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Effect of barley (*Hordeum vulgare* L) / faba bean (*Vicia fabae* L) intercropping on productivity and land use efficiency in highlands of Southern Ethiopia

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Abstract
Field experiment was conducted at Bule testing site of Hawassa Agricultural Research Center during 2006 to 2008 cropping season to assess the effect of barley faba bean intercropping on productivity and profitability of the component crops. The treatments consisted of one, two and three rows of barley with one, two and three rows of faba bean combined in factorial and laid out in a randomized complete block design with three replications. Sole crops of barley and faba bean were included in the treatments as control. Sole barley was planted at row spacing of 20 cm while inter and intra row spacing for barley were 40 and 10 cm, respectively. Biomass, grain yield, productivity and profitability reacted differently to spatial arrangement of barley and faba bean intercropping. Significantly the highest biomass yield recorded for sole cropping barley and followed by spatial arrangement of 1B:3FB. Similarly, significantly the highest grain yield was recorded for spatial arrangement of 1B:1FB and followed by 1B:2FB. The highest biomass yield was obtained from sole faba bean which was followed by spatial arrangement of 3B:2FB. In line with this the greatest grain yield was achieved from sole faba bean followed by spatial arrangement of 3B:2FB.In general productivity and profitability improved in intercropping as compared to sole cropping. Based on this result spatial arrangements of 1B:1FB and 1B:2FB could be used in considering barley as main crop and faba bean as bonus crop.
Keywords: - intercropping, changing climate, monetary benefit, productivity, subsistence

1. Introduction

Barley (*Hordeum vulgare* L.) ranks fourth among the cereals in worldwide production and is grown annually on 48 million hectares in a wide range of environments. In some developing countries, barley is mostly cultivated by resource-poor farmers in marginal environments, receiving modest or no inputs. Barley is widely grown in seven diverse rain-fed agro-ecologies of Ethiopia at altitudes of 1400 to over 4000 masl. The crop is more diversified and prominent in areas between 2400 to 3400 masl (Zemede, 2002). It can be grown twice a year on the highlands of Ethiopia. The two growing seasons of barley are Meher (June to September) and *Belg* (February to May). The report of Central Statistical Authority (CSA, 2010) shows that area coverage of food barley at the national and regional (southern Ethiopia) level was 1,046,555.3 and 111,756.36 ha and the productivity was 1.6 and 1.8 t ha^{-1}, respectively. Faba bean (*Vicia fabae L.*), on the other hand, is widely cultivated in the highlands of Ethiopia. It has area coverage of 512067 and 53628 ha of land in Ethiopia and southern region, respectively. Ethiopia ranks second in faba bean production with a world share of 22.4% (WWW.factfish.com. , 2014). Both barley from cereals and faba bean from pulses are major staple food crops in high altitude areas of Ethiopia.

Soil fertility, weeds, diseases and insect pests are the major production constraints in barley production. Soil fertility in particular nitrogen and phosphorus are some of the major yield limiting nutrients in crop production. Currently, use of chemical fertilizers and improved seeds are low due to high cost that is not affordable by farmers. On the other hand, farmers land owning is than 0.5 ha where farmers are forced to practice multiple cropping systems. Practice of growing many crops on the same land results in high crop intensity, which depletes soil nutrients. The low yield is also attributed to minimal use of improved barley variety but a wide use of local seed (98.66% of the total barley area is allotted to local barley), low application of urea (0.91% of the total area) and DAP (28.30% of the total production area of barley), and combination of DAP and Urea (9.45% of the total barley production area), and natural fertilizer (farmyard manure in 15.42% of the total barley area) is very low (CSA, 2011a). Because of the high cost of chemical fertilizer, intercropping of legumes with cereals is an alternative means to boost production and productivity and increase farmers' income in the country particularly southern region.

Various studies show that faba bean crop enhances nitrogen fixation (Phelps *et al*., 2008). According to Strydhorst *et al*. (2008), faba bean–barley, lupin–barley, and pea–barley intercrops had 64, 27, and 55% higher protein yields, respectively, compared to sole crop barley. One of the benefits of cereal-legume intercropping in the high land areas of Ethiopia is the ability of the component crops to efficiently utilize different sources of N (Willey, 1979; Benites *et al*., 1993). The finding of Dordas *et al*. (2012) shows that growth rate of both pea and cereals in an intercrop was 39 and 64% less compared with their respective sole crops, respectively. Moreover, better monetary benefit and system productivity can be achieved from intercrops than sole crops. The complementary use of growth resources by the component crops is particularly important in low input subsistence farming systems of those in the highlands of southern Ethiopia. Hence, this study was initiated with objective to assess the effect of barley/faba bean intercrop on productivity and profitability of component crops in intercropping.

2. Materials and methods

2.1. Experimental site

Consecutive field experiments were conducted from 2006 to 2007 cropping season at Bule testing site of Hawassa Agricultural Research Center. An approximate geographical coordinates of the site is 6°37' N latitude and 38°44' E longitude. It is a highland area with an altitude of 2700 masl and the commonly growing crops include barley, wheat, faba bean, field pea, fruits and oil crops. The annual rainfall ranges from 1401 and 1800 mm with mean annual temperatures of 12.6 to 20°c. Physical and chemical properties of the soil at experimental site are presented in Table 1.

Table1. Physical and chemical properties of the soil at experimental site

Parameter	Value
Textural class	Clay loam
Bulk density	1.04
pH	5.8
EC	0.04ds/m
Total N	0.45%
OC	4.5%
Available P	57ppm
CEC	35c mol(+)kg $^{-1}$

2.2. Treatments and experimental design

Treatments consisted of one, two and three rows of barley and faba bean were combined in factorial as shown in Table 2. The treatments were laid out in a randomized complete block design (RCBD) with three replications. Sole crops of barley and faba bean were planted as control treatments. The inter and intra row spacing of faba bean were 40 cm and 10 cm, respectively while inter row spacing of barley was 20.cm. In this study six-rowed-barley variety (HB-42) and faba bean variety Messay were used with seed rate of barley 85 kg/ha and faba bean 150 kg/ha. Fertilizer DAP was applied at planting at the rate of 100 kg ha^{-1} for both sole and intercrops of barley and faba bean. Planting was carried out following the cropping season of the area.

Table 2. Treatment combinations in spatial arrangement of barley and faba bean intercropping

Treatments	Combinations
1B : 1FB	One row of barley with one row of faba bean
1B : 2FB	One row of barley with two rows of faba bean
1B : 3FB	One row of barley with three rows of faba bean
2B : 1FB	Two rows of barley with one row of faba bean
2B : 2FB	Two row of barley with two rows of faba bean
2B : 3FB	Two rows of barley with three rows of faba bean
3B : 1FB	Three rows of barley with one row of faba bean
3B : 2FB	Three rows of barley with two rows of faba bean
3B : 3FB	Three rows of barley with three rows of faba bean

2.3. Data collection and analysis

Data were collected on plant height, spike length, seeds per spike, thousand seed weight (TSW), total dry matter and harvest index of barley. Similarly, agronomic traits collected for faba bean were plant height, pods plant^{-1}, seeds pod^{-1}, TSW, grain and total biomass yields. Seed moisture content was adjusted to 12.5%. Harvest index (HI) was calculated by dividing grain yield to total biomass. To evaluate productivity and profitability total land equivalent ratio (LER) of the companion crops were estimated as,

$$LER = \frac{IBY}{SBY} + \frac{IFBY}{SFBY}$$ Where LER= Land equivalent ratio

IBY= Intercrop yield of barley
SBY= Sole crop yield of barely
IFBY= Intercrop yield of faba bean
IFBY= Sole crop yield of faba bean

System productivity index (SPI) estimated according to Odo (1991) as:

$$SPI = \frac{Sa}{Sb} Yb + Ya$$ Where SPI = System productivity index

Sa = Mean yield of sole barley

Sb = Mean yield of sole faba bean
Ya = Mean yield of barley in intercrop
Yb = Mean yield of faba bean in intercrop

Economic benefit of barley-faba bean intercropping was estimated using respective yield of components crops at their local market prices of faba bean at 15 birr/kg and barley 10 birr/kg.
Variable costs of seeds and labor for field operations such as planting and harvesting were determined for each treatment. The costs of improved seeds of barley (8.53 birr/kg) and faba bean (14.50 birr/kg) were obtained from Ethiopian Seed Enterprise (ESE), Southern Region (ESE, 2012). The incurred labor cost for planting and harvesting of both crops was 70 persons day^{-1} ha^{-1} with a payment of 16 birr/day. All cost and price estimations were done in Ethiopian birr (currency). Net income (NI) was determined as the difference of gross income and variable cost (Babatunde, 2003). Data were combined over seasons after carrying out the homogeneity test of variances (Gomez and Gomez, 1984) and subjected to analysis of variances using the general linear model of SAS version 9.1 (SAS Institute, 2003). Treatment means were compared using Tukey test of significance at the 5% level of significance.

3. Results

3.1. Barley

Spatial arrangement of row spacing did not have significant effect on plant height, spike length, seeds per spike and TSW on intercropped barley. However, spatial arrangement had significant effect on biomass yield, grain yield and HI (Table 3). The highest biomass yield (8772 kg/ha) recorded for sole cropping barley and followed by spatial arrangement of 1B:3FB with mean biomass yield of 7386 kg/ha. The lowest biomass yield (3360 kg/ha) was observed for spatial arrangement of 3B:1FB. Regarding grain yield, the highest grain yield (2798 kg/ha) was recorded for spatial arrangement of 1B:1FB and followed by 1B:2FB with mean grain yield 2679 kg/ha. The lowest grain yield (1250 kg/ha) was seen for spatial arrangement of 3B:2FB. Similarly, the highest HI (0.47) was observed for spatial arrangement of 1B:1FB followed by 3B:1FB with the HI value of 0.44. The lowest HI (0.24) was seen sole barley.

3.2. Faba bean

Combined analysis of variance revealed that spatial arrangement of barley/faba bean intercropping resulted in significant differences on biomass and grain yield (Table 4). The highest biomass yield (9822 kg/ha) was obtained from sole faba bean which was followed by spatial arrangement of 3B:2FB with mean biomass yield of 6448 kg/ha. The lowest biomass yield of 2480 kg/ha was recorded for spatial arrangement of 1B:3FB. In line with this the greatest grain yield (4603 kg/ha) was achieved from sole faba bean followed by spatial arrangement of 3B:2FB with mean grain yield of 3671 kg/ha. The least grain yield of 833 kg/ha was seen for spatial arrangement of 1B:3FB. In contrast, spatial arrangement of barley/faba bean intercropping did have significant effects on plant height, pods per plant, seeds per pod and HI.

Table 3. Effect of spatial arrangement on yield and related traits of barley

Treatments	Plant height (cm)	Spike length (cm)	Seeds/spike	TSW (gm)	Biomass yield (kg/ha)	Grain yield (kg/ha)	HI
1B : 1FB	112.5	6.97	24.0	43.7	5158bcd	2798a	0.47a
1B : 2FB	110.3	6.28	23.3	51.6	6728abc	2679ab	0.30c
1B : 3FB	104.5	5.77	22.8	51.6	7386ab	2659ab	0.28c
2B : 1FB	116.3	6.00	26.3	52.7	4974cd	2044abc	0.34abc
2B : 2FB	109.3	6.37	23.3	53.1	5263bcd	2064abc	0.29c
2B : 3FB	108.8	6.47	22.7	53.3	4825cd	2024abc	0.34abc
3B : 1FB	114.0	6.70	24.6	51.2	3360d	1885abc	0.44ab
3B : 2FB	112.3	6.38	24.9	52.0	3509d	1250c	0.28c
3B : 3FB	111.3	6.42	22.4	52.3	4096d	1587bc	0.31bc
Sole barley	104.8	6.10	20.9	50.9	8772a	2309abc	0.24c
LSD	NS	NS	NS	NS	2246	763	0.13
1B	109.1	6.34	23.4	48.9	6424a	2712a	0.35
2B	111.5	6.28	24.1	53.0	5021b	2044b	0.32
3B	112.5	6.50	23.9	51.8	3655c	1008c	0.34
LSD	NS	NS	NS	NS	1123	219	NS
CV (%)	5.9	12.6	17.1	15.3	24.4	24.7	22.0

Table 4. Effect of spatial arrangement on yield and related traits of faba bean

Treatments	Plant height (cm)	Pods/plant	Seeds/pod	TSW (gm)	Biomass yield (kg/ha)	Grain yield (kg/ha)	HI
1B : 1FB	126	15	3.0	840	3968cde	1925cd	0.52
1B : 2FB	126	16	2.8	910	3095de	1825cd	0.58
1B : 3FB	126	14	3.0	940	2480e	833d	0.33
2B : 1FB	129	15	3.0	900	6052bc	3154abc	0.53
2B : 2FB	126	16	3.0	930	4861bcd	2639bc	0.54
2B : 3FB	130	15	3.0	870	4861bcd	2480bc	0.50
3B : 1FB	132	18	2.8	850	6151b	3254abc	0.49
3B : 2FB	131	16	3.0	830	6448b	3671ab	0.46
3B : 3FB	134	19	2.7	910	5952bc	3115abc	0.51
Sole faba bean	138	18	3.0	890	9822a	4603a	0.47
LSD	NS	NS	NS	NS	2181	1592	NS
1FB	129	16	2.9	863	5390a	2778a	0.51
2FB	129	16	2.9	890	4801ab	2711ab	0.53
3FB	130	16	2.9	907	4431b	2142b	045
LSD	NS	NS	NS	NS	892	542	NS
CV (%)	5.8	12.8	17.4	21.2	14.3	22.7	19.4

3.3. Discussion

In barley/faba bean intercropping did not have significant effects on almost all growth and yield components of both crops. However, it had a profound impact on biomass, grain yield, productivity and profitability of component crops in intercropping. The averaged biomass yield for both crops tended to decline with increasing number of rows in spatial arrangements (Table 3 &4). Sole crops out yielded the intercrops in producing biomass yield. Increasing the proportion of barley and faba bean in the spatial arrangements reduced biomass yield of both crops. This might be probability attributed to increasing number of plants per unit area aggravated competition for resources leading to plants with smaller sizes. Increasing faba bean proportion from one to three rows led to a decline in grain yield (Table 3). More barley yield reduction is expected with the increase in faba bean density beyond used in this study implying domination of barley by faba bean. Spatial arrangement of one row with all three levels of row gave grain yield higher than the sole barley. The yields of barley from one, two and three rows barley combined with one row of faba bean yielded 21.2, 16.0, and 15.2% more yield as compared with sole crop. This might probably indicated the complementarily between the component crops in intercropping. On the other hand, two and three rows of barley with all levels of faba bean yielded lower than the sole barley for grain yield. This might be attributed to increased competition for resources within and between plants due to increased number of plants per unit area. All spatial arrangements of barley and faba bean gave lower grain yield than sole faba bean. This suggests that faba bean is weak competitor in intercropping while barley is relatively stronger competitor. This suggests the suppression of faba bean by barley.

The data for LER, SPI, RVT and net income as affected by spatial arrangement of barley/faba bean intercropping are depicted in Table 5. In general productivity measured in total LER ranged from 1.32 to 1.56 where all spatial arrangements were more productive than their respective sole crops. This means the sole culture of each crop requires 32 to 56% more land than the intercropped crop to produce equal yields indicating greater land-use efficiency of intercrops. The highest total LER (1.56) was recorded for 1B:1FB spatial arrangements followed by 1B:2FB with total LER value of 1.52. The lowest total LER (1.32) was obtained from spatial arrangement of 3B:3FB. Similar results were reported for mixed cultures of lentil and barley (Kallu and Erhabor, 1990), pea and barley (Jensen, 1996), field bean and wheat (Bulson *et al*., 1997), maize and faba bean (Li *et al*., 1999) and pea and barley (Chen *et al*., 2004). On the other hand, partial LER values indicated that 1B:1FB, 2B:1FB and 3B:1FB spatial arrangements more productive than its respective sole of barley. However, the remaining all combination were lower the sole barley. In contrast, the intercrop productivity of faba bean for all spatial arrangements were lower than that of its respective sole faba bean. System productivity index according to Odo (1991) standardizes faba bean yield of the secondary crop in terms of the primary crop (barley). The result indicated that combinations of 1B:1FB, 1B:2FB and 2B:1FB were more productive than other planting patterns with the highest for spatial arrangement of 1B:1FB. All spatial arrangements had the relative values total of more than 1 (RVT > 1). The RVT varied from 1.51 to 4.93 with the highest for spatial arrangement of 3B:3FB. It indicated that intercropping has economic advantages. With respective of net income spatial arrangements 1B:1FB, 1B:2FB and 1B:3FB greater than the sole barley with the highest for 1B:1FB. All other combinations generated the net income lower than the sole barley. Conversely, intercrops of barley with faba bean produced lower income compared to its respective sole faba bean.

Table 5. Effect of spatial arrangement on productivity and profitability of component crops

Treatments	LER (B)	LER (FB)	LER (B + FB)	SPI	Relative value	Net income		
						Barley	Faba bean	Intercrop
1B : 1FB	1.12	0.44	1.56	3734	2.86	26870	30345	53365
1B : 2FB	0.85	0.67	1.52	3600	2.61	25442	28345	50137
1B : 3FB	0.71	0.70	1.41	3369	3.71	25202	8505	32041
2B : 1FB	1.12	0.38	1.50	3598	1.99	17822	54928	66439
2B : 2FB	0.82	0.57	1.39	3396	3.15	18062	44625	57409
2B : 3FB	0.54	0.79	1.33	3139	4.53	17582	41445	54067
3B : 1FB	1.15	0.18	1.33	3065	1.51	15914	56925	66331
3B : 2FB	0.85	0.51	1.36	3234	2.87	8294	65265	66217
3B : 3FB	0.66	0.66	1.32	3169	4.93	12338	54145	60253
Sole	1.00	1.00	-	-	-	21002	85354	97150

3.4. Conclusion

Biomass, grain yield, productivity and profitability reacted differently to spatial arrangement of barley and faba bean intercropping. The highest biomass yield recorded for sole cropping barley and followed by spatial arrangement of 1B:3FB. Significantly the highest grain yield was recorded for spatial arrangement of 1B:1FB and followed by 1B:2FB. Similarly, the highest biomass yield was obtained from sole faba bean which was followed by spatial arrangement of 3B:2FB. In line with this the greatest grain yield was achieved from sole faba bean followed by spatial arrangement of 3B:2FB. In general productivity and profitability improved in intercropping as compared to sole cropping. Based on this result spatial arrangements of 1B:1FB and 1B:2FB could used considering barley as main crop and faba bean as bonus crop.

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