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Effect of barley (*Hordeumvulgare* L.) and fababean (*Viciafabae* L.) intercropping on barley and fababean yield components

Abstract

Fababean and barley intercropping promotes efficient use of land, and minimize the agricultural inputs. Legume intercropped with cereal fixes molecular nitrogen from air. Understanding this, fababean and barley experiment was conducted at Debre Birhan University Research Station, Ethiopia. The treatments were sole barely (control),Sole fababean (control), 1 row barley with 1 row fababean, 2 row barley with 1 row fababean and 1 row barley with 2 row fababean. The design of the experiment was randomized block design. The result showed that tiller number of barley plant was statically significant in control, 3, and 5 treatments. Similar trend was observed in 1, 3 and 5 treatments for spike length. There was highly significant correlation between fresh and dry weight of barley and it was high in 3 and 5treatments. Similar trend was observed on tiller number and plant height in treatments 3 and 5. Significant mean difference was recorded for fresh weight in 2, 3, 4 and 5 treatments. Fababean branching was significant in treatments 2, 3 and 4.Correlation between fresh and dry weight of fababean, branch, and pod and root nodules numbers showed statistically significant differences. Branch number of fababean correlates significantly with pod and root nodules numbers. Fresh and dry weight of fababean in treatment 2 was the highest of all treatments.

Keywords: barley, fababea, intercropping, monetary advantage index, productivity, subsistence, relative crowding coefficient

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Introduction

Barley (*Hordeum vulgare L.*) ranks fourth among the cereals in worldwide production and it is grown over 45 million hectors in different climatic zones of the World. In Ethiopia, poor farmers in marginal environments with low agricultural inputs[1] mostly cultivate barley. It is a unique source for beer, food for human and animal feed and domesticated cereals originating in the Fertile Crescent land of Abyssinia (Ethiopia) and Southeast Asia.

In Ethiopia it grows from 1400–4000 m.a.s.l. The crop is more diversified and prominent in areas between 2400 to 3400 m.a.s.l. and grows twice a year on the high lands of Ethiopia. The two growing seasons of barley are June - September and February-May. Both barley and Fababeen is major staple food crops for people inhabiting the highland of Ethiopia. In Ethiopia, barley is cultivated as mono crop and has a negative impact on soil plant nutrients balance. Thus, intercropping barley with fababean can give synergy to barley in low soil fertility land. Faba bean can fix atmospheric nitrogen and increase soil nitrogen pool available to both crops and will increase nitrogen content of the soil for future crops.[2,3] Legume based cropping systems improves soil organic matter, thereby enhancing soil quality.

When two or more crops intercropped, there could be competition for nutrient and sunlight energy. Thus, the land equivalent ratio (LER) is useful in evaluating the yield advantage of intercropping systems.[4,5] LER method permits an effective comparison of different yields from the same surface of each intercrop compared with its sole stand and permits to produce more crops intensively on small land with low levels of external inputs.[2] Production efficiency in intercropping is important, especially for small-scale farmers where growing season is short.[6]

Intercropping can result in higher growth rate, reduction of weeds, pests, and diseases, and more effective use of resources due to differences in resource consumption.[2,7–9] In addition, there are complementary effects between the components of intercropping and production increases due to reduced competition between them.[5,10]

Cereals and legumes intercropping are important for the development of sustainable food production systems, particularly in cropping system with limited external inputs.[11] In tropics cereal legumes intercropping gives greater yield stability and lower risks of crop failure that are often associated with monoculture.[12] Yield increases can result from better resource use efficiency of the mixed crop and buffering effects of the mixtures against disease and weeds.[5,13,14] It is advantageous as compared to sole cropping due to the interaction between components in intercrops and the difference in competition for the use of environmental and land resources.[10,12,15,16]

Nowadays, chemical fertilizer and improved seed are scares and low due to unaffordable high input costs, hence farmers are opted to practice multiple cropping systems on the same farm field.[1] Legumes are often less competitive than cereal species and may require higher plant densities relative to achieve inter cropping benefits.[17] Intercropping reduces pest and disease damages of the crop by reducing populations of pests and diseases.[18,19] Strydhorst et al.,[20] showed that intercropping barley and fababean increase yield per unit surface area and yield stability.[13] Forage obtained from cereal-legumes inter crops always has a higher quality than that of cereals sole crops.[21]

Conservation of soil fertility in intercropping is a form of rotation that each season is done on land. Rhizobium bacteria are able to have a symbiotic relationship with plants of leguminosae family, and thereby fixation of atmospheric nitrogen into available nitrogen for plants uptake.[7,13,19] Competition for light, water, nutrients, and allelopathic effects may reduce yields in intercropping.[3,18,22,23] However, selection of appropriate crops, planting rates, and changes in the spatial arrangement of the crops can reduce competition.[24,25] Finally, the main aim this study was to assess the effects of barley and faba intercrop on barley and faba agronomic parameters.

Materials and methods

Description of the study area

The research was conducted at Debre Birhan University Research Station, located at 9°30 to Latitude 39°38 longitudes, and at altitude of 2780m.a.s.l. The mean maximum temperature was 18.6°C and the mean minimum temperature was 8.2°C. The annual precipitation was 1045.5 mm and the major soil type was Litosols.

Experiential treatments, design and Procedure

Afield experiment under irrigated condition was conducted during the 2016 off season (February-May) to determine the effect of inter cropping between fababean and barley at Debre Berhan area. The treatment included-

Treatment 1 Solebarely (control)

Treatment 2 Sole fababean(control)

Treatment 3 1 row barley with 1 row fababean (1:1)

Treatment 4 2 row barley with 1 row fabbean (2:1)

Treatment 5 1 row barley with 2 row fababean (1:2)

The experiment was randomized complete block Design (RCBD). Five treatments with three replications were tested for intercropping (5*3=15). Local barley variety was Sabina and Lalo fababean variety was planted. Seed rate of faba bean and barley was 130kg/ha and 75kg/ha, respectively. The fababean and barley rate was weighed prior to planting in each plot. Sole barley and fababean was planted as a control unit with spacing of 20cm. Inter and intra row spacing for fababean was 40-20cm, respectively. Hand drilling in plot of 3.2m^2 with 8 rows was applied. Hand weeding and irrigation was used throughout the experimental periods as needed.

Here is the experimental layout:

T1	T2	T3	T4	T5
T5	T1	T2	T3	T4
T4	T5	T1	T2	T3

Unit plot area site=1.6 x 2=3.2m^2

Space between plot=0.5m

Space between block=1m

Space at each edge of plots or outside of work =0.5m

Total net experimental area=12 x 6.8=81.6 m^2

Total Gross area = 13x7.8=101.4m^2

Data to be collected

Agronomic Variables

1. Plant height (cm): average height was measured for both crops from the ground to the tip of spike excluding the individual for barley and for fababean up to flag leave.
2. 2. Biomass of fresh weight: the fresh weight was measured by weighting the above ground cut of the plants as an average fresh weight in gram per plot for both crops.
3. Biomass of dry weight dry: weight was measured by weighting the oven dried (at 60°C for 72hours) above ground cut of the plants expressed as average plants dry weight in gram per plot for both crops.
4. Number of pod per plant: the number of pods were counted from the five randomly tagged plants and expressed as the average number of pods per plant for fababean.
5. Tiller per plant: The number of stem arises from a single seeding from the five randomly tagged plants for barley.
6. Branch per plant: the total number of branch was counted from tagged plants and average computed and expressed as the average number of branches per plant for faba bean.
7. Number of root nodule: the number of root nodule was counted by uprooted the fababean randomly from tag plant.
8. Spike length: Average height of Spike per plant for barley.
9. Number of seed per spike: the number of seed was counted from the tag plant for barley.

Land equivalent ratio

To evaluate productivity and profit adaptability total Land Equivalent Ratio (LER) of the crops was estimated as:

LER=IBY/SBY+IFBY/SFBY

Where LER; Land equivalent ration

IBY; Intercrop yield of barley

SBY; Sole crop yield of barley

IFBY; Intercrop yield of faba bean

SFBY; Sole crop yield of faba bean

Competitive ratio (CR), actual yield loss (AYL) and monetary advantage index (MAI)

CRbarley = (LERbarley/LERfababean)(Zfbb/Zbfb), and

CRfababean=(LERfababean/ LER barley)(Zbfb/ Zfbb)

Where: Zfbb; the proportion of fababean and barley in mixture

Zbfb; the proportion of barley and fababean in mixture

AYL=AYLbarley+AYLf ababeanWhere,

AYLbarley=((Ybfb/Zfbb)/(YB/ZB))-1

AYLfababean= ((Yfbb/Zfbb)/ (YFB/ZFB))-1

Where YB; Yield of barley

ZB; proportion barley in mixture

YFB; Yield of faba bean

ZFB; proportion faba bean in mixture

MAI; (value of combined intercrops) (LER-1)/LER

Crowding coefficient (k)

K= (Kbarely*Kfababean), where

Kbarely=Ybfb*Zfbb/ ((YB-Ybfb)* Zbfb)

Kfababean=Yfbb*Zbfb/ ((YFB-Yfbb)*Zfbb

WhereYbfb; Yield of barley and faba bean as inter crops

Yfbb; Yield of faba bean andbarleyas inter crops

Zfbb; the proportion of fababean and barley in mixture

Zbfb; the proportion of barley and fababean in mixture

YFB; Yield of faba bean

YB; Yield of barley

Data analysis

SPSS version 20 software was used for statistical analysis and Means comparison or separations were carried out using Least Significance Difference (LSD) (Figure 1).

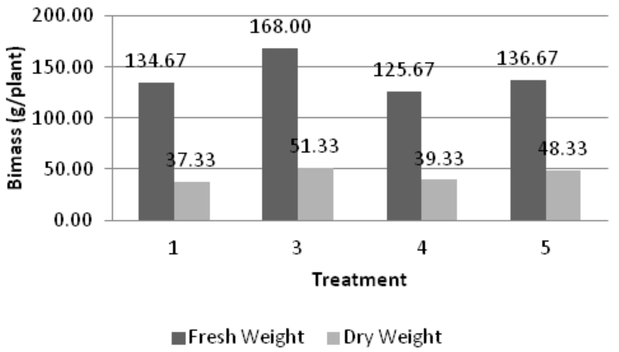

Figure 1 Effect of faba bean and barley intercropping on fresh and dry weight of barley.

Results

Barley

There was highly significant correlation between Fresh and dry weight of barley. Dry weight and tiller number showed also significant correlating between them (Table 1). The plant height and spike number correlated significantly between each other. Tiller number of barley plant showed statistical significant difference in treatments 1, 3 and 5 (Table 2). The highest Tiller number (7.67n/p) recorded for1B:1FB and followed by spatial arrangement of 1B:2FB with mean Tiller number of (6.8n/p). The lowest Tiller number (4.73n/p) was observed for spatial arrangement of sole barley (Figure 2). Similar trend was observed in treatments 1, 3 and 5 for spike length. The highest spike length (8.71cm) was recorded for spatial arrangement of 1B:2FB and followed by 1B:1FB with mean spike length 8.25cm. The lowest spike length (7.43cm) was obtained for spatial arrangement of 2B:1FB (Figure 3).

Fababean

There was significant correlation between fresh and dry weight of faba bean, branch, and pod and root nodules numbers (Table 3). The branch number of faba bean significantly correlates with pod and nodules numbers. It is interesting to note here that faba bean plant height did not correlate with any agronomic variables (Table 3) (Figure 4).

In contrast to barley fresh and dry weight of the significant mean difference was recorded in treatments 2, 3, 4 and 5for fababean (Table 4). Similar trend was observed in treatments 1, 3 and 5 for root nodule. The highest Number of root nodule (49n/p) was obtained from sole faba bean which was followed by spatial arrangement of 1B:1FB with mean Number of root nodule of (36n/p). The lowest Number of root nodule of (31 n/p) was recorded for spatial arrangement of 1B:2FB and 2B:1FB (Figure 5). However, thefaba bean branch and pod numbers significant mean difference was observed in treatments 2, 3, and 4 for faba bean Number of pod (77n/p) was obtained from sole faba bean, which was followed by spatial arrangement of 1B:2FB with mean Number of pod of (50n/p). The lowest Number of pod of (36n/p) was recorded for spatial arrangement of 1B:1FB. The highest number of branch (4n/p) was obtained from sole faba bean which was followed by spatial arrangement of 2B:1FB and 1B:2FB with mean Number of branch of (3 n/p). The lowest Number of branch of (2n/p) was recorded for spatial arrangement of 1B:1FB. In contrast, spatial arrangement of barley /fababean intercropping did not have significant effects on plant height (Table 5).

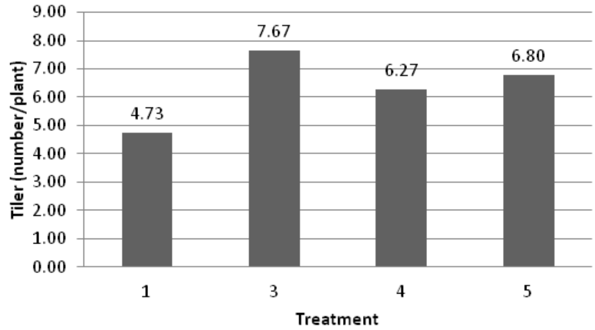

Figure 2 Effect of faba bean and barley intercropping on barley tiller.

Table 1 Effect of fababean and barley intercropping on barley agronomic variables

Variables	Fresh Weight(g/p)	Dry Weight (g/p)	Tiller (n/p)	Plant Height (m/p)	Spike Length (cm/p)	Spike (n/p)
Fresh weight (g/p)	1	.831**	0.464	0.479	0.255	0.067
Dry Weight (g/p)	.831**	1	.631*	0.495	0.324	0.183
Tiller (n/p)	0.464	.631*	1	0.271	0.47	0.467
Plant height (cm/p)	0.479	0.495	0.271	1	0.422	.584*
Spike length (cm/p)	0.255	0.324	0.47	0.422	1	0.465
Spike (n/p)r	0.067	0.183	0.467	.584*	0.465	1

** Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).
Abbreviations: g, gram; p, plant; n, number; cm, centimeter.

Table 2 Effect of fababean and barley intercropping on barley agronomic variables

		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Fresh weight (g/p)	1	-33.333	26.334	0.241	-94.06	27.39
	3	33.333	26.334	0.241	-27.39	94.06
	4	-9	26.334	0.741	-69.73	51.73
	5	2	26.334	0.941	-58.73	62.73
Dry Weigh	1	-14	8.557	0.14	-33.73	5.73
t(g/p)	3	14	8.557	0.14	-5.73	33.73
	4	2	8.557	0.821	-17.73	21.73
	5	11	8.557	0.235	-8.73	30.73
Tiller	1	-2.933*	0.829	0.008	-4.84	-1.02
(n/p)	3	2.933*	0.829	0.008	1.02	4.84
	4	1.533	0.829	0.101	-0.38	3.44
	5	2.067*	0.829	0.037	0.16	3.98
Plant Height	1	-6.037	4.523	0.219	-16.47	4.39
(cm/p)	3	6.037	4.523	0.219	-4.39	16.47
	4	-4.047	4.523	0.397	-14.48	6.38
	5	1.323	4.523	0.777	-9.11	11.75
Spike	1	-.787*	0.335	0.047	-1.56	-0.01
Length	3	.787*	0.335	0.047	0.01	1.56
(cm/p)	4	-0.027	0.335	0.939	-0.8	0.75
	5	1.253*	0.335	0.006	0.48	2.03
		1.280*	0.335	0.005	0.51	2.05
Spike	1	-2.667	1.946	0.208	-7.15	1.82
(n/p)	3	2.667	1.946	0.208	-1.82	7.15
	4	0.667	1.946	0.741	-3.82	5.15
	5	2.033	1.946	0.327	-2.45	6.52

*The mean difference is significant at the 0.05 level.
Treatment 1 Sole barely (control)
Treatment 2 Sole fababean (control)
Treatment 3 1 row barley with 1 row fababean (1:1)
Treatment 4 2 row barley with 1 row fabbean (2:1)
Treatment 5 1 row barley with 2 row fababean (1:2)

Table 3 Effect of faba bean and barley intercropping on the correlation of agronomic variables of faba bean

Variables	Dry Weight (g/p)	Fresh Weight (g/p)	Branch (n/p)	Plant Height (cm/p)	Pod (n/p)	Root Nodules (n/p)
Dry Weight (g/p)	1	.936**	.739**	0.113	.720**	.935**
Fresh Weight(g/p)	.936**	1	.753**	0.127	.762**	.837**
Branch (n/p)	.739**	.753**	1	0.373	.682*	.692*
Plant Height (cm/p)	0.113	0.127	0.373	1	0.044	0.272
Pod (n/p)	.720**	.762**	.682*	0.044	1	.583*
Root Nodules (n/p)	.935**	.837**	.692*	0.272	.583*	1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).
Abbreviations: g, gram; p, plant; n, number; cm, centimeter.

Table 4 Impact of faba bean and barley intercropping on agronomic variables of faba bean

Treat		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Dry Weight (g/p)	2	64.667*	4.944	0	53.27	76.07
	3	-64.667*	4.944	0	-76.07	-53.27
	4	-64.000*	4.944	0	-75.4	-52.6
	5	-67.667*	4.944	0	-79.07	-56.27
Fresh Weight (g/p)	2	283.667*	10.236	0	260.06	307.27
	3	-283.667*	10.236	0	-307.27	-260.06
	4	-317.333*	10.236	0	-340.94	-293.73
	5	-226.333*	10.236	0	-249.94	-202.73
Branch (n/p)	2	1.867*	0.533	0.008	0.64	3.1
	3	-1.867*	0.533	0.008	-3.1	-0.64
	4	-1.533*	0.533	0.021	-2.76	-0.3
	5	-1.067	0.533	0.081	-2.3	0.16
Plant Height (cm/p)	2	-5.637	8.184	0.51	-24.51	13.24
	3	5.637	8.184	0.51	-13.24	24.51
	4	-8.777	8.184	0.315	-27.65	10.1
	5	0.337	8.184	0.968	-18.54	19.21
Pod (n/p)	2	41.100*	11.682	0.008	14.16	68.04
	3	-41.100*	11.682	0.008	-68.04	-14.16
	4	-28.700*	11.682	0.04	-55.64	-1.76
	5	-26.8	11.682	0.051	-53.74	0.14
Root Nodules (n/p)	2	12.290*	2.5	0.001	6.53	18.05
	3	-12.290*	2.5	0.001	-18.05	-6.53
	4	-17.067*	2.5	0	-22.83	-11.3
	5	-17.900*	2.5	0	-23.66	-12.14

*The mean difference is significant at the 0.05 level.

Table 5 Effect of faba bean and barley intercropping on Relative Crowding coefficient

Parameters		Yield			LER of yield			Relative Crowding (K)		
Planting pattern	Mix proportion%	Faba ben	Barley	total	FB	Barley	total	FB	Barley	total
Faba bean(sole)	100	103	-	103	-	-	-	1	-	1
Barley(sole)	100	-	37.3	37.3	-	-	-	-	1	1
1B:1FB	50:50:00	38.3	51.3	69.6	0.37	1.375	1.745	0.59	-3.66	-3.07
2B:1FB	75:25:00	39	39.3	78.6	0.35	1.05	1.43	1.8	-6.55	-4.75
1B:2FB	25:75	35	45.3	83.6	0.34	1.25	1.63	0.17	-13.17	-13

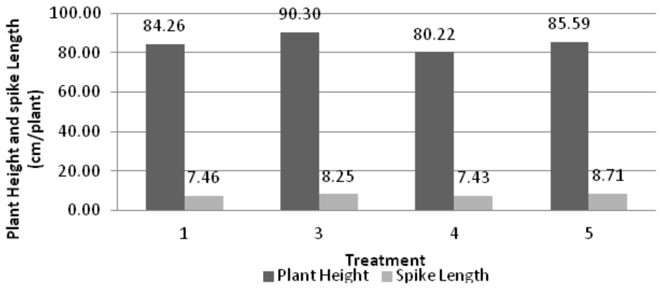

Figure 3 Effect of faba bean intercropping on barley plant height and spike length.

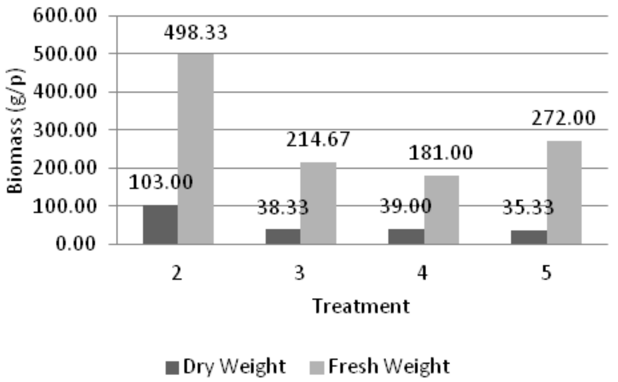

Figure 4 Effect of faba bean and barley intercropping on faba bean fresh and dry weight.

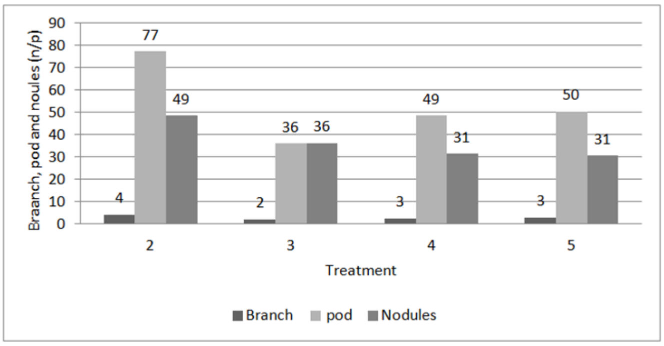

Figure 5 Effect of faba bean and barley intercropping on faba bean root nodules.

Discussion

Barley fresh and dry weight showed significant statistical difference in treatments 1, 3 and 5. Similar trend was observed in treatments 1, 3 and 5 for spike length of the barley plant. Here differences were attained due high efficiency with low external inputs,[6] and higher growth rate, reduction of weeds, pests and diseases;[2,5,7,8] better resource use efficiency of the mixed crop and buffering effects of intercrops against disease and weeds.[5,13] Fresh and dry weight and tiller number showed also significant correlation among them. The barley fresh and dry weight was high in treatments 3 and 5. Similar trend was observed in tiller number and plant height of the barley plant in treatments 3 and 5, which were attributed to the presence of complimentary effects of intercropped crops.[12–14]

In contrast to barley, fresh and dry weight showed significant mean difference in treatments 2, 3, 4 and 5 for fababean, and fresh weight in treatments 2, 3, 4 and 5. Faba bean branching was also statistically significant in treatments 2, 3 and 4. Several authors indicated that[4,12,25] cereal- legumes intercropping gave greater yield, stability and lower risks against monoculture. It is interesting to note here that fababean plant height did not correlate with any agronomic variables, which could be due to competition for light, water, nutrients and allelopathic effects that occurred between mixed crops may reduce yields in intercropping.[23]

Increasing fresh and dry weight for fababean was attributed to increasing the nitrogen content in non-legume plants, due to the intercrops with plants of leguminosae family.[7,13] Mixed cropping of legume with cereal gave synergy to fix atmospheric increase the pool or nitrogen available to both crop and increases soil nitrogen content for future crops.[5] Thus, the competitive ability of intercropping with spatial arrangement of treatment 4 (2B:1FB) was higher than barley with main of 5.37, which is followed by spatial arrangement.

Treatment 3 (1B:1FB) with main of 2.05 and the competitive ability for fababean was higher than in Treatment 5 1B:2FB) with mean of 1.65; which was followed by spatial arrangement Treatment 3(1B:1FB) with mean of 0.48 (Table 6). Actual yield loss measured from the dry mass for treatment 5 was low followed by treatment 3.The higher yield loss recorded in treatment 4 (Table 6). Economical advantage of intercropping calculated by monetary advantage index (MAI) showed that intercropping was economically advantageous than sole. Treatment 3 showed higher MAI which was followed by treatment 5 (Table 6). Relative Crowding coefficient indicated that yield advantage of inter cropping in treatment 3 was high as compared to the rest of the treatments (Table 5).

Table 6 Effect of faba bean and barley intercropping on Competitive ratio (CR), actual yield loss (AYL) and monetary advantage index (MAI)

Yield parameter	Component crops	1B:1FB	2B:1FB	1B:2FB
Competitive ratio	Barley	2.05	5.37	0.6
	Fababean	0.48	0.2	1.65
Actual yield loss	Barley	67.75	238.48	9.78
	Fababean	17.26	2.15	74.76
	Total	85.01	240.63	84.54
LER	Barley	1.23	1.04	1.16
	Fababean	0.6	0.64	0.64
	Total	1.83	1.62	1.8
Monetary advantage index(MAI)		38.25	23.54	32.3

Land equivalent ratio (LER)

The data for LER net income was affected by spatial arrangement of barley/faba bean (Table 5). Total LER ranged from 1.32 to 1.56 where all spatial arrangements were more productive than their respective sole crops. 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 2B:1FB. On the other hand, partial LER values indicated that 1B:1FB, 1B:2FB and 2B:1FB were more productive than its respective sole barley. In contrast, the intercrop productivity of fababean for all spatial arrangements was lower than that of its respective sole fababean. System productivity index standardizes faba bean yield of the secondary crop in terms of the primary crop (barley). Here, the result indicated that combinations of 2B:1FB was more productive than other planting patterns. All spatial arrangements had the land -equivalent ratio values of more than one (LER> 1). It indicated that intercropping had economic advantages in land use efficiency (Table 6).

Conclusion

Biomass, productivity, and profitability reacted differently to spatial arrangement of barley and fababean intercropping. The highest biomass yield was recorded for spatial arrangement of 1B:1FB and followed by spatial arrangement of 1B:2FB. Higher plant height was recorded for spatial arrangement of 1B:1FB and followed by 1B:2FB. Similarly, the highest biomass yield was obtained from sole fababean followed by spatial arrangement of 1B:2FB. In addition to this, high plant height was obtained from sole fababean followed by spatial arrangement of 1B: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 considering barley as main crop and fababean as bonus crop. Growing two crops has an advantage over sole crops in building soil health, efficient use of farmland, diseases, and pest control. Agronomist must consider the spacing of intercropping crops and the component of crop types and variety.

Recommendation

Based on our results we recommend to the smallholder farmers to practice legume and barley intercropping in order to achieve high crop productivity (biomass). Here, we firmly recommend the spatial arrangements of 1B:1FB and 1B:2FB of barley and faba bean intercropping.

Acknowledgments

None.

Conflicts of interest

The author declares there are no conflicts of interest.

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