

Grain Yield and Economic Benefit of Intercropping Barley and Faba Bean in the Highlands of Southern Ethiopia

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Abstract: Farmers in the highland areas of southern Ethiopia own less cultivable land. Barley and faba bean are important crops in the southern highlands of Ethiopia. However, rapid population growth in the region, which has led to scarcity of cultivable land, is threatening cultivation of these crops. Therefore, farmers often resort to alternative ways of maximizing crop yields from the small plots of land they own through intercropping. However, little empirical information is available on the agronomic and economic benefits obtained from intercropping barley and faba bean as well as on the influence of pattern of intercropping the two crops on productivity. Thus, a study was conducted during 2011 and 2012 years to evaluate the effect of barley (Ba)-faba bean (Fb) intercrop on yield, yield related traits and economic benefit in the highlands of southern Ethiopia. The treatments consisted of planting patterns of one (1Fb), two (2Fb) and three (3Fb) rows of faba bean combined with one (1Ba), two (2Ba) and three (3Ba) rows of barley. The experiment was laid out as a randomized complete block design in a factorial arrangement with three replications per treatment. Data were collected on a number of plant parameters on both crops. The results indicated that there were significant main effects of year and planting pattern on grain, straw and total biomass yields, harvest index and net income of barley. The number of barley seeds per spike was significantly influenced by the main effect of year, and was 12% less in 2011 than in 2012. Grain yield of barley in 2011 was 67% more than in 2012 while straw and total biomass yields were 45 and 23% less, respectively. Intercropping of 1Faba bean: 1Barley yielded 2176 kg ha⁻¹ grain, HI of 96%, LER of 1.56, system productivity index of 3013, better monetary benefit of 9056 Ethiopian birr, and additional land benefit of 36% over the control treatment. Intercropping in this pattern also produced 91% more energy and significantly more income (167%) compared to sole crop barley. Intercropping of 1Faba bean: 1Barley, 1Faba bean: 2Barley and 1Faba bean: 3Barley yielded 52 to 79% less grain of faba bean than sole faba bean. The productivity of barley-faba bean intercrop was more (LER>1) and varied between 32 and 56%. In conclusion, this study indicated that farmers with subsistence and low-input farming can benefit more from intercropping of one row of faba bean combined with one, two and three rows of barley in terms of productivity and economic benefit.

Keywords: Land equivalent ratio; Land benefit; Monetary benefit; Planting pattern; System productivity index; Row ratio.

1. Introduction

Barley (*Hordeum vulgare* L.) is one of the major cereal crops grown in the highlands of southern Ethiopia. According to CSA (2014), barley covered 76,763.7 ha of land. The mean grain yield of barley in southern Ethiopia is low (1724 kg ha⁻¹) (CSA, 2014) while the potential yield varies between 2000 and 4900 kg ha⁻¹ under research and 1500 to 4300 kg ha⁻¹ under on-farm condition (MoARD, 2007). Faba bean in southern region covers 71763 ha of land. The average grain yield of faba bean at the regional level is 1461 kg ha⁻¹ (CSA, 2014). The low productivity of barley is attributed to low soil fertility, mainly soil nitrogen and phosphorus deficiency (IFPRI, 2010), and weed and insect pests (CSA, 2014) and cultivation of low-yielding local cultivars for production and limited use of improved barley varieties (about 1% of the total barley production area). Application of urea, Diammonium Phosphate (DAP) and farmyard manure to the crop is at 0.91, 28.3 and 15.42% of the total production area, respectively (CSA, 2014). Currently, the highland areas

of southern Ethiopia are densely populated and led to a decline in farm size (Headey *et al.*, 2013). Farmers, thus, practice intercropping of cereals with legumes and horticultural crops due to less cultivable land (≤ 0.5 ha) (CSA, 2014) per household. In addition, farmers expect increased crop yield, better soil fertility and economic return (Tenaw *et al.*, 2006). The finding of Andersen *et al.* (2007) indicates that barley benefited more from pea-barley intercrop. An increase in barley grain N concentration when intercropped with faba bean was also reported by Knudsen *et al.* (2004). According to Strydhorst *et al.* (2008), faba bean-barley, lupin-barley, and pea-barley intercrops produced 64, 27 and 55% more protein yields, respectively, compared to sole crop barley. Getachew *et al.* (2006) reported that total yield, land equivalent ratio (LER) and system productivity index (SPI) of barley-faba bean mixtures exceeded those of sole crop barley.

The component crops in cereal-legume intercropping efficiently utilize the different sources of nitrogen (Willey, 1979) that may be considered as monetary benefit for farmers in the high land areas of southern

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Ethiopia (Dordas *et al.*, 2012). Crop combination of 50:50% seed ratio of barley-field pea yielded 20% less grain than the respective sole crops, and LER of 23 and 68% more yields of field pea and faba bean, respectively, compared to crops grown separately (Pristeri *et al.*, 2012), Eslami-Khalili *et al.* (2011) reported that intercropping of 25% faba bean and 75% barley was better in LER compared with 50:50% faba bean-barley combination; however, more yield was obtained from sole crops of barley and faba bean. Various studies (Sadeghpour *et al.*, 2014; 2013; Takim, 2012; Yilmaz *et al.*, 2008) have shown that cereals are more competitive in intercropping but legumes can fix atmospheric nitrogen symbiotically if effective strains of rhizobium are present in the soil. The complementary use of growth resources by the component crops is particularly important in low input subsistence farming such as those in the highlands of southern Ethiopia. However, limited research has been done to elucidate the effect of intercropping faba bean and food barley on the productivity of the crops. Therefore, this research was conducted with the objective of evaluating the effect of barley-faba bean intercrop on growth, grain yield of the component crops, and economic benefit.

2. Materials and Methods

2.1. Experimental Site Description

Field experiment was conducted during the 2011 and 2012 main cropping season at Bulle testing site located in the southern region of Ethiopia. Bulle is a highland area with an altitude of 2700 meters above sea level. It is located between 6.11 and 6.37°E latitude and 38.29-38.44°N longitude. It has an annual rainfall varying between 1401 and 1800 mm with a mean annual temperature of 12.6 to 20°C. The soil of Bulle area is classified as Haplic luvisol and Leptic phaeozems (FAO/UNESCO, 1988) in which the latter is the dominant soil type. The soil texture of the study site is clay loam with a bulk density of 1.04 g cm⁻³, while pH of the soil varies between 5.8 and 6.1 (medium). The soil has EC 0.02 to 0.6 dS/m, total nitrogen (TN) content ranging between 0.393 to 0.510% (medium), organic carbon (OC) content of 3.8 to 5.6% (medium), and available phosphorus content of P 32.2 to 82 ppm (high). The exchangeable Na, K, Ca, and Mg contents of the soil varies between 0.35-0.52, 0.60-0.98, 12.03-17.86, and 1.48-2.06 cmol (+) kg⁻¹, respectively, while its CEC varies between 30.0 and 41.6 cmol (+) kg⁻¹ (high) (Hawassa Centre report, 2011, unpublished report) and the ratings were indicated according to Landon (1984).

2.2 Treatments and Experimental Design

The treatments consisted of planting patterns of one (1Fb), two (2Fb) and three (3Fb) rows of faba bean combined with one (1Ba), two (2Ba) and three (3Ba) rows of barley. The experiment was laid out as a randomized complete block design in a factorial

arrangement and replicated three times per treatment. Sole crops of barley and faba bean were planted as control treatments, and the net harvestable area during the two growing years was 8.4 m². Plant and row spacing of sole faba bean were 0.1m and 0.4 m, respectively, while the row spacing of sole barley was 0.20 m.

Improved cultivars of six-rowed food barley (var HB-42) and faba bean (var Messay) were used for this study. The seeding rates of barley and faba bean were 85 and 150 kg ha⁻¹, respectively. Only Diammonium phosphate (DAP) fertilizer was applied to both sole and intercropped barley and faba bean at the rate of 100 kg ha⁻¹ (18 N and 46 kg P₂O₅ ha⁻¹). The crops were planted simultaneously on 27 August 2011 and 25 August 2012 cropping years/seasons.

2.3. Data Collection

Data were collected on plant height, spike length, seeds spike⁻¹, 1000 seed weight, grain and total biomass yields, and harvest index of barley. Similarly, plant height, pods plant⁻¹, seeds pod⁻¹, grain and total biomass yields of faba bean were measured. Moisture contents of barley and faba bean seeds were adjusted to 12.5% and 10%, respectively, using a moisture tester. All data of growth and yield components of both crops were collected from 10 randomly selected plants from the central rows while data on total biomass yields were collected from a net plot size of 8.4 m² for intercrop barley and 9.6 m² for sole barley while harvest index was derived from grain and total biomass yields.

Partial and total land equivalent ratios of the companion crops (LER_P and LER_T), energy yield (EY), system productivity index (SPI), monetary advantage index (MAI), economic and land benefits of the system were calculated as follows.

$$LER_T = (Y_{BaFb}/Y_{Ba}) + (Y_{FbBa}/Y_{Fa}) \quad (1)$$

Where: Y_{BaFb} and Y_{FbBa} were intercrop grain yields of barley and faba bean, respectively; Y_{Ba} and Y_{Fa} were yields of sole barley and faba bean, respectively (Yilmaz *et al.*, 2008). Land equivalent ratio (LER) values >1 indicates resources are used more efficiently by the intercrop than sole crop. Energy yield (EY) using caloric measurement was used to evaluate how much energy is produced from intercropping system relative to sole crops, and coefficient values of 17.8 and 16.8 KJ g⁻¹ were used to convert crop yield into energy yield for barley and bean, respectively (Tsubo *et al.*, 2004).

Energy Yield (EY):

$$EY_{Ba} = EY_{Ba} * YS_{Ba} \text{ (barley)} \quad (2)$$

$$EY_{Fb} = EY_{Fb} * YS_{Fb} \text{ (faba bean)} \quad (3)$$

Where: EY_{Ba} and EY_{Fb} are energy yields of barley and faba bean while YS_{Ba} and YS_{Fb} are yields of sole barley and faba bean, respectively.

Total energy yield (EY_T) from intercropping was calculated as:

$$EY_T = EY_{Ba} * Y_{iBa} + EY_{Fb} * Y_{iFb}. \quad (4)$$

Where: Y_{iBa} and Y_{iFb} are yields of barley and faba bean in intercrop, respectively.

System productivity index (SPI), which standardizes the grain yield of the secondary crop faba bean in terms of the primary crop barley, was computed to assess the efficiency of intercropping (Getachew *et al.* 2006) using the model:

$$SPI = (S_{Ba}/S_{Fb} * Y_{Fbi}) + Y_{Bai} \quad (5)$$

Where: S_{Ba} and S_{Fb} are mean grain yields of barley and faba bean, respectively, in sole crop and Y_{Fbi} and Y_{Bai} are mean yields of faba bean and barley in intercrop, respectively.

Monetary advantage index (MAI) was calculated as described by Esmacili *et al.* (2011), where MAI= (value of combined intercrops) was calculated as $(LER-1)/LER$.

Economic benefit of barley-faba bean intercrop was assessed using grain yield and the mean market prices of faba bean and barley as 15 and 10 Ethiopian birr kg^{-1} , respectively. Variable costs of improved seeds (costs of barley and faba bean), and labor (planting and harvesting) were determined for each treatment. The costs of improved seeds of barley and faba bean were 8.53 and 14.50 ETB kg^{-1} , respectively (ESE, 2012), where 1USD was 17.60 ETB. Other costs were also

estimated from the market price during the experimental period. Net income (NI) was determined as the difference of gross income and variable cost (Babatunde, 2003).

2.4. Data Analysis

Analysis of variance (ANOVA) was carried out using SAS version 9 (2000) on the variables measured (SAS, 2000). Combined analysis across years/seasons was conducted after test of homogeneity with pooled error variance (Gomez and Gomez, 1984). The comparison of means was made for the variables that exhibited significant differences due to the applied treatment in ANOVA using Tukey's HSD (honest significant difference) test of significance at 5% probability level.

3. Results

3.1 Growth and Yield Components

Plant height and spike length were not significantly affected by year and planting pattern despite an increase of plant height and spike length by 7.3 and 14.3%, respectively, compared with sole crop barely. On the other hand, the straw yield of barley was significantly affected by variation in year and intercrop (Table 1) and there was 80% increase in 2012 (Table 3). The straw from all intercrops was significantly low ranging from 20.6 to 71% compared to the straw of sole barley. On the other hand, the straw from 1Fb:2Ba and 1Fb:3Ba combinations was significantly 53.3 and 75% more, respectively, compared with single alternate row intercrop (Table 4).

Table 1. Growing year and intercrop combination mean squares from analysis of variance (ANOVA) of barley under faba bean-barely intercropping during 2011 and 2012 in the highland area of Bulle, southern Ethiopia.

Variables	Mean squares of variables for barley			
	Error (40)	Year /Y/ (1)	Intercrop combination/IC/ (9)	Y*IC (9)
Seeds spike ⁻¹	15.51	156.49**	13.59	31.21
Grain yield, kg	0.26	12.51**	1.14**	0.13
Stover yield, kg	1.67	92.75**	16.55**	1.99
Total biomass yield, kg	2.27	37.13**	23.47**	1.60
Harvest index	0.005	0.97**	0.03**	0.02
Land equivalent ratio/barley/	0.13	0.03	0.27*	0.03

Note: * and ** significant at $P < 0.05$ and $P < 0.01$, respectively. Numbers in parenthesis indicate degrees of freedom.

Table 2. Mean squares of growing year and intercrop combination combined ANOVA across years/2011 and 2012/for pods plant⁻¹, grain and total biomass yields, and harvest index in the highland area of Bulle, southern Ethiopia.

Variables	Mean squares of variables for faba bean			
	Error (40)	Year /Y/ (1)	Intercrop combination/IC/ (9)	Y*IC (9)
Plant height (cm)	77.83	2870.4**	103.09	73.7
Pods plant ⁻¹	7.35	141.07**	13.19	12.25
1000 seed weight, (g)	1799.77	883112.5**	1450.1	1545.3
Grain yield (kg)	0.46	27.47**	4.76**	0.63
Total biomass yield (kg)	0.88	11.79**	18.06**	2.08**
Harvest index	0.02	0.63**	0.03	0.04

Note: * and ** significant at $P < 0.05$ and $P < 0.01$, respectively. Numbers in parenthesis indicate degrees of freedom.

The results showed that variation in year significantly affected seeds spike⁻¹ (Table 1) but no interaction effect of year by intercrop was observed. Seeds spike⁻¹ was significantly 14.6% more in 2012 (Table 3). Neither year nor intercrop or their interaction significantly affected thousand seed weight of barley. Variation in year significantly affected total biomass of barley in which a 29.3% increase was observed in 2012 (Tables 1, 3). All intercrops produced significantly less biomass of barley relative to that of sole barley while combinations of 1Fb: 2Ba and 1Fb: 3Ba produced more biomass (30.3 and 43% more, respectively) compared to single alternate row intercrop. Planting pattern and year significantly affected harvest index of barley (Tables 1). There was more dry matter partitioning (125%) in 2011 (Table 3). Single alternate and 3Fb:1Ba intercrops had significantly more dry matter partitioning (95.8 and 83.3%, respectively) compared to sole barley (Table 4).

The biomass of faba bean was significantly affected by variation in year (Table 2) and it was 21.3% more in 2011 compared to 2012. All planting patterns had significantly less biomass compared to sole crop faba bean in which the reduction varied between 25 and 71% (Table 5). Statistically, variation in year affected the dry matter partitioning of faba bean (Table 2) and in 2011 harvest index was 51.3% more while all intercrop combinations except 1Fb:3Ba were at par with sole bean harvest index.

Table 4. Effect of planting pattern on grain, straw and total biomass yields and harvest index of barley in barley-faba bean intercrop from combined ANOVA over years/2011 and 2012/Bulle, southern Ethiopia.

Year/season	Barley yield (kg ha ⁻¹)			Harvest index
	Grain	Straw	Total biomass	
Sole barley	2052.4ab	7206.6a	9259.0a	0.24 c
Planting pattern				
1Fb: 1Ba	2175.9a	3271.5de	5447.4c	0.47a
1Fb: 2Ba	2083.3ab	5015.3bc	7098.6b	0.30bc
1Fb: 3Ba	2067.9ab	5725.1b	7793.0b	0.28bc
2Fb: 1Ba	1589.5bc	3657.3d	5246.8c	0.34b
2Fb: 2Ba	1604.9bc	3950.5cd	5555.4c	0.29bc
2Fb: 3Ba	1574.0bc	3518.5d	5092.5c	0.34b
3Fb: 1Ba	1466.0cd	2083.3e	3549.3e	0.44a
3Fb: 2Ba	972.2d	2731.4de	3703.6e	0.28bc
3Fb: 3Ba	1234.5cd	3086.4de	4320.9cde	0.31bc

Note: The same alphabets in a column show no significant variation at 5% probability level. 1, 2 and 3 are row ratio/ planting patterns/ of either faba bean or barley in faba bean/ barley intercrop.

Variation in grain yield of faba bean was observed between years and among treatments and interaction effect (Table 2). There was 83.4% more grain in 2011 than in 2012 (Table 5). The finding showed that intercrops of 2Fb:1Ba, 3Fb:1Ba, 3Fb:2Ba and 3Fb:3Ba produced yields not statistically different from the yield

Table 3. Effect of growing year on growth, yield and yield components and harvest index of barley under faba bean- barely intercropping.

Parameter	Season	
	2011	2012
Seeds spike ⁻¹ (number)	22 b	25a
Grain yield (kg ha ⁻¹)	2104.9a	1259.2b
Straw yield (kg ha ⁻¹)	2873.4b	5175.8a
TBMY (kg ha ⁻¹)	4978.3b	6435.0a
Harvest index	0.45a	0.20b

Note: TBMY = total biomass yield; Means followed by the same letter(s) in a row indicate non-significant difference at 5% probability level.

3.2 Yield of Component Crops

Variation in year and intercrops significantly affected grain yield of barley (Table 1). The yield in 2011 was 67.2% more compared with 2012 (Table 3) while single alternate row intercrop significantly increased grain yield by 6% but it was at par with the yield of sole barley and 1Fb:2Ba and 1Fb:3Ba (Table 4). On the other hand, lower grain yield of barley that varied between 21.8 and 52.6% was observed from two and three rows of faba bean combined with the different rows of barley.

of sole faba bean. Faba bean yielded 52.2, 54.7 and 79.3% less from combinations of 1Fb:1Ba, 1Fb:2Ba and 1Fb:3Ba relative to the yield of sole faba bean (Table 5).

Table 5 Faba bean grain and total biomass yields and harvest index (HI) of faba bean in barley-faba bean intercropping.

Year/ Season	Faba bean yield (kg/ha)		Harvest Index
	Grain	TBM*	
2011	3485.1a	5750.6a	0.59a
2012	1899.8b	4742.2b	0.39b
Planting pattern			
Sole faba bean	4027.9a	8594.0a	0.47ab
1Fb:1Ba	1924.6c	3968.4de	0.52ab
1Fb:2Ba	1825.4c	3095.3ef	0.58a
1Fb:3Ba	833.3d	2480.2f	0.33b
2FB:1Ba	3154.8ab	6051.6bc	0.53ab
2Fb:2Ba	2638.9bc	4861.1cd	0.54a
2Fb:3BA	2480.2bc	4861.1cd	0.50ab
3Fb:1Ba	3254.0ab	6150.8b	0.49ab
3Fb:2Ba	3670.6a	6448.4b	0.46ab
3Fb:3Ba	3115.1ab	5952.4bc	0.51ab

Note: TBM* = Total biomass; The same alphabets in a column show no significant variation at 5% probability level. Fb-faba bean; Ba-barley

3.3 Productivity and Profitability of Intercropping

Productivity of barley in 1Fb:1Ba, 1Fb:2Ba and 1Fb:3Ba planting patterns showed partial LER >1 with the respective productivity of 12, 12 and 15% higher than sole crop barley. The contribution of barley to the total productivity from 1Fb:1Ba, 1Fb:2Ba and 1Fb:3Ba planting patterns were 71.8, 74.7 and 86.5%, respectively (Table 6). In all these treatments, the total productivity of barley-faba bean intercrop (LER_T) was greater than one which varied between 32 and 56%.

System productivity index (SPI) of barley-faba bean intercrop did not exhibit statistically significant differences due to treatments but better SPI was achieved from planting patterns of 1Ba:1Fb, 1Fb:2Ba and 2Fb:1Ba. At a constant row of faba bean, there was a decrease in SPI as the number of rows of barley increased from one to three.

The energy yield was significantly influenced by the treatments and growing years. Single alternate and 1Fb:2Ba intercrops produced significantly 153.9 and 141.8% more energy, respectively, compared to the energy from sole-cropped barley (Table 6). On the other hand, the energy yield from one and two rows of faba bean intercropped with one, two and three rows of barley was at par with the energy from single alternate row. Combinations of one row of faba bean with one and two rows of barley had relatively higher monetary advantage compared to the other row arrangements.

Planting patterns of 1Fb:1Ba, 1Fb:2Ba and 2Fb:1Ba had 35.9, 33.3 and 34.2% saved more land, respectively, compared with other row arrangements. The net income from barley-faba bean intercrop was significantly higher than the income of sole crop barley. Except 1Fb:2Ba and 1Fb:3Ba planting patterns, other intercrops showed no significant variation in net benefit (Table 6). On the other hand, the net income in 2011 was 86.7% more than the income in 2012. Overall, the benefit from barley faba bean intercrop varied between 71.4 and 248.6% more over the income from sole crop barley.

Table 6. Effect of cropping system on LER, SPI, EY, MAI and land benefit (LB) of barley in barley faba bean intercropping.

Cropping system	Partial LER		Total LER	SPI	EY	MAI	LB (%)	Net income (Etb/ha)
	LER _{Fb}	LER _{Ba}						
Sole crop		-	-		39.5b		-	17979c
Planting pattern								
1Fb:1Ba	0.44cd	1.12a	1.56	3012.9	102.9a	9056	35.9	48083ab
1Fb:2Ba	0.38de	1.12a	1.50	2903.0	95.5a	7860	33.3	45908b
1Fb:3Ba	0.18e	1.15a	1.33	2430.8	89.6ab	4677	24.8	30813c
2Fb:1Ba	0.67abc	0.85ab	1.52	2979.6	72.8ab	6940	34.2	61157ab
2Fb:2Ba	0.57a-d	0.82ab	1.39	2793.8	75.9ab	5404	28.1	53087ab
2Fb:3Ba	0.51b-d	0.85ab	1.36	2653.2	72.2ab	4682	26.5	50688ab
3Fb:1Ba	0.70ab	0.71ab	1.41	2787.0	70.7ab	3689	29.1	61471ab
3Fb:2Ba	0.79a	0.54b	1.33	2661.9	43.0b	3006	24.8	62672a
3Fb:3Ba	0.66a-c	0.66ab	1.32	2647.7	56.3ab	3832	24.2	56527ab

Note: LER_{Fb}-partial land equivalent ratio of faba bean; LER_{Ba}- partial land equivalent ratio of barley; SPI-system productivity index; EY-energy yield; MAI-monetary advantage index; LB--Land benefit from intercrop; Etb-Ethiopian birr/currency. The same alphabets in a column shows no significant variation at 5% probability level.

4. Discussion

The dominance of barley ($RY > 1$) in 1Fb:1Ba, 1Fb:2Ba and 1Fb:3Ba intercrops resulted in higher mean grain yield of the crop. However, grain yield of faba bean was reduced due to competition from the intercropped barley and lower bean population. The above intercrops might have more canopy cover due to higher tillering capacity that might have intercepted more light in which barley became more competitive resulting in higher plant height, spike length and more seeds spike⁻¹, leading to better resource use. In addition, more dry matter partitioning from 1Fb:1Ba intercrop might show more resource flow to the grain and thus better crop performance. Various studies have shown that cereals are more competitive in intercropping (Sadeghpour *et al.*, 2014; 2013; Takim, 2012; Yilmaz *et al.*, 2008). Similarly, Esmacili *et al.* (2011) reported more grain yield of barley from more cropping ratio of barley in barley-annual medic (*Medicago scutellata* CV Robinson) intercrop.

Reduction in barley grain yield from intercrops of two and three rows of faba bean combined with one, two and three rows of barley varied between 22 and 53%, which was attributable to low plant density of barley but more population of faba bean. Consistent with the results of this study, Getachew *et al.* (2006) reported lower grain yield of barley in a barley-faba bean mixed intercropping due to more plant density of faba bean. The work of Mariotti *et al.* (2006) indicates that the yields of cereals and vetch was reduced by about 40 and 20%, respectively, compared to sole crop yields.

Increased population of faba bean caused a competitive effect towards barley that reduced the relative yields of both crops ($RY < 1$), which could be competition within and between crops and larger seed size of faba bean (Benincasa *et al.*, 2012). Reduction in grain yield of faba bean from various planting patterns of one row of faba bean with one, two and three rows of barley that varied between 52 and 79% was because barley was more competitive and aggressive in most planting patterns, which is also supported by the finding of Esmacili *et al.* (2011).

Barley in 1Fb:1Ba intercrop might have also benefitted from faba bean due to high N uptake from the transfer of nitrogen from the associated faba bean crop, which is supported by the work of Fujita *et al.* (1990) who reported the transfer of N from the legume crop to the associated maize crop. Increase in barley grain yield from 1Fb:1Ba, 1Fb:2Ba and 1Fb:3Ba combinations might also be due to the contribution of N and P from faba bean to the growth and yield of barley. In addition, more growth and grain yield of intercropped barley with faba bean might be less use of water by faba bean than barley as indicated by the finding of Papastylianou *et al.* (1981). The report of Eskandari *et al.* (2009) shows supply of N from legumes in grass-forage legume intercrop thus more forage yield than sole crop grass grown alone. Their report

shows more protein yield of barley (64, 27, and 55%) in faba bean-barley, lupin-barley and pea-barley intercrops compared to sole crop barley, respectively.

Intercropping of 1Fb:1Ba, 1Fb:2Ba and 1Fb:3Ba was more efficient in using resources than sole crop barley ($RYT > 1$). Single alternate row intercrop had a 12 % increase in grain yield, higher yield advantage, system productivity index, and land benefit. Partial land equivalent ratios indicated more contribution of barley to the total productivity of the system and was higher (72 to 87%) in 1Fb:1Ba, 1Fb:2Ba and 1Fb:3Ba intercrops as compared to faba bean, and it showed intercropping of barley was more efficient (partial LER > 0.5) in land use. But the current research result was in contrast to Benincasa *et al.* (2012) finding that resource use efficiency in wheat-faba bean intercrop compared with one species crop was lower.

Higher grain yield of barley in some planting patterns was reported by Dordas *et al.* (2012) and Workayehu and Wortmann (2011). It was also reported higher total land equivalent ratio (Workayehu and Wortmann, 2011), system productivity index (Dordas *et al.*, 2012), monetary advantage index (Dordas *et al.*, 2012), land benefit, energy yield (Workayehu and Wortmann 2011), and net income (Dordas *et al.*, 2012) relative to sole crop barley.

Energy yield obtained from intercrop (91%) compared with the energy obtained from sole crop barley would help the low input farmers in developing countries to supplement dietary balance with protein and carbohydrate nutrition.

The net income in 2011 (83% more) might be due to rainfall variation in which better amount and distribution of rainfall contributed to better growth and grain yield of the crops and less weed infestation, and this resulted in higher monetary benefit from intercropping and this agrees with the finding of Esmacili *et al.* (2011) because of shade effect and more competition from both intercropped barley and faba bean crops. Increased growth and productivity in barley intercropping might be due to better N uptake obtained from faba bean which fixes atmospheric nitrogen (Kopke and Nemecek, 2010).

In mixed farming systems, faba bean offers the potential of enhancing the productivity and sustainability of intercropping, which is in agreement with the work of Reynolds *et al.* (1994) in that faba bean add N to the soil making additional soil N available. This achievement becomes an example of ecological intensification of cereal systems of the farmers who live in the highland areas at the same time intercropping exploiting the resources of the environment.

5. Conclusions

The finding showed that intercropping of one, two and three rows of barley combined with one row of faba bean produced higher partial and total LER of barley, energy yield, system productivity index, monetary

advantage, land benefit and net income. On the other hand, more grain yield and harvest index was obtained from single alternate row of barley and faba bean intercrop. The overall result suggests that intercropping of cereals (barley) with legume (faba bean) can be of a benefit to the low-input farming system in particular in the highland areas of the country due to better productivity, economic benefit and energy yield while the system could be an eco-friendly approach. Barley-faba bean intercrop would provide not only carbohydrate but also improved protein supply for balanced diet of farmers' family members. This finding showed that barley-faba bean intercrop is beneficial for farmers in the study area who cannot afford to buy inorganic chemical fertilizers.

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7. References

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