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Effect of Integrated Crop-Management Packages on Yield and Yield Components of Faba Bean (*Vicia faba* L.) Cultivars in Southern Ethiopia

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Abstract

Faba bean (*Vicia faba* L.) is one of the most important pulse crops grown by farmers in Hula Woreda, southern Ethiopia. However, the actual farm yield of 1.2-1.6 t ha^{-1} is much lower than the potential yield, which is 1.5-3.5 t ha^{-1} on farmers' fields under improved management and 2-5 t ha^{-1} in research station. This lower yield is due to poor management of the crop including lack of proper weed control, planting methods and fertilizer application. Hence, a field trial was conducted in Hula Woreda, during 2011 cropping season to determine the effect of integrated crop-management packages on yield and yield components of Gebelcho and local faba bean varieties. Varieties were factorially combined with nine management packages in RCBD design with three replications. Varieties were significantly different for days to flowering, days to maturity, leaf area index, nodule number, nodule dry weight, crop biomass, grain yield and yield components. Variety Gebelcho exceeded the local variety by 11% for leaf area index, 14% for nodule number, 21% for nodule dry weight, 7% for crop biomass, and 24% for grain yield. Gebelcho also gave more number of pods $plant^{-1}$, number of seeds pod^{-1} and 100 seed weight than local variety. Varieties did not differ significantly for crop stand count, plant height, weed count and weed biomass. Management packages differed significantly for crop growth attributes, weed count, weed biomass, grain yield and yield components. More number of pods $plant^{-1}$, number of seeds pod^{-1}, 100 seed weight and grain yield were obtained from the improved (package 1) than control (package 9). Economic analysis showed that, Gebelcho (improved cultivar) and package 1 (row planting, twice weeding and application of 100 kg DAP ha^{-1}) gave higher net benefits of Birr 12400 and 12715 ha^{-1} with 980% and 109% marginal rates of return, respectively, and these were identified to be the best options.

Keywords

Faba bean; Fertilization; Management packages; Variety; Weeding; Yield; Yield components

Introduction

Faba bean (*Vicia faba* L.) is the most important grain legume in Ethiopia in terms of area, production, source of protein and as a rotation crop improving soil fertility. In spite of its importance in socio-economic life of farming communities [1], yield level of this crop under farmers' condition is very low (1.2 t ha^{-1}) [2] which is below world average (1.7 t ha^{-1}) [3]. But, the potential yield of this crop depending on the variety ranges from 1.5 to 3.5 t ha^{-1} under farmers' condition and from 2 to 5 t ha^{-1} on station [4]. This wide yield gap between actual and potential yield is due to major production constraints and inadequate supply of improved technology to the farmers [5]. To minimize the gap between the actual and potential yield, it is essential to introduce agronomic packages that could be used by farmers to enhance productivity.

Fertilizer application plays an important role for optimum production of crops among other factors. Research results revealed that P application increased the rate of crop development from emergence to floral initiation and shortened the days to flowering [6,7]. Phosphorus could reduce the days to physiological maturity by controlling some key enzyme reactions that are involved in hastening crop maturity [8]. Moreover, P application showed significant differences for number and dry weight of nodules, plant height, leaf area, number of pods and seeds among faba bean cultivars [9-11]. However, there has been limited application of both organic manure and chemical fertilizers on pulse crops in Ethiopia. Fertilizer in the form of DAP or urea was applied only to 19.9% of total area of pulse crops in the country [12]. Fertilizer applied area under faba bean ranges between 21% in 2000/01 to 28% in 2010/11 cropping season [13]. This shows there is still large proportion of production area for which fertilizer application is needed to maximize yield. Recommended rate of fertilizer for faba bean is 100 kg Di-ammonium phosphate (DAP) ha^{-1} [4].

Although, faba bean is sensitive to competition from weeds, in Ethiopia, mostly weed control in faba bean is practiced to a very limited amount due to many reasons [14]. However, most research outputs support importance of weed management in faba bean. It has been reported that faba bean suffered significant yield loss of about 24% due to weed competition [15,16]. The crop is highly sensitive to weed competition from early establishment to early flowering stage and it requires weed control during this critical period. There are many ways of weed control such as hand weeding. Hand pulling of individual plants is a practical and most feasible method in subsistence agricultural system [17,18]. It was recommended that two hand weeding at 25-30 and 45-50 DAE rely on the ecology and resources of farmers to improve faba bean productivity [19,20].

Tradtionally, Ethiopian farmers broadcast faba bean and cover by local plough [21]. But, row spacing and population density are powerful management tools whereby a grower can strongly influence early season light interception and crop growth [22]. Generally, crops grown in rows have large seeds, develop in to larger and more vigorous plants, and require more space $plant^{-1}$ than broadcast planted ones [23]. Research results revealed significantly higher number of pods $plant^{-1}$ and grain yield were produced from row planted compared with broadcast planted treatments in faba bean [23-25] and haricot bean [26,27], respectively.

Improved crop varieties, fertilizer application, effective weed control and planting method are among the main components of integrated crop-management packages. Various field trial results showed integrated use of row planting, fertilizer application and twice

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weeding significantly increased number of pods $plant^{-1}$, number of grains pod^{-1} and grain yield over the control (broadcast planted, no fertilizer applied and unweeded) [24,27]. In the study area most of the farmers do not practice appropriate weed management, planting methods and fertilizer application on faba bean [28]. Besides, these factors are interrelated and have to be looked at as a whole not separately. Therefore, the present study was initiated with the objective to determine the optimum and economically feasible crop-management package that would help to improve yield and yield components of faba bean cultivars at Hula Woreda.

Materials and Methods

Description of the study area

The study was conducted at Hula Woreda, Sidama Zone of the Southern Nations, Nationalities and Peoples Regional State (SNNPRS). It is found at 366 km south of Addis Ababa, at 5° 4' to 6° 9' N and 33° 5' to 35° 3' E and altitude of 2475 meters above sea level (m.a.s.l.). The soil of the site is clay loam. The area has mean annual rainfall of 1200-1600 mm with a bimodal pattern, which extends from June to October (long rain) and March to May (short rain) [28]. The mean minimum and maximum temperatures are 12 and 22 °C, respectively. Soil physico-chemical properties were determined for samples taken. Before planting soil texture, soil pH, organic carbon, organic matter content, total N, available P, cation exchange capacity of the experimental field were evaluated. After harvest, except soil texture, all other properties were examined.

Treatments, experimental design and procedures

Factorial combination of nine selected packages and two cultivars of faba bean were used to form 18 treatments (Table 1). Each package was constituted from a combination of three factors; planting method, fertilization and weed control. The two cultivars used for the experiment were; one high yielding cultivar called Gebelcho (Var 1) and local cultivar used in Hula (Var 2). The cultivar Gebelcho was released in 2006 for altitudes of 1900-3000 m.a.s.l. with potential yield of 2.5-4.4 t ha^{-1} on station and 2-3 t ha^{-1} on farm. It needs 103-167 days for maturity. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications.

Prior to carrying out the experiment, soil was prepared by ploughing three times to make it suitable for optimum growth of the crop. Planting was made on July 30, 2011. The seeds of Gebelcho and local variety are categorized under medium and small size; hence the seed rates used were 250 and 200 kg ha^{-1}, respectively, for broadcasted treatments. Thinning was made at 15 days after emergence to maintain similar population with row planted plots at early stage. Seeds were planted on plots having an area of 2.8 m x 2 m (5.6 m^2). The blocks were separated by 1 m path and every plot by 0.5 m. There were 7 rows on every plot for row planted plots and two seeds were planted $hill^{-1}$ at 40 cm x 5 cm inter and intra-row spacing, respectively. Thinning was made 15 days after emergence to maintain one plant $hill^{-1}$. Fertilizer was applied through broadcasting for broadcast planted plots and side dressing along rows for row planted plots at the recommended rate of 100 kg DAP ha^{-1} at the time of planting, for fertilizer treated plots.

Agronomic data collection and sampling

Agronomic parameters collected were flowering (when 50% of the plants produce their first flower) and maturity (when 95% of the plant leaves show yellowness and when lower pods changed to black) dates; leaf area index, number of nodules and dry weight of nodules (average of five plants at flowering stage for each); crop stand count (at physiological maturity), plant height (average of ten plants), total above ground biomass, number of pods $plant^{-1}$ (average of ten plants), number of seeds pod^{-1} (average of ten plants), seed yield and hundred seed weight; weed count, weed dry weight and identification of major weed species (at crop physiological maturity). To estimate total biomass and seed yields of faba bean a 2.4 m^2 sample was harvested from each plot. The harvested materials were sun-dried and manually threshed. After threshing, seeds were cleaned, weighed and adjusted at the 12% moisture level. Total biomass and seed yields recorded on plot basis were converted to t ha^{-1} for statistical analysis.

Economic analysis

To examine the economic feasibility of the treatments, partial

Table 1: Factors and their combination.

Varieties	Management packages	Variety × Management packages
Gebelcho	Package 1 = R + F_1 + W_2	Gebelcho × Package 1
Local	Package 2 = R + F_1 + W_1	Gebelcho × Package 2
	Package 3 = R + F_0 + W_2	Gebelcho × Package 3
	Package 4 = R + F_0 + W_1	Gebelcho × Package 4
	Package 5 = B + F_1 + W_2	Gebelcho × Package 5
	Package 6 = B + F_1 + W_1	Gebelcho × Package 6
	Package 7 = B + F_0 + W_2	Gebelcho × Package 7
	Package 8 = B + F_0 + W_1	Gebelcho × Package 8
	Package 9 = B + F_0 + W_0	Gebelcho × Package 9
		Local × Package 1
		Local × Package 2
		Local × Package 3
		Local × Package 4
		Local × Package 5
		Local × Package 6
		Local × Package 7
		Local × Package 8
		Local × Package 9

R= Row planted, B= Broadcast planted, F_1 = Fertilizer applied, F_0 = No Fertilizer applied, W_2 = Twice weeded, W_1 = Once weeded, W_0 = Unweeded. The first and second hand weeding were performed, respectively, at 28 and 58 days after emergence (DAE).

budget, dominance and marginal analyses were conducted based on CIMMYT [29]. The average yield was adjusted downwards by 15% to reflect the difference between the experimental yield and the expected yield of farmers from the same treatment.

Data analysis

Data collected were subjected to analysis of variance (ANOVA) suitable to Randomized Complete Block Design (RCBD) using SAS statistical software (SAS software version 9.0) with a General Linear Model (GLM) procedure. Mean separation was done by LSD at 5% significance level. Correlation analysis was performed using Pearson's simple correlation coefficient for the intended parameters.

Results and Discussion

Soil physico -chemical properties of the study area

The soil analysis result showed that the values of sand, silt and clay were 42%, 29% and 29%, respectively. Hence, texturally the soil of the study site belongs to clay loam, which is optimal for faba bean production. The soil pH before planting was 6.01, which is lower than the optimum range (6.5-7.3) for faba bean. But, soil pH is an essential but not widely known factor affecting yield of the crop [30]. The pH value after harvest remained unchanged. The total N, available P, OC, OM and CEC of the soil before planting were 0.248%, 13.72 mg kg^{-1}, 2.23%, 3.84% and 20.12 cmol kg^{-1}, in that order (Table 2). The mean values of the above listed parameters after harvest were 0.242%, 13.17 mg kg^{-1}, 2.23%, 3.84% and 19.89 cmol kg^{-1}, respectively. As to the comparison of these parameters before planting and after harvest, the values of some parameters like N and P were reduced after harvest as the crop and weeds have used them for their growth and survival and also some of them might have been lost during physico-chemical processes of the soil.

The total N content of the soil was within the range of medium as reported by Havlin et al. [31] who classified the range of total N <0.1, 0.1-0.15, 0.15-0.25 and >0.25% as very low, low, medium and high, respectively. Olsen et al. [32] classified available P content of the range <5 as very low, 5-15 as low, 15-25 as medium and > 25 mg kg^{-1} as high. Thus, the available P of the soil both before planting and after harvest lies under low range. Landon [33] explained that soil OM content ranges of 1-2, 2-4, and 4-6% are rated as low, medium and high, respectively whereas cation exchange capacity (CEC) ranges of 5-15, 15-25 and 25-40 cmol kg^{-1} are rated as low, medium and high, respectively. Based on these ratings the OM content (3.84%) and CEC (20.12 cmol kg^{-1} before planting and 19.89 cmol kg^{-1} after harvest) of the study field were both in the medium ranges.

The analysis of variance revealed that the two varieties in the trial had no significant effect on soil parameters studied. However, soil parameters were significantly affected by the crop management packages. The highest values of all parameters were recorded for package 1, which was significantly varied from all packages except package 5 for total N, OC and OM. The lowest mean values for all parameters were recorded from package 9 (control), which was significantly inferior to all packages except packages 4 and 8 for total N (Table 2). There was an increasing trend of the soil parameters with improving management practices or a decreasing trend as the management practices become less optimal. The decreasing tendency of soil parameters as the management practices become less optimal may be attributed to the increased weed population that depleted soil nutrients aggressively. Similar results have been reported previously [24,27,34].

Effect of Factors on Crop Growth and Development

Days to flowering

Days to flowering was significantly affected by faba bean varieties. The mean days required to flowering for Gebelcho exceeded the local by 1 day (Table 3). The variation in days to flowering is primarily a genetically controlled character. This result was in line with the works of many authors [35,36]. On the contrary, Nadal et al. [37] found that no significant difference existed among genotypes in terms of days to flowering. This may be due to the similarity among the genotypes for growth duration.

The effect of crop management packages on days to flowering was

Table 2: Mean comparison of soil parameters as affected by varieties and crop management packages.

Treatment	pH	N (%)	P (mg kg^{-1})	OC (%)	OM (%)	CEC (cmol kg^{-1})
Before planting	6.01	0.248	13.72	2.23	3.84	20.12
After harvest	6.01	0.242	13.17	2.23	3.84	19.89
Varieties						
Gebelcho	6.02	0.242	13.19	2.24	3.86	19.88
Local	6.01	0.242	13.16	2.22	3.83	19.89
$LSD_{0.05}$	ns	ns	ns	ns	ns	ns
Packages						
1=R+F_1+W_2	6.51^a	0.268^a	17.79^a	2.95^a	5.08^a	24.00^a
2=R+F_1+W_1	6.19^b	0.251^b	15.39^c	2.65^b	4.56^b	22.33^c
3=R+F_0+W_2	5.91^c	0.242^{bc}	13.67^d	2.11^d	3.64^d	20.09^d
4=R+F_0+W_1	5.90^c	0.226^{cd}	9.86^e	1.79^e	3.08^e	17.06^e
5 =B+F_1+W_2	6.19^b	0.268^a	16.72^b	2.93^a	5.05^a	23.18^b
6=B+F_1+W_1	5.89^c	0.243^b	13.82^d	2.41^c	4.15^c	20.00^d
7=B+F_0+W_2	5.89^c	0.242^{bc}	13.51^d	2.08^d	3.58^d	19.95^d
8=B+F_0+W_1	5.88^c	0.226^{cd}	9.48^e	1.71^e	2.95^e	16.99^e
9=B+F_0+W_0	5.76^d	0.210^d	8.32^f	1.45^f	2.50^f	15.48^f
$LSD_{0.05}$	0.12	0.017	0.95	0.11	0.18	0.14
CV (%)	0.84	2.983	3.12	2.07	2.07	0.31

Means with the same letter within a column are not significantly different at 5% level of probability; ns = non-significant. R= Row planted, B= Broadcast planted, F_1 = Fertilizer applied, F_0 = No Fertilizer applied, W_2 = Twice weeded, W_1 = Once weeded, W_0 = Unweeded. The first and second hand weeding were performed, respectively, at 28 and 58 days after emergence (DAE).

significant. The longest mean days to flowering (45.5) were required for package 9 (control), which was broadcast planted, no fertilizer applied and unweeded (Table 3). It varied significantly from all the rest of packages, except packages 8 and 4. The shortest mean days to flowering (40.8) were needed for package 1 (row planted, fertilized and twice weeded), and this was not significantly different from packages 2 and 5.

The delay in days to flowering of these packages with reduced crop management particularly package 9 may be attributed to poor growing environment causing high competition with weeds for resources leading to reduced availability of P in the soil. The soil analysis result (Table 2) obviously confirms this argument. Phosphorus increases rate of crop development and enhances flowering as it is essential for physiological processes such as photosynthesis, respiration, cell division and energy storage. It has been stated that P plays a vital role in plant root development, flowering and fruiting [38]. Our result was in accord with the works of Likisa, Kedir and Turk et al. [24,29,39]. Generally, fertilizer applied packages with once or twice weeding needed reduced number of days to flowering, regardless of planting methods. However, weed control seems to exert more impact on days to flowering on broadcasted than row planted stands. Overall, poor agronomic practices may needlessly delay the development of the crop.

Days to maturity

There was a significant difference for days to maturity between the two varieties. The number of days needed by Gebelcho to mature (127.2) was greater than that of the local variety (126.0) (Table 3). Though the difference is small the local variety relatively possessed a shorter period for accumulation of vegetative and reproductive dry matter than Gebelcho. Such varietal differences in days to maturity were previously reported by Sliman and Abdalla et al. [35,40] in faba bean.

The crop management packages employed in this study have shown highly significant variation on days to maturity. The effects were similar to what has been observed for flowering duration. The longest mean days to maturity (129.2) was obtained from package 9 (control) which was statistically different from other packages except packages 8 and 4. The shortest mean days to maturity (124.0) was recorded from package 1, which was not significantly varied from packages 2 and 5 (Table 3). The result revealed that fertilizer application is the major factor influencing duration of growth followed by weed control particularly under broadcast planting. Fertilizer applied plots matured sooner than those non-applied ones. In general, P is known to hasten maturity. Therefore, it is the P limitation that possibly played a key role in delaying maturity in non fertilizer applied and in unweeded plots. This result is in line with those reported by Likisa and Yilmaz [7,24].

Leaf Area Index (LAI)

There was significant difference between the faba bean varieties in leaf area index. The mean leaf area index (LAI) of Gebelcho was greater (5.1) compared to the local variety (4.6) (Table 3). This finding was in line with that reported by Ahmed and El-Abagy [9]. However, Sliman and Likisa [24,33] found that there were no significant variations in leaf area index among faba bean varieties they compared. This might be due to the genetic similarity among the cultivars evaluated.

Leaf area index (LAI) was significantly affected by the crop management packages. Four packages involving 1, 2, 3, and 4 had similar greater leaf area indices. The lowest mean LAI (2.8) was obtained from package 9, which was significantly lower than all other packages (Table 3). Concerning the management components, planting methods, fertilizer application and weed control, all influenced LAI. Row planted stand had greater and similar leaf area indices irrespective of fertilization and weeding frequency as compared to broadcasting. On the other hand, fertilized and twice weeded plots produced greater LAI compared to unfertilized and once weeded plots under broadcasting. This may indicate the fact that row planting improves the competition ability for growth resources even under limited nutrient availability and high weed infestation.

Table 3: Effect of varieties and crop management packages on growth, development, yield and yield components.

Treatment	Days to flower-ing	Days to maturi-ty	Leaf area index	Nodule number ($plant^{-1}$)	Nodule dry weight (g $plant^{-1}$)	Stand count (plant m^{-2})	Plant height (cm)	Crop biomass (t ha^{-1})	Pods $plant^{-1}$	Seeds pod^{-1}	100-seed weight (g)	Grain yield (t ha^{-1})	Harvest index×
Varieties													
Gebelcho	43.4^{a}	127.2^{a}	5.1^{a}	104^{a}	0.132^{a}	47.7	168.6	10.4^{a}	13.3^{a}	2.88^{a}	81.71^{a}	3.21^{a}	0.31^{a}
Local	42.4^{b}	126.0^{b}	4.6^{b}	91^{b}	0.109^{b}	46.5	168.4	9.7^{b}	11.7^{b}	2.75^{b}	50.46^{b}	2.58^{b}	0.27^{b}
$LSD_{0.05}$	0.30	0.30	0.30	11	0.011	ns	ns	0.50	0.7	0.12	1.17	0.19	0.02
Packages													
$1=R+F_1+W_2$	40.8^{d}	124.0^{d}	6.1^{a}	130^{a}	0.154^{a}	49.6^{a}	173.2^{a}	12.2^{a}	17.3^{a}	3.48^{a}	69.87^{a}	3.86^{a}	0.32
$2=R+F_1+W_1$	41.3^{d}	124.5^{d}	6.0^{a}	115^{ab}	0.142^{ab}	49.1^{ab}	171.2^{a}	11.3^{ab}	15.7^{b}	3.15^{b}	67.26^{bc}	3.41^{b}	0.31
$3=R+F_0+W_2$	42.8^{b}	126.8^{b}	5.5^{ab}	100^{bcd}	0.123^{bcd}	49.1^{ab}	166.8^{b}	10.0^{c}	12.3^{d}	2.73^{c}	66.26^{cd}	2.83^{c}	0.29
$4=R+F_0+W_1$	45.0^{a}	128.8^{a}	5.5^{ab}	82^{d}	0.105^{d}	49.1^{ab}	166.5^{b}	8.6^{d}	10.3^{e}	2.45^{de}	63.89^{de}	2.41^{d}	0.28
$5=B+F_1+W_2$	41.3^{d}	124.5^{d}	5.1^{b}	122^{ab}	0.140^{ab}	46.2^{b}	172.7^{a}	11.4^{ab}	15.2^{b}	3.00^{b}	69.51^{ab}	3.42^{b}	0.30
$6=B+F_1+W_1$	42.0^{c}	125.2^{c}	5.1^{b}	111^{abc}	0.134^{abc}	46.2^{b}	171.0^{a}	11.1^{b}	13.8^{c}	3.00^{b}	66.60^{c}	3.17^{bc}	0.29
$7=B+F_0+W_2$	42.7^{b}	127.3^{b}	4.2^{c}	88^{cd}	0.111^{cd}	46.2^{b}	165.5^{b}	9.9^{c}	12.0^{d}	2.70^{cd}	66.25^{cd}	2.83^{c}	0.28
$8=B+F_0+W_1$	45.0^{a}	128.8^{a}	3.5^{c}	78^{d}	0.104^{d}	45.9^{b}	164.8^{b}	8.0^{d}	9.0^{e}	2.43^{e}	63.76^{e}	2.14^{de}	0.27
$9=B+F_0+W_0$	45.5^{a}	129.2^{a}	2.8^{d}	54^{e}	0.073^{e}	42.4^{c}	164.5^{b}	7.9^{d}	6.9^{f}	2.38^{e}	61.42^{e}	2.00^{e}	0.26
$LSD_{0.05}$	0.60	0.60	0.70	24	0.024	3.40	4.20	1.10	1.4	0.26	2.48	0.41	ns
CV (%)	1.19	0.40	12.70	20.94	17.15	6.13	2.10	9.50	9.62	7.99	3.20	12.10	15.19

Means with the same letter (s) within a column are not significantly different at 5% level of probability. R= Row planted, B= Broadcast planted, F_1 = Fertilizer applied, F_0 = No Fertilizer applied, W_2 = Twice weeded, W_1 = Once weeded, W_0 = Unweeded. The first and second hand weeding were performed, respectively, at 28 and 58 days after emergence (DAE).

Thus, among crop management practices used in this trial, planting method had maximum influence followed by fertilizer and weeding, respectively. Comparable results have been reported by various authors (Ahmed and El-Abagy; Odabas, Likisa [9,24,41].

Nodule number per plant

The varieties used in this trial were significantly different in nodule number plant^{-1}. Higher mean nodule number plant^{-1} (104) was recorded in Gebelcho while lower mean nodule number plant^{-1} (91) was obtained from the local variety (Table 3). This can demonstrate that varieties are different for their nodulation capacity. This result was in conformity with the findings of Iyad et al. [42] and Tayel and Sabreen [11]. However, Vandorpe [43] reported that there was no significant difference between varieties of faba bean in mean nodule number plant^{-1}. This may be attributed to the similarity in morphological and physiological characteristics of the varieties used.

As it was shown in the varieties, mean nodule number plant^{-1} was significantly varied among crop management packages. The highest mean nodule number plant^{-1} (130) was observed in package 1 (row planted, fertilizer applied and twice weeded), which was statistically similar to packages 5, 2 and 6. The lowest mean nodule number plant^{-1} (54) was obtained from package 9 (control) which was significantly inferior to all other packages (Table 3). The results indicated that fertilizer applied packages gave far greater mean nodule number plant^{-1} compared with non fertilized ones irrespective of weeding frequency and planting method. Weed control has only been important under unfertilized, broadcast planting. Phosphorus is probably the most limiting nutrient for production of leguminous crop, possibly by its influence on the activity of rhizobium bacteria and nodule formation [44]. Our results agree with previous works of Osman and Abd-Elaziz and Abdalla et al. [45,46] who indicated that the application of fertilizer significantly increased nodule number plant^{-1} over the control in faba bean and chick pea, respectively.

Nodule dry weight per plant

Nodule dry weight plant^{-1} was significantly influenced by the varieties. Higher mean nodule dry weight plant^{-1} (0.132 g) was obtained from Gebelcho whereas lower mean nodule dry weight plant^{-1} (0.109 g) was observed in the local variety (Table 3). Genetic variability affecting traits like nodule number and mass or nitrogenase activity has been observed within grain legume species [47]. This was in line with the findings of Talaat and Abdallah and Tayel and Sabreen [10,11].

Similar to varieties, nodule dry weight plant^{-1} was significantly affected by crop management packages, too. The highest mean nodule dry weight (0.154 g) plant^{-1} was recorded in package 1 (combined use of row planting, fertilizer application and twice weeding), which was significantly varied from all other packages except packages 2, 5 and 6. The lowest mean nodule dry weight plant^{-1} (0.073 g) was observed in package 9 (control) which was significantly inferior to all other packages (Table 3). The effects followed a similar pattern to that observed for nodule number plant^{-1}. The results indicated that the fertilizer applied packages provided greater nodule dry weight plant^{-1} over non fertilizer applied ones under both planting methods and weeding frequencies. The impact of weeding was apparent only under non fertilized and broadcast planting. Similar findings have been reported by many authors [46,48]. In relation to the relative importance of nodule number and its dry weight, Fatima et al. [49] reported that increasing nodule dry weight can be generally a prerequisite for increasing N-fixation in legumes rather than number of nodules.

Stand count

Stand count at harvest showed no significant variation between the faba bean varieties. On the other hand, stand count was significantly varied among the packages. The first four packages consisting of 1, 2, 3 and 4 had all similar and relatively greater stand count of 49 plants m^{-2}. These packages were planted in rows while they varied in fertilization and weed control frequency. The lowest stand count (42 plants m^{-2}) was produced from the package 9 (control). The results showed that row planted packages ensure higher mean stand count than broadcast planted ones. This could be due to the reality that row planted treatments had a consistently enough space plant^{-1}, free of canopy effects and better possibility of efficient utilization of the available resources than broadcast planted ones. In agreement with our finding, Likisa and Tenaw et al. [24,50] obtained significant effect of integrated crop management packages in faba bean and weed management in haricot bean stand count, respectively, in Jimma Rare and Awassa.

Plant height

Plant height was not significantly varied between the faba bean varieties. Contrary to the varieties, management packages significantly affected plant height. All fertilized packages (packages 1, 2, 5 and 6) regardless of planting method and weeding frequency had relatively greater and similar plant height without a significant difference among each other. In the next category are all the non fertilized packages regardless of planting method or weeding frequency including the control. The result revealed that fertilizer application was obviously the dominant factor determining plant height irrespective of planting methods and weeding frequencies. Our result was in agreement with those of Ahmed and El-Abagy and Asefa and Kedir [9,51] who reported that P application significantly increased plant height in faba bean and field pea, respectively. Plant height is one of the parameters that are used to measure the rate of plant growth and development within the range of a given genetic potential of a plant. The rate of growth and final height of a plant is a function of the growth factors under which the crop is grown.

Crop biomass

There was a significant variation between the two varieties in biomass. The biomass obtained from Gebelcho exceeded the biomass from the local variety by 7% (Table 3). This might be attributed to the genetic variations between the varieties in competition, assimilation and translocation. The greater biomass recorded for the cultivar Gebelcho is consistent with the other differences observed in terms of growth duration, leaf area index and plant height for this cultivar. The result is consistent with those of Ahmed and El-Abagy and Likisa [9,24] who observed significant differences among faba bean varieties in dry matter productivity.

Similarly, crop biomass was considerably affected by the management packages. Package 1 (row planted, fertilized and twice weeded) produced the highest crop biomass (12.2 t ha^{-1}) which was significantly superior to other packages except packages 2 and 5. Package 9 (control) gave the lowest crop biomass (7.9 t ha^{-1}) which was statistically similar to packages 8 and 4 (Table 3). The crop biomass obtained from packages 1, 2 and 5 surpassed the biomass from the control by 54%, 43% and 44%, respectively.

Regarding management components, fertilizer application, weed management and planting method, all affected crop biomass. Fertilizer applied packages in both planting methods and weeding frequencies were significantly superior in their crop biomass to non fertilized ones. Generally, reduced weeding frequency or its absence affected biomass production only when it was combined with other less optimum management components such as lack of fertilization and/or broadcasting. When all other package components were at their optimum, there was no advantage of row planting over broadcasting (package 1 vs. 5). However, an equal amount of biomass was produced either from one or two weedings under fertilized and row planting while one less weeding reduced biomass under broadcasting for a similarly fertilized treatment (package 1 vs. 6). Moreover, there are other additional advantages of row planting such as ease of management for weed control, cultivation, harvesting and spraying especially when the production area increases. Our result is in harmony with those of Likisa and Kedir [24,27] who reported significant effect of integrated crop management packages on biomass of faba bean and haricot bean, respectively.

Yield and yield components

Number of pods per plant: The two varieties were significantly varied in number of pods plant^{-1}. A higher number of pods plant^{-1} (13.3) was recorded in Gebelcho while lower number of pods plant^{-1} (11.7) was obtained from the local variety (Table 3). Similar results were reported by Likisa and Ahmed and El-Abagy [9,24].

Pod number plant^{-1} was significantly influenced by the management packages. The highest and significantly greater number of pods plant^{-1} (17.3) was obtained from the combined use of row planting, fertilizer application and twice weeding (package 1). The least and significantly inferior number of pods plant^{-1} (6.9) was recorded for the control (package 9) (Table 3). The results showed considerably better performance of fertilizer applied packages produced greater number of pods plant^{-1} than non-fertilized packages regardless of planting method. Likewise, weeding frequency significantly influenced number of pods plant^{-1} under packages within the same planting method and fertilization regime. Plots that were weeded twice produced larger number of pods plant^{-1} than those weeded once under either of the planting methods. These results were in harmony with those of Likisa and Kedir [24,27] who reported significant effect of integrated crop management packages on pod number plant^{-1} in faba bean and haricot bean, respectively. Ghizaw et al. and Agegnehu and Fessehaie [1,52] also found that P application resulted in significant increase in number of pods plant^{-1}.

Number of seeds per pod: Number of seeds pod^{-1} was significantly affected by varieties. The mean seed number pod^{-1} (2.88) of Gebelcho was significantly higher than that of the local variety with 2.75 mean seed number pod^{-1} (Table 3). The result was in agreement with Ahmed and El-Abagy [9]. Also, the number of seeds pod^{-1} was significantly influenced by crop management packages. Package 1 produced the highest (3.5) and significantly greater number of seeds pod^{-1} followed by packages 2, 5 and 6 with seed numbers of 3.1, 3.0 and 3.0, respectively. These packages (2, 5 and 6) had statistically similar seed number to each other but significantly varied from other packages. The least seed number was recorded for the control, which did not differ significantly from packages 4 and 8 (Table 3). The importance of an integrated management was obvious from the highest number of seeds pod^{-1} recorded for package 1, which was significantly varied from all other packages. These results were in line with those obtained by Likisa and Kedir [24,27].

Hundred seed weight

Hundred seed weight was significantly influenced by varieties. The hundred seed weight obtained from Gebelcho exceeded that of the local variety by 60% (Table 3). Similar results have been reported by Tayel and Sabreen [11] Hundred seed weight was significantly affected by management packages. There was 14% difference in hundred seed weight between the highest (package 1) and lowest (package 9) (Table 3). Similar findings were obtained by Abiy, Likisa and Kedir [24,26,27].

Grain yield

Grain yield was significantly influenced by the varieties. A 24% grain yield advantage was obtained from Gebelcho, which was attributed to the significantly higher values of its yield components such as pod number plant^{-1}, number of seeds pod^{-1} and 100 seed weight (Table 3). Comparable results were reported by Likisa and Ahmed and El-Abagy [9,24]. Management packages had a significant effect on grain yield. Package 1 (row planted, fertilizer applied and twice weeded) gave significantly higher grain yield (3.86 t ha^{-1}) than all other packages. Package 9 (control) produced significantly lower (2.00 t ha^{-1}) grain yield than all other packages except package 8 (Table 3). A yield increment of 93% was recorded for using package 1 over package 9 (control).

All the management components, fertilization, weeding frequency and planting methods contributed to the impacts of the nine packages on grain yield. Application of fertilization was important in raising grain yield irrespective of planting method and weeding frequency while weeding frequency was important only under non fertilized broadcast planting. Fertilizer applied packages in both planting methods and weeding frequencies gave considerably higher grain yield than non-fertilized ones except when broadcast planting is combined with once weeding. Row planting was superior in grain yield to broadcasting only when combined with fertilizer application and twice weeding indicating the importance of integrated management strategies, too. The advantage of integrated management packages was also reported by Likisa and Kedir [24,27] in faba bean and haricot bean respectively. Furthermore, significant positive response of grain yield in faba bean has been reported with P application rates Agegnehu and Fessehaie, Ahmed and El-Abagy [1,9,52] and appropriate weed control [19,53,54].

Harvest index

There was significant difference in harvest index between the two varieties. The harvest index of Gebelcho (0.31) was significantly higher than that of the local variety (0.27) (Table 3). This is attributed to their variation in distribution of the photosynthetic product in to grain yield and vegetative biomass. On the other hand, Sliman and Likisa [24,35] reported no significant difference in harvest index among faba bean varieties. This may be due to the genetic similarity in partitioning of dry matter between the varieties employed. Unlike with the varieties, harvest index was not significantly affected by the management packages.

Weed Parameters

Weed count

The result showed that the varieties had no significant effect on weed count. Contrary to varieties, management packages had significant influence on weed count. The highest (65 m^{-2}) and lowest (30.4 m^{-2}) weed numbers were counted from the unweeded control and package 1 (row planted, fertilized and twice weeded), respectively. The weed count from package 1 did not vary significantly from the other twice weeded packages regardless of planting methods, which were packages 3, 5 and 7. Package 9 (control) had very high weed density and was significantly varied from all other packages (Table 4). The results indicate that weeding frequency is an important management component to prevent damage by weeds. This finding was in line with those of Abiy, Likisa and Kedir [24,26,27].

Weed biomass

Similar to weed count, weed biomass was not significantly varied between the two varieties. However, weed biomass was significantly affected by the management packages. The highest weed biomass (5.34 t ha^{-1}) was recorded for the control (package 9) which was significantly varied from all other packages while the lowest was observed from the twice weeded packages of 1, 3, 5 and 7 (Table 4). The highest weed biomass for package 9 shows the far greater impact of total disregard of proper management on weed competition. Likewise, Likisa and Kedir [24,27] indicated considerable variation of weed biomass due to crop management packages in faba bean and haricot bean, respectively.

Economic Analysis

According to the result of partial budget analysis, Gebelcho had higher net benefit (12400 Birr ha^{-1}) than the local variety (9950 Birr ha^{-1}). Regarding crop management packages, net benefits ranging from Birr 7600 to 12715 were obtained from the various crop management packages in the trial. The highest net benefit of Birr 12715 ha^{-1} was recorded for package 1 (row planted, fertilizer applied and twice weeded) while the lowest net benefit of Birr 7600 ha^{-1} was obtained from the control (package 9) (Table 5). The marginal analysis result (Table 5) revealed that, Gebelcho had the marginal rate of return (MRR) of 980% which is well above the minimum acceptable rate of return (100%). This shows that farmers could receive a net return of Birr 9.80 for each Birr invested in Gebelcho variety rather than local variety. About crop management packages, the marginal rate of return (MRR) of 109% and 883%, respectively, were obtained from packages 1 and 7. Similar findings were obtained by many workers [24,27]. Therefore, Gebelcho (improved variety) and package 1 (row planted, 100 kg DAP ha^{-1} applied and twice hand weeded) were economically the most feasible alternatives for faba bean production in this experiment.

Labour costs needed for faba bean production in broadcast planting were Birr 850, 230, 450 and 300 for sowing seeds, fertilizer application, first and second weeding, respectively, while the labour costs required for production of the crop in row planting were Birr 350, 900, 230, 380 and 270 for row preparation, sowing seeds, fertilizer application, first and second weeding, respectively. The costs of DAP and seed were Birr 1550 and 500/100 kg, in that order. The price of grain yield was Birr 500/100 kg.

Conclusion

Varieties were significantly different for days to flowering, days to maturity, leaf area index, nodule number, nodule dry weight, crop biomass, grain yield and yield components. Variety Gebelcho exceeded the local variety by 11% for leaf area index, 14% for nodule number, 21% for nodule dry weight, 7% for crop biomass, and 24% for grain yield. Gebelcho also gave more number of pods plant^{-1}, number of seeds pod^{-1} and 100 seed weight than the local variety. Varieties did not differ significantly for crop stand count,

Table 4: Effect of varieties and crop management packages on weed parameters.

Treatment	Weed count (m^{-2})	Weed biomass (t ha^{-1})
Varieties		
Gebelcho	42.5	3.12
Local	42.9	3.18
$LSD_{0.05}$	ns	ns
Packages		
1=R+F_1+W_2	30.4^c	1.72^c
2=R+F_1+W_1	48.9^b	4.05^b
3=R+F_0+W_2	30.7^c	1.73^c
4=R+F_0+W_1	48.8^b	3.87^b
5=B+F_1+W_2	30.5^c	1.89^c
6=B+F_1+W_1	48.8^b	4.07^b
7=B+F_0+W_2	30.9^c	1.98^c
8=B+F_0+W_1	50.3^b	3.73^b
9=B+F_0+W_0	65.0^a	5.34^a
$LSD_{0.05}$	7.99	0.99
CV (%)	15.96	26.87

Means with the same letter within a column are not significantly different at 5% level of probability; ns = non-significant. R= Row planted, B= Broadcast planted, F_1 = Fertilizer applied, F_0 = No Fertilizer applied, W_2 = Twice weeded, W_1 = Once weeded, W_0 = Unweeded. The first and second hand weeding were performed, respectively, at 28 and 58 days after emergence (DAE).

Table 5: Partial budget analysis of faba bean varieties and crop management packages in Hulla Woreda during 2011 cropping season.

Treatment	Adjusted yield (t ha^{-1})	Gross field benefit (Birr ha^{-1})	Total costs that vary (Birr)	Net benefit (Birr ha^{-1})	Change in net benefit (Birr ha^{-1})	MRR (%)
Varieties						
Local	2.19	10950	1000	9950		
Gebelcho	2.73	13650	1250	12400	2450	980
Packages						
9=B+F_0+W_0	1.7	8500	900	7600		
8=B+F_0+W_1	1.82	9100	1300	7800	200	50
7=B+F_0+W_2	2.41	12050	1600	10450	2650	883
4=R+F_0+W_1	2.05	10250	1630	8620d		
3=R+F_0+W_2	2.41	12050	1900	10150d		109
6=B+F_1+W_1	2.69	13450	3085	10365d		
5=B+F_1+W_2	2.91	14550	3385	11165	715	40
2=R+F_1+W_1	2.90	14500	3415	11085d		
1=R+F_1+W_2	3.28	16400	3685	12715	1550	517

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plant height, weed count and weed biomass. Management packages differed significantly for crop growth attributes, weed count, weed biomass, grain yield and yield components. More number of pods plant^{-1}, number of seeds pod^{-1}, 100 seed weight and grain yield were obtained from the improved (package 1) than the control (package 9). Economic analysis revealed that, Gebelcho (improved cultivar) and package 1 (row planting, twice weeding and application of 100 kg DAP ha^{-1}) gave higher net benefits of Birr 12400 and 12715 ha^{-1} with 980% and 109% marginal rates of return, respectively, and these were identified to be the best options.

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