: Inter and intra row spacing had a significant effect on number of seeds per pod. However, the interaction effect of inter and intra row spacing was not significant on number of seeds per pod (Table IV). The highest number of seeds per pod were obtained in wider (40 cm and 50 cm inter and 10 and 12 cm intra) row spacing. In contrast, the lowest number of seeds per pod were obtained in 30 cm inter and 8 cm intra row spacing. This result may be due to wide spaces between the plants decreased inter plant competition that leads to increased plant capacity for utilizing the environmental inputs in building great amount of metabolites to be used in developing new tissues and increasing its yield components. This result is in line with Khalil et al. [6] who found the highest number of seeds per pod in low plant density.

Seed yield per plant (g): Seed yield per plant was significantly affected by inter and intra row spacing, but not the interaction effect (Table IV). The narrowest inter (30 cm) and intra row spacing (8 cm) gave significantly lower seed yield per plant than the rest of the treatments. The seed yield per plant between 40 cm and 50 cm inter row spacing were not significantly (P>0.05) different. Similarly, the seed yield per plant between 10 cm and 12 cm intra row spacing were not significantly different. The reduction in yield per plant in narrow spacing (9cm and 30cm inter and intra spacing) was due to the effect of high plant density which chased altered competition within adjacent plants. This result is in agreement with Al-Suhaibani et al. [15] who reported higher seed yield per plant at low plant density. Singh and Singh [16] also reported that the yield potential of an individual plant is fully exploited when sown at wider spacing.

Hundred seed weight (g): Unlike those agronomic parameters discussed above, 100 seed weight was not significantly affected by main and interaction effect of inter and intra-row spacing (Table IV). This agrees with Thangwana and Ogola [17] who reported the non-significant effect of plant density on 100 seed weight of chickpea.

Seed yield (kgha^{-1}): Seed yield was significantly affected by inter and intra-row spacing. Interaction effect of inter and intra row spacing was not significant on seed yield of faba bean (Table IV). Significantly higher seed yield (4222 kg/ha) was observed in the 40 cm inter-row spacing as compared to 50 cm inter-row spacing which gave the lowest seed yield per hectare (3138 kg/ha). The seed yield (4008 kg/ha) obtained from 30 cm inter-row spacing was not significantly different (P>0.05) from the one obtained from the 40 cm inter row spacing. Similarly, higher seed yield was observed in the 10 cm intra-row spacing as compared to the widest intra-row spacing (12 cm) which gave the lowest seed yield per hectare . The seed yield obtained in the 8 cm intra row spacing was not significantly different (P>0.05) from the one obtained in the 10 cm inter row spacing. However, higher number of pods per plant, seeds per pod and seed yield per plant were obtained in the wider spacing (50 cm inter and 12 intra row spacing), the seed yield per hectare was significantly lower in wider inter and intra-row spacing. The higher seed yield in 40 cm inter and 10 cm intra row spacing indicated that the main determinant of seed yield was plant population which along with other yield attributes contributed towards significant increase in seed yield. The result is in agreement with Al-Suhaibani et al. [15] who stated that when the planting density is too low each individual plant may perform at its maximum capacity but there may be insufficient total plants to reach the optimum yield. Dahmardeh et al. [18] also found high seed yield on faba bean in sandy loam soil at 20 plants/m^2. However, Gezahegn et al. [4] found highest seed yield of faba bean at Vertisol in 30 cm inter and 8 cm intra row spacing compare to 40 cm inter and 10 cm intra row spacing.

Dry matter yield (kg/ha): Inter and intra row spacing had a significantly affected on dry matter yield of faba bean. However, the interaction effect of inter and intra row spacing was not significant (Table IV). The higher biomass (9258 kg/ha) was obtained in narrower inter row spacing (30 cm) while the lower dry matter yield (5988 kg/ha) was found in the wider inter row spacing (50 cm). Likewise, the higher dry matter yield (8469 kg/ha) was found narrower intra row spacing (8 cm) while the lower (6840 kg/ha) was found in the wider inter row spacing (12 cm). The dry matter yield obtained from 10 cm intra row spacing was not significantly different (P>0.05) from 8 cm intra row spacing. Dry matter yield was higher in high plant densities compared to low plant densities. This was due to the higher LAI which provided a larger surface area for light interception resulting in higher net photosynthesis and might have led to greater biomass per unit area. The result is in line with Moosavi et al. [19] who reported a positive effect of increase plant density on dry biomass. Al-Rifaee et al. [20] also reported that the dry matter yield of faba bean increased with increasing plant population due to the increase in the number of plants per unit area and the associated increase in plant height.

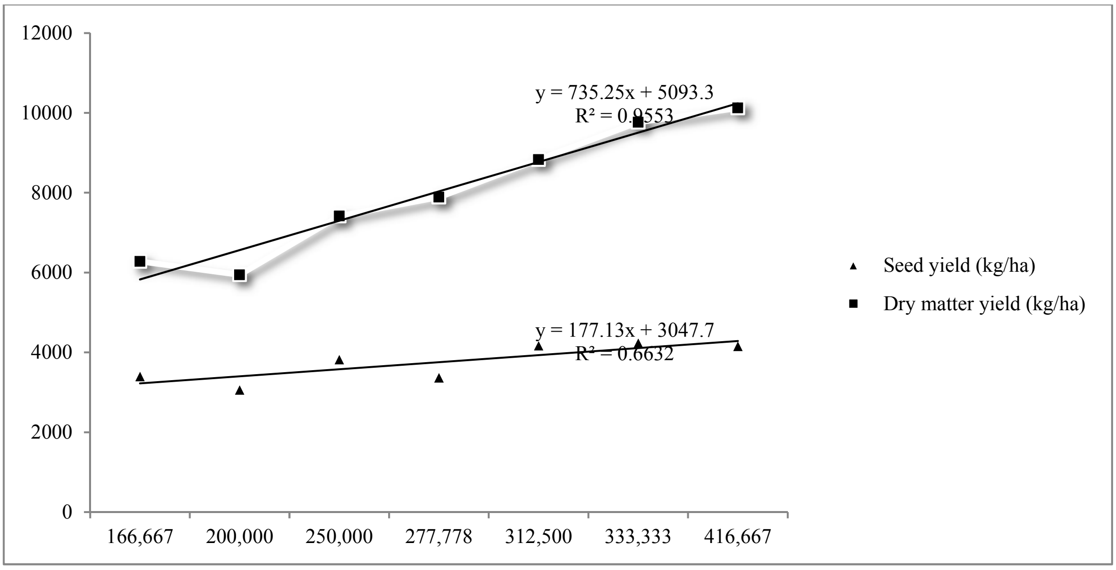

Figure 1. Relationship of plant density with seed yield and dry matter yield of faba bean grown on fluvisol

Harvest index (HI): HI was significantly affected by inter row spacing but not intra row spacing and the interaction of inter and intra row spacing (Table IV). The wider inter row spacing (50 cm) gave higher harvest index than narrow inter row spacing (30 cm), but it was not significantly different from 40 cm inter row spacing. The higher plant density gave the lowest HI. This is due to competition and shading among plants in high plant density that can limit carbohydrate supply. On the other hand, the highest harvest index in low plant density might be a better utilization of available nutrients by faba bean plants. The result is in line with Imran et al. [21] who found maximum harvest index at lower plant density as compared to high plant density. However, Edwards and Purcell [22] who worked on Vertisol and they reported that harvest index of soybean increased with increased plant density.

IV. CONCLUSION

Based on the result, variation of inter and intra row spacing has a significant effect on growth, yield and yield component of faba bean under Fluvisol. The highest seed was recorded in 40 cm inter and 10 cm intra row spacing. Therefore, it can be conclude that 40 cm inter and 10 cm intra row spacing is recommended for obtaining high yield of faba bean under Fluvisol.

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