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Original Research

Growth and Yield Performance of Faba Bean Varieties in Western Ethiopia with Varying Intra Spacing's

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Abstract

The availability of improved cultivars and enhanced agronomic procedures is a key requirement for achieving high faba bean output in Western Ethiopia. As a result, it is critical to select a wide variety at high density. The purpose of this study was to look at the effects of intraspacing on yield and yield components in Faba bean varieties. The main influence of variety and intraspacing was highly significant (P<0.01) on the majority of phonological, growth, yield components, and yield of faba beans. The 'Gora' variety produced the maximum yield performance at 10 cm intraspaced, with the highest net benefit and marginal rate of return.

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INTRODUCTION

The faba bean (*Vicia faba* L.) is one of the earliest domesticated edible legumes, having been farmed for at least 5,000 years in the Mediterranean region (Metayer, 2004). Faba bean is grown in temperate and subtropical climates around the world (Torres et al., 2006). In Ethiopia, faba bean is grown on almost 492,271.60 hectares of land, with an annual yield of 1041953.5 tons showing 2.1ton ha^{-1} (CSA, 2019). India, Myanmar, Brazil, China, the United States, Mexico, Tanzania, Uganda, Kenya, and Ethiopia are among the top ten global producers of faba bean (FAOSTAT 2019). Ethiopia is the world's tenth largest faba bean producer. However, production and productivity remain poor in comparison to available potential.

Faba bean is the most significant pulse crop since it is a nitrogen-fixing leguminous plant that provides high-quality protein and is utilized as human food in underdeveloped nations as well as animal feed in developed countries (Talal & Ghalib, 2006). According to research, faba bean varieties exhibit considerable variability in yield and yield components (Daur et al., 2010). Furthermore, planting density impacts growth, development, and grain productivity per unit area in practically all agricultural crops, including faba beans (Lemerle et al., 2006). It has been found that proper plant populations with appropriate intra-row spacing play a crucial role in boosting faba bean yield among various packages of improved production technology (Gezahegn et al., 2016). The optimal plant density varies by variety and location since each area has a varied soil type, soil wetness, soil fertility, and relative humidity (Elhag et al., 2014). As a result, farmers in the Guduru District of Western Ethiopia have relied on a local faba bean variety with a different population density, resulting in a low yield. Identifying the high-yielding potential variety and the appropriate plant population is thus critical for increasing faba bean production. As a result, the study sought to investigate the optimal intra-spacing for yield and yield components of faba bean types, as well as their interaction effects, in the Guduru region of Western Ethiopia

MATERIALS AND METHODS

Description of the study area

The research was conducted at "Yeron Amma Tole," Guduru district, Horro Guduru Wollega Zone, western Oromia Regional State, Ethiopia (Figure 1) during the cropping season of 2018-2019. The elevation ranges from 1500 to 2400 meters above mean sea level, and the site is located at 09º29'N latitude and 37º34'E longitude. During the trial season, the highest total monthly rainfall of 382.5 mm was recorded in June, while the lowest total monthly rainfall (0 mm) was obtained in December. During the trial, the highest average maximum and minimum monthly temperatures were 28.3ºC and 14.3ºC, respectively (Figure 2).

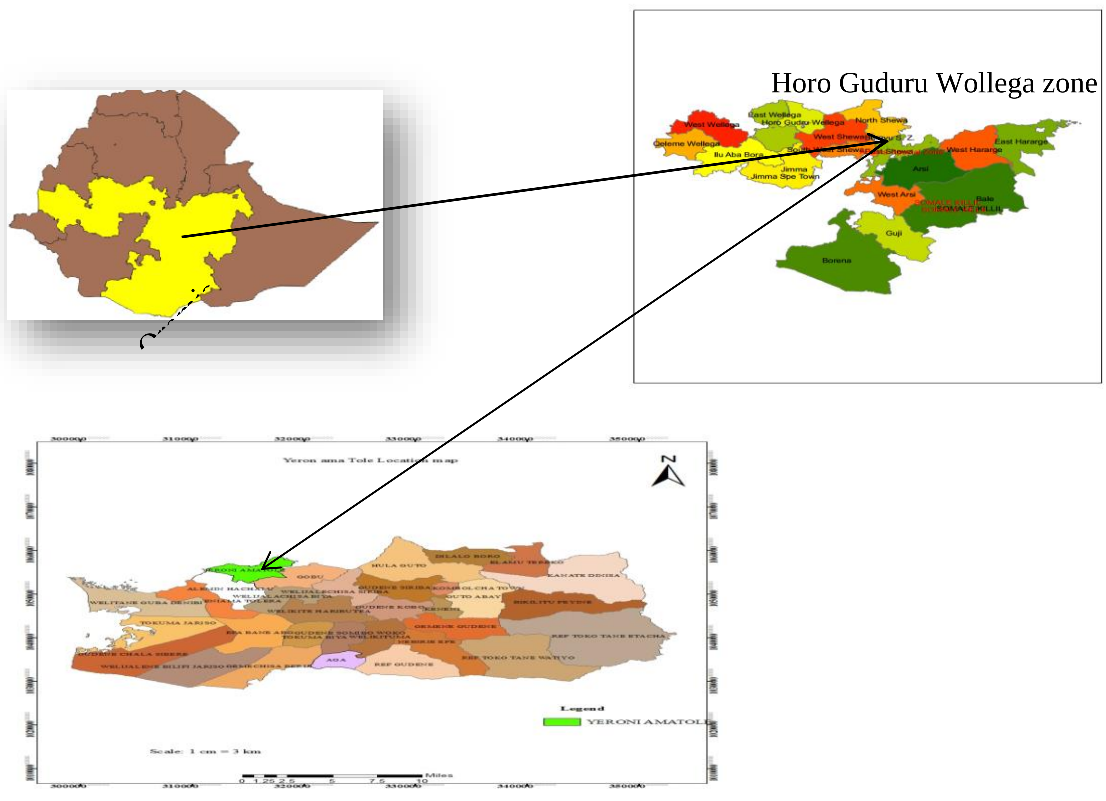

Figure 1 *Map of the study areas*

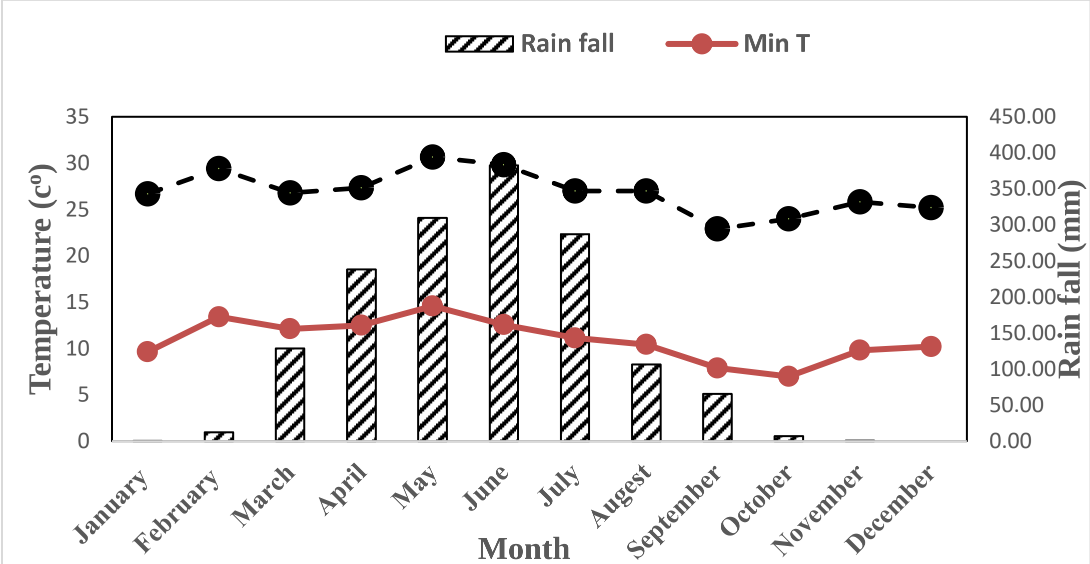

Figure 2 *The monthly total rainfall, mean maximum and minimum temperatures at Guduru district*

Experimental materials

'For the experimental proposal, Moti, 'Gora,' and local faba bean cultivars were chosen (Table 1). The cultivars 'Moti' and 'Gora' were purchased from the Holeta Agricultural Research Center, and the local variety from the study region was included. The enhanced varieties were chosen because they were preferred by farmers due to their better adaptation to the local environments. The treatments consisted of three faba bean cultivars and four intrarow spacing's of 5, 10, 15, and 20 cm, for a total of 12 experimental treatments put out in a Randomized Complete Block design with three replications. Each plot had dimensions of 4.8 m X 4m (19.2 m^2), and each plot and block was separated by 0.50 m and 1 m, respectively. In addition, each trial unit received the necessary dose of 100 kg NPS ha^{-1} fertilizer.

Table 1
Experimental materials

Characteristics	Name of Variety	
	'Gora'	'Moti'
Year of release	2013	2006
Days to maturity	126-168	116-135
Altitude adaptation (m.s.a.1)	1900-2800	1900-2800
Rainfall adaptation (mm)	700-1100	700-1000
1000 seed weight(gm)	938	763
Flower Color	White by black	White by black
Seed color	Light brown	Light green
Recommended intra spacing(cm)	10	10
Center of releasing	Holeta	Holeta
Yield(q/ha) On station	22-57	27-50
Yield(q/ha) On farm	20-40	20-25

Data collection

Data on various parameters were collected from the experimental plot's central rows on days to 50 percent physiological maturity, plant height, number of leaves plant-1, number of branches plant-1, plant stand count, number of pods plant-1, number of seeds pod-1, number of seed plant-1, 100 seed weight (g), biomass yield (above ground dry biomass) (kg ha-1), seed yield (kg ha-1) and harvest index.

Partial budget analysis

Economic study was carried out to assess the economic feasibility of the treatments, and the average seed yield was reduced by 10% to compensate for the difference between the experimental yield and the yield farmers expect from the same treatment, according to CIMMYT (1988). A market price of 25 Ethiopian birr (ETB) kg-1 was obtained. The amount of seed required varied depending on the intra spacing. Other input costs, such as fertilizer and labor, were assumed to be constant throughout all treatments. The therapy deemed a worthwhile alternative for farmers with a minimum acceptable rate of return (MARR) of 100 percent should be used (CIMMYT, 1998). As a result, the gross field benefit (GFB) (ETB ha-1) was calculated as GFB = AGY field or farm gate price of the crop. Furthermore, total variable cost (TVC) (ETB ha-1) was estimated by adding all variable costs, including seed costs. Furthermore, net benefit (NB) (ETB ha-1) was computed by deducting total variable costs from gross field benefits for each treatment. GFB – TVC = NB. The marginal rate of return (MRR) was calculated by dividing the change in net profit by the change in total variable cost. 6*MRR= (ΔNB×100)/ΔTC=NBN

Data analysis

The measured data were subjected to analysis of variance (ANOVA) using the Gen Stat software version 15's General Linear Model (GLM). For the significant parameters, the LSD (least significant difference) test was performed at 5% and 1% probability levels.

RESULTS AND DISCUSSION

The results demonstrated that the major influence of faba beam variety and intra spacing was very significant (P< 0.01) on days to flowering, days to maturity, and plant height. Furthermore, the primary influence of intra spacing was very significant (P< 0.01) on the number of leaves plant-1 and the number of branches plant-1. Furthermore, the interaction impact of variety and intra spacing was significant in terms of plant height and number of leaves plant-1 (Table 2).

The local variety (50 days) bloomed earlier than 'Moti' (55 days) and 'Gora' (57 days), demonstrating a genetic difference between the kinds. Whereas the longest days to 50% flowering (57) were reported at narrower (5 cm) intra spacing, the shortest (50 days) were recorded at broader (20cm) intra spacing. In terms of maturity, the varieties 'Gora' (144 days) and 'Moti' (136 days), which appear to have larger seed sizes, were late maturing, but the local variety smaller seeded was early in maturity (129 days) (Table 3).Similarly, Iyad et al. (2004) and Wondimu (2016) report. According to Al-Rifaee et al. (2004), little seeds of faba bean mature faster than large seeds. Furthermore, when the intra row spacing grew from 5cm to 20cm, the days to maturity reduced from 141 days to 133 days. As a result of the severe competition for limited resources, increasing plant density tends to delay faba bean maturity. Lopez et al. (2005) and Almaz and Kindie (2017) achieved a similar report earlier (2017).

The maximum plant height (153 cm) was recorded on the local variety, while the shortest plant heights (124 cm and 136 cm, respectively) were recorded for the 'Moti' and 'Gora' varieties, respectively. The narrowest intra spacing of 5 cm resulted in the highest plant height (149 cm) than the rest of the spacing (Table 3). Furthermore, the highest plant height (174 cm) was obtained from a combination of local varieties with intra spacing of 5cm, while the lowest plant height was obtained from a 'Moti' variety with intra spacing of 20 cm, which was statistically at parity with intra spacing of 15cm for the same variety (Table 4). Whereas the largest intra spacing (20cm) resulted in the greatest number of branches (2.6) plant-1, there were no significant differences between 20 and 15cm intra spacing (Table 3). As stated by Al-Suhaibani et al. (2013), Bakry et al. (2011) that lower faba bean plant population had the highest number of branches plant-1 than higher population, the production of more branches at the wider spacing could be attributed to the more efficient use of available growth nutrients, water, and light energy, which could favor more photosynthesis and allocation of carbohydrate for all growth points.

The largest number of leaves plant-1 (32) was observed from the wider intra spacing (20 cm), while the lowest number (26) was recorded from the smallest intra spacing (5cm) (Table 3). The number of leaves plant-1 is an essential element in boosting production since leaves are the seat of photosynthetic activities in crops. As a result, the number of leaves generated by a plant is exactly proportionate to photosynthesis production as a result of the photosynthesis process (Gupta and Shukla, 2000).

The main effect of faba beam variety and intra spacing on number of pods plant-1, number of seeds pod-1, number of seeds plant-1, 100 seed weight, above-ground dry biomass, grain yield (kg ha-1) and harvest index was highly significant ($P < 0.01$), while the main effect was significantly ($P < 0.05$) for stand count at harvest. The primary influence of intra spacing on the number of pods plant-1 was also very significant ($P < 0.01$). Moreover, the interaction impact of variety and intra spacing had a highly significant ($P < 0.01$) effect on the quantity of seeds planted. However, there was a substantial interaction effect on plant height, the number of pods plant-1, and the weight of 100 seeds.

Table 2: Mean squares values of various phonological, growth and yield related traits to the responses of faba bean varieties under different intra row spacing at Guduru District, Ethiopia, *and ** - significance at 5 and 1% probability levels, respectively, NS- not significant Df-degree of freedom, DF-days to 50% flowering, DM- days to 90 % physiological maturity, PH- plant height, NLPP -number of leave plant-1, NBPP - Number of branches plant-1, SCH- stand count at harvest, HSW -100 seed weight , NPPP -number of pod plant-1, NSPPd - number of seeds pod-1, NSPPt -number of seed plant-1 , AGMB- above ground biomass SY- seed yield , HI- harvest index.

Table 2 *Mean squares values of various parameters*

Source of variations	D.f	Mean squares												
		DF	DM	PH	NLPP	NBPP	SCH	HSW	NPPP	NSPPd	NSPPt	AGMB	SY	HI
Rep	2	213.36	1071.19	1431.44	200.55	1.12	788.08	208.47	56.31	3.52	191.99	441963	4472	10.462
Var	2	153.038**	716.69**	2475.19**	71.04NS	0.09NS	105.08*	4303.52**	70.99**	0.73**	369.87**	45588315**	16840882**	697.7**
Spac	3	76.30**	109.6**	668.56**	31.62*	3.45**	641.67**	123.99**	25.85**	0.03NS	151.81**	1620937**	732927**	36.83**
Var ×Spac	6	6.5NS	1.36NS	106.42*	10.57NS	0.05NS	7.97NS	24.00*	3.97*	0.001NS	12.76**	152990Ns	12836NS	1.76NS
Error	22	5.30	4.89	30.05	10.12	0.04	12.90	24.00	1.35	0.014	1.70	159194	23761	2.71
CV (%)		4.3	1.6	4.0	11.2	9.9	4.3	5.8	7.7	4.6	3.7	5.6	5.6	4.5

Table3

Some phonological and growth parameters as influenced by the main effects of variety and intra spacing at Guduru district, Western Ethiopia,

Treatment	D.f	DM	PH	NLPP	NBPP	NPPP	NSPPt	NSPPd $^{-1}$	HSW
Variety									
'Moti'	55^{a}	136^{b}	124^{c}	28	2.1	13.0^{c}	32.2^{b}	2.5^{b}	54.4^{b}
'Gora'	57^{a}	144^{a}	136^{b}	30	2.1	14.4^{b}	41.2^{a}	2.8^{a}	70.5^{a}
Local	50^{b}	129^{c}	153^{a}	27	2.0	17.7^{a}	31.1^{b}	2.3^{c}	32.7^{c}
LSD (5%)	2.0	1.9	4.6	NS	NS	1.0	1.1	0.1	2.6
Intra row spacing (cm)									
5	57^{a}	141^{a}	149^{a}	26^{b}	1.2^{c}	12.8^{c}	29.6^{d}	2.5	47.5^{c}
10	56^{ab}	137^{b}	137^{b}	27^{b}	2.0^{b}	14.7^{b}	33.7^{c}	2.5	52.2^{b}
15	53^{bc}	135^{bc}	133^{bc}	29^{ab}	2.4^{a}	15.9^{a}	36.9^{b}	2.6	54.3^{ab}
20	50^{c}	133^{c}	130^{c}	32^{a}	2.6^{a}	16.7^{a}	39.0^{a}	2.6	56.1^{a}
LSD (5%)	2.3	2.2	5.359	3.1	0.2	1.1	1.3	NS	3.0
CV (%)	4.3	1.6	4.0	11.2	9.9	7.7	3.7	4.6	5.8

Means in columns followed with the same letter (s) are not significantly different to each other at 5% probability level of significance; ns: Non-significant, LSD (0.05): Least Significant Difference at 5%; CV: Coefficient of Variation Mean.

Thus, larger 100 seed weights were obtained from the 'Moti' (54.4g) and 'Gora' (70.5g) varieties than from the Local variety (32.7g) (Table 3), which could be attributed to the fact that the 'Moti' and 'Gora' varieties are large seeded. Similarly, Tamane et al. (2015) discovered that the hundred seed weight of large-seeded faba bean cultivars was higher. A wider intra spacing of 20 cm resulted in a greater 100 seed weight of 56.1g than a narrow intra spacing of 5cm, which resulted in a 47.5g 100 seed weight (Table 3), indicating that higher 100 seed weight was recorded with lower plant populations. Furthermore, Turk and Tawaha (2003), Matthews et al. (2008), and Khalil et al. (2011) revealed that faba bean seed weight was adversely associated to plant density. The greatest 100 seed weight (73.1g) was recorded for the 'Gora' variety at 20 cm intra spacing, which is statistically non-significant for the same types at 15 cm intra spacing, while the minimum 100 seed weight (23g) was recorded for the local variety at the lowest intra space (5cm) (Table 4). The largest number of pods plant^{-1} was reported from the local variety (17.7), while the lowest pod plant^{-1} was recorded from the 'Moti' variety (13.0). With increasing intra spacing, the pod number plant^{-1} rose. The highest number of pods plant^{-1} (16.7) was obtained with a wider spacing (20 cm), which was statistically equivalent to 15cm intra space (Table 3). This is consistent with Bakry et al. (2011) and Al-Suhaibani et al. (2013) findings on faba bean. The Local variant generated more seeds per pod with greater spacing than the other kinds (Table 4). 'Gora' had the highest number of seeds plant-1 (41.2), followed by 'Moti' (32.2). Furthermore, plant density at 15 and 20cm intra spacing produced the most seeds (36.9 and 39.0, respectively) (Table 3). Competition may be to blame for the decrease in yield plant-1 at high plant density. Similar findings support the findings of Al-Suhaibani et al. (2013) and Turk and Tawaha (2002) on faba bean.

In this investigation, the variety 'Gora' had the maximum total quantity of seed per plant (45.3) with larger intra spacing (20 cm) (Table 4). Similarly, the 'Gora' (2.8) and 'Moti' (2.5) varieties yielded the most pod-1 seeds (Table 3). And, during harvest, the 'Moti' and 'Gora' varieties produced the most plants (84 percent and 87 percent, respectively) (Table 5). The highest stand count (91%) was obtained at 20 cm intra spacing. While closer intra spacing of 5cm and 10cm resulted in the lowest stand count of 72 percent and 84 percent, respectively (Table 5), this could be due to competition at greater plant density. Similarly, Abdel (2008) found that as plant density rose, plant mortality increased.

Table 4 Interaction *effect of variety and intra row spacing on plant height,100 seed weight, number of pod plant$^{-1,}$ and number of seed plant^{-1} of faba bean at 'Guduru' district, western Ethiopia*

Intra spacing	Plant height (cm)			100 seed weight (g)			Number of pods plant^{-1}			Number of seeds plant^{-1}		
	'Moti	'Gora	Local	Moti	Gora	Local	Moti'	'Gora'	Local	Moti	Gora	Local
5	128^{def}	147^{b}	174^{a}	50.8^{c}	68.8^{a}	23.0^{e}	9.0^{g}	12.3^{f}	17.1^{abc}	27.7^{h}	38.5^{c}	22.7^{i}
10	127^{def}	136^{cd}	149^{b}	53.6^{bc}	68.9^{a}	33.9^{d}	13.5^{ef}	13.7^{ef}	16.9^{abc}	31.8^{fg}	38.6^{c}	30.7^{g}
15	122^{ef}	132de	145^{bc}	56.0^{bc}	70.9^{a}	35.9^{d}	14.3^{def}	15.5^{cde}	17.9^{ab}	33.9^{ef}	42.4^{b}	34.4^{de}
20	119^{f}	129^{def}	142^{bc}	57.3^{b}	73.1^{a}	38.0^{d}	15.0^{cde}	16.2^{bcd}	18.9^{a}	35.3^{de}	45.3^{a}	36.6^{cd}
LSD (5%)	9.3			5.2			2.0			2.2		
CV (%)	4.0			5.8			7.7			3.7		

Furthermore, the 'Gora' (8525 Kg ha^{-1}) and 'Moti' (7997 Kg ha^{-1}) types had the highest above ground biomass weight (biomass yield). Total biomass yield increased somewhat with increased intra-row spacing up to 10 cm, after which it declined dramatically, following the pattern of seed yield. Thus, overall biomass yield was highest at 10 cm intra spacing (7644 Kg ha^{-1}) and lowest at 20 cm intra spacing (6632 Kg ha^{-1}) (Table 5). This could be because the availability of narrow space results in stronger intra-specific competition for resources at higher plant density (5cm intra space). According to Bakry et al. (2011), Moosavi et al. (2012), and Mtaita and Mutetwa (2014), at the final harvest of faba bean, the above-ground dry matter yield increased with decreasing plant population up to optimal space and subsequently decreased with decreasing plant population .

Table 5 *Stand count at harvest, above-ground dry biomass, seed yield, and harvest index as influenced by the main effects of variety and intra spacing at 'Guduru' district, western Ethiopia.*

Treatment	SCH	AGMB	SY	HI (%)
Variety				
'Moti'	84^{ab}	7997^{b}	3189^{b}	40^{b}
'Gora'	87^{a}	8525^{a}	3643^{a}	43^{a}
Local	81^{b}	4916^{c}	1402^{c}	28^{c}
LSD (5%)	3.0	337.8	130.5	1.4
Intra row spacing (cm)				
5	72^{c}	7035^{bc}	2645^{b}	36^{bc}
10	84^{b}	7644^{a}	3080^{a}	39^{a}
15	89^{a}	7273^{ab}	2845^{b}	38^{ab}
20	91^{a}	6632^{c}	2410^{c}	35^{c}
LSD (5%)	3.5	390.1	150.7	1.6
CV (%)	4.3	5.6	5.6	4.5

Means in columns followed with the same letter (s) are not significantly different from each other at 5% probability level of significance; LSD (0.05): Least Significant Difference at 5%; CV: Coefficient of Variation Mean. SCH- stand count at harvest, AGMB- above ground biomass SY- seed yield, HI- harvest index

Higher seed yield was obtained from the same 'Gora' (3643 kg ha-1) and 'Moti' (3189 kg ha-1) types, whereas local varieties produced the lowest seed yield (1402 kg ha-1) (Table 5). Both the 'Gora' and 'Moti' varieties had a greater number of seeds pod-1, number of seeds plant-1, number of leaves plant-1, hundred seed weight, above-ground dry biomass, and harvest index than the variety local, leading in a better seed yield. Similarly, Tamane et al. (2015) and ICARDA (2010) discovered a considerable difference in seed output among faba bean varieties, while Fekadu (2013) reported that faba bean varieties had a strong influence on seed yield. In this investigation, seed yield increased with increasing intra-row spacing up to 10cm, after which it fell dramatically (Table 5). Thus, the smaller intra spacing (10 cm) produced the largest seed production (3080 kg ha^{-1}) while the widest intra spacing (20 cm) produced the lowest (2410 t ha^{-1}) (Table 5). Thus, 10 cm intra spacing was discovered to be the best intra spacing for faba bean seed yield. This conclusion is consistent with Almaz and Kindie (2017) and Yucel (2013) findings in faba beans. Furthermore, Dahmardeh et al. (2010) and Al-Suhaibani et al. (2013) stated that when planting density is too low, each plant may perform to its maximum potential, but there may not be enough total plants to provide the optimum output. Furthermore, the highest harvest index value was recorded from 'Gora' (43%) and 'Moti' (40%) varieties, while the lowest value was recorded from local (28%) types (Table 5). Better seed yielding cultivars also had a higher harvest index. It is regarded as the endpoint measure of photosynthetic portioning toward productive organs during the actual buildup of yield. Furthermore, the highest harvest index value was recorded from 'Gora' (43%) and 'Moti' (40%) varieties, while the lowest value was recorded from local (28%) types (Table 5). Better seed yielding cultivars also had a higher harvest index. It is regarded as the endpoint measure of photosynthetic portioning toward productive organs during the actual buildup of yield.

Because the cost of faba bean seeds rises year after year, there is a greater need to specify optimum plant density in order to maximize output and economic return. Dominance analysis revealed that a combination of local and 5cm, local with 10 cm, 'Moti,' and 10 cm intra spacing prevailed (Table 6) due to their lower net benefits than treatments with lower variable costs. The MRR for all undominated treatment combinations was more than the minimum acceptable rate of return (100%). 'Gora' with 10cm intra spacing produced the highest MRR. The partial budget, marginal analysis, and minimal rate of return all provide the information required to make a preliminary suggestion. Therefore, 'Gora' and 10 cm intra spacing gave the highest net benefit and a MRR which was higher than the minimum rate of return (100%).

Table 6 *Dominant and marginal analysis of the effect of intra spacing for faba bean varieties.*

Treatments		UGY (kg ha^{-1})	AGY (kg ha^{-1})	GFB (*ETB ha^{-1}*)	TVC (*ETB ha^{-1}*)	NB (*ETB ha^{-1}*)	MRR (%)
Variety	Intra spacing						
Local	20	1048	943	23573	1177	22396	-
Local	15	1570	1413	35325	1548	33777	3068
Moti	20	2888	2599	64973	1781	63192	12624
Gora	20	3315	2984	74595	2167	72428	2393
Local	10	1738	1565	39115	2367	36748	D
Moti	15	3290	2961	74025	2371	71654	872650
Gora	15	3689	3320	82995	2887	80108	1638
Moti	10	3451	3106	77648	3551	74097	D
Gora	10	4061	3655	91373	4328	87045	1666
Local	5	1270	1143	28575	4737	23838	D
Moti	5	3146	2831	70778	7111	63667	1678
Gora	5	3524	3172	79290	8659	70631	450

UGY =Unadjusted grain yield; AGY = adjusted grain yield; GFB = gross field benefit; NB = net benefit, MRR = marginal rate of return; D = dominated treatments: ETB ha^{-1} = Ethiopian Birr per hectare., The market price of 25 Ethiopian Birr (ETB) kg^{-1} was considered, 1USD=~33Birr.

CONCLUSIONS

The study revealed that the main effect of faba beam variety and intra spacing was highly significant (P<0.01) for days to 50% flowering, days to 90 % maturity, plant height, number of pods plant^{-1}, number of seeds pod^{-1}, number of seeds plant^{-1}, 100 seed weight, above-ground dry biomass, grain yield (kg ha^{-1}) and harvest index while, the main effect of variety and intra spacing was significantly (P<0.05) for stand count at harvest and number of leaves plant^{-1}, respectively. Furthermore, the main effect of intra spacing was highly significant (P<0.01) on number of branches plant^{-1}, the number of pods plant^{-1}. The interaction effect of variety and intra spacing had a highly significant effect (P<0.01) on the number of a seed plant. Whereas, significant interaction effect on plant height, number of pods plant^{-1}and 100 seeds weight. The 'Gora' variety gave the highest number of days to 50% flowering (57 days), days to 90% maturity (144 days), stand count at harvest (87%), above-ground dry biomass (8525 Kg ha^{-1}), grain yield (3643 Kg ha^{-1}) and harvest index (43%). The maximum values obtained on above-ground dry biomass (7644 Kgha^{-1}), grain yield (7644 Kg ha^{-1}) and harvest index (39 %) at 10 cm intra spacing, while, lowest for 20 cm abdicating that the number of plants per unit area seems to be more critical than the number of branches and/or pods plant^{-1} for influencing seed yield. Thus, the finding suggests that 'Gora' variety with 10 cm intra spacing had the highest seed yield performance and found to give the highest net benefit and marginal rate of return which was higher than the minimum rate of return (100%).

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Declaration of competing interest

The authors declare no competing financial or personal interests that may appear and influence the work reported in this paper.

Authors' contributions

Berhanu Barsisa, Kinde Lamessa and Adugna Hunduma contribute to design of the research proposal, field work, data collection, analysis and interpretation of the data using GenStat 15 version software and writing the manuscript. Dr. B. C. Nandeshwar and Dr. Zerihun Jalata assisted in analysis and interpretation of the data and also in writing the manuscript. All authors read and approved the final manuscript.

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