System Productivity and Yield of Component Crops as Affected by Intercropping Maize and Common Bean Varieties with Distinct Morphological Characteristics

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በበቆሎና ጥራጥሬ ሲካሄድ የቆየው የዝርያ መረጣ ሁለቱ ሰብሎች ሲሰባጠሩ የሚኖራቸውን ጥምረት ከግምት ውስጥ ያላስገባ ነበር፡ የዚህ ጥናት ዓላማ የተለያዩ የቦሎቄና የበቆሎ ዝርያዎች ተሰባጥረው ሲዘሩ በምርትና ተጓዳኝ ባህርያት ላይ ያለውን ተፅዕኖ መለየት ነው። ጥናቱ BH543, BH661 ጊቤ 2 የተባሉ የበቆሎና አንገር፣ ናስርና ሀሮማያ የተባሉ የቦሎቄ ዝርዎችን በማሰባጠርና ያለ ማሰባጠር ሲዘሩ በምርት ላይ ያላቸውን ተፅዕኖ በባኮ ግብርና ምርምር ማዕከል በ2003 እና 2004 ዓም ተመልክቷል። በቆሎና ቦሎቄን ሳያሰባጥሩ መዝራት ከማሰባጠር ጋር ሲነፃፀር የበቆሎን በ7% እና የቦሎቄን በ70% ምርት ቀንሷል። ማሰባጠር የቦሎቄን ቁመት በ48% ጨምሯል። ሀሮማያ የቦሎቄና *BH661* የበቆሎ ዝርያዎች የተሻለ ስብጥር ቅንጅትና በሄክታር 23 328 ብር የተጣራ ትርፍ ያስበዘገቡ ሲሆን በባኮ አካባቢ በቆሎና ቦሎቄን አሰባጥሮ መዝራት አስፈላጊ ሆኖ ሲገኝ እነዚህ ዝርያዎች ተመራጭ መሆናቸውን ጥናቱ አረጋግጧል።

Abstract

Selection of maize and legumes variety selection in Ethiopia target only sole cropping system without considering the relative performance of varieties of varying morphologies under maize/legume intercropping. The objective of this study was to assess the effects of intercropping maize and common bean varieties with different morphologies on yield and system productivity of maize/common bean intercropping system. The treatments consisted of factorial combinations of three maize (BH543, BH661 and Gibe-2) and three common bean (Anger, Nassier and Haramaya) varieties and sole crops of the six varieties, which were laid out in randomized complete block design with three replications. The experiment was conducted at Bako, western Ethiopia, during the main cropping seasons of 2011 and 2012. Main effects due to variety and cropping system were significant for maize biomass and grain yield in both years. Relative to sole cropping system, intercropping significantly reduced maize and common bean grain yields by 7% and 70%, respectively. Intercropping increased plant height of common bean by 48% relative to sole crop conditions. Among the different intercropping combinations, growing common bean variety, Haramaya with maize hybrid BH661 gave the highest land equivalent ratio of 1.28, highest relative crowding coefficient of 6.75 and highest net benefit of Birr 23,328 ha^{-1}. As a strategy to maximize land productivity and resource use efficiency, intercropping that involves the two compatible varieties of the component crops is recommended for Bako and similar areas of western Ethiopia.

Introduction

Common bean (*Phaselus vulgaris* L.) is planted in intercrops, alleys and rotations with maize (*Zea mays* L.) in mid altitude sub-humid areas of western Ethiopia where maize/legume cropping systems show considerable promise in boosting productivity and helping reverse the decline in soil fertility (Dagne *et al.,* 2012). In these areas, both maize and common bean are the most important crops as main staple and important dietary protein sources (CSA, 2011). Maize and bean co-existence can be considered as strategic mitigation of mono cropping which is drastically reducing land and crop productivity. Maize mono cropping reduced yield by 30% at Bako, western Ethiopia whereas complete crop failure in continuous maize mono-cropping without N application was reported for Central Rift Valley of Ethiopia (Tesfa *et al.,* 2001).

In Ethiopia, improved maize and common bean varieties have been recommended for various agro-ecologies over the years. Farmers' variety preference assessment in southern Ethiopia demonstrated that selection of common bean varieties is primarily based on seed size, color and marketability (Abush and Leta, 2001). In Bako area, early maturing varieties are more preferred by farmers for sole production (Girma *et al.,* 2004). Certainly, compatibility study of varieties in maize/common bean intercropping systems is not well-addressed (Tesfa *et al.*, 2012). Hence, the works have limitations in identifying varieties of the two crops suitable for intercropping. Although maize/common bean intercropping research activities have been undertaken in Ethiopia in many places, concrete information is lacking on morphological characteristics positively influencing performance of component crops useful for use in intercropping. The focus of common bean breeding program has been on market acceptance for canning industries (Ferris and Kaganzi, 2008). In selection of suitable common bean genotypes for a maize/common bean intercrop, Atuahene *et al.* (2004) identified genotypes of different canopy width and canopy height preferred for better ground cover in intercropping systems.

Interaction effects of variety by cropping system are expected to be arising from morphological features such as leaf arrangement, canopy shape and growth habit. For sustainable intensification of maize and common bean in maize-based cropping system of western Ethiopia, growth and morphological characters governing compatibility of varieties of the component crops under intercrop conditions need to be understood. The information generated can further be used in future breeding programs aimed at developing varieties that can be used across a range of cropping systems. The objectives of the study were to assess the effects of intercropping maize and common bean varieties with different morphologies on yield of the component crops and to identify maize and common bean varieties that ensure higher land use efficiency and economic benefit in maize/common bean intercropping system.

Materials and Methods

Description of experimental site

The experiment was carried out at Bako Agricultural Research Center, which is situated in the western part of Ethiopia at an altitude of 1650 masl. The area has a warm-humid climate with annual mean minimum and means maximum temperatures of 13.6^0C and 29.1^0C, respectively. Long-term average annual rainfall of the area is 1264 mm. The rainfall received during 2011 and 2012 cropping seasons was 1425 and 886 mm, respectively. The area is characterized by reddish-brown clay-loam Nitosol, which is slightly acidic with pH of 5.6 and CEC of 17.8 cmol/kg.

Planting materials

Three morphologically distinct maize varieties, droopy, semi-erect and erect represented by BH543, Gibe-2 and BH661, respectively were used. Regarding common bean, three varieties, Anger, Nassier and Haramaya representing three distinct growth habits, determinate bush, indeterminate bush and indeterminate prostrate, respectively were used for the study.

Experimental design and procedure

Fifteen treatments consisted of factorial combinations of three maize and three common bean varieties as well as their respective sole crops were laid out in Randomized Complete Block Design with three replications. The experiment was carried out for two consecutive years, 2011 and 2012 main cropping seasons (June to November). Maize was planted at a spacing of 75 cm x 30 cm and received 110 kg ha^{-1} N and 46 kg ha^{-1} P_2O_5. Common bean was intercropped 20 days after maize planting between maize rows using a spacing of 75 cm x 10 cm, which is 53% of plant population of the recommendation for sole production. Sole bean was planted at 40 x 10cm spacing using 18 kg N and 46 kg per ha. Gross plot area for sole and intercropped maize was 15.75 m^2 whereas sole bean was planted on plot area of 15.12 m^2. Net plot areas of 8.1 m^2, 9 m^2 and 8 m^2 for maize, intercrop bean, and sole bean, respectively were used for data measurements and harvest.

Data collection and management

Five randomly selected plants were used for leaf area, plant height, and pods per plant measurements. Leaf area for maize was recorded by measuring the length and the width at the widest portion and multiplying by 0.733 (Burren *et al.*, 1974). Bean leaf area was measured using leaf meter, CI-202. Leaf area index was then obtained using the formula:

$$LAI = \frac{\text{Leaf area per plant}}{\text{Area occupied by the plant}}$$

Days to maturity and plant height were recorded when 95% of the plants in the harvestable plots showed physiological maturity. Grain yield and thousand seed weight were corrected to 12.5% and 10% moisture content standards for maize and common bean, respectively. Above ground biomass was sun-dried until constant weight was maintained.

Overall advantage of the intercropping, land equivalent ratio (LER), of the crops was assessed using the formula proposed by Devasenapathy *et al.* (2008) as follows:

$$LER = \frac{Ymb}{Ymm} + \frac{Ybm}{Ybb}$$

Ymb: yield of maize intercropped with bean
Ybm: yield of bean intercropped with maize
Ymm: yield of maize in pure stand
Ybb: yield of bean in pure stand

Relative crowding coefficient (RCC) in maize/common bean intercropping system was assessed using the formula suggested by Reddy (1999): $RCC = \frac{LM}{1-LM} x \frac{LB}{1-LB}$

where LM: LER of maize and LB: LER of bean.

Economic evaluation

Economic evaluation was done using partial budget, marginal rate of return (MRR) and dominance analysis following from agronomic data to farmer recommendation (CIMMYT, 1988). Results of both years were considered for economic evaluation whereby two years average cost of production and average farm gate prices were considered. Treatments with similar cost of production were not included in economic evaluation. Costs of seed, planting, weeding, and harvesting were among variable costs considered in partial budget whereby yield was down adjusted by 10%. Sensitivity analysis was made subjected to cost and price changes considering minimum acceptable MRR as 100%.

Data analysis

Data were analyzed using SAS version 9.0 (SAS, 2002) computer software and were subjected to ANOVA to determine significant differences among factors and their interactions. Means were separated using LSD test. For all analyzed parameters, $P < 0.05$ was interpreted as statistically significant.

Results and Discussion

Maize component

Main effects due to variety were significant for LAI and days to maturity (Table 1). The lowest (3.19) maize LAI was recorded in the intercrop which involved common bean variety Haramaya whereas the highest (3.66) was found for maize intercropped with common bean variety, Anger (Fig. 1). Haramaya has indeterminate growth habit that show a tendency to climb on maize whereas the growth of the main stem or branches of Anger ceases after flowering. Thus, the competitive effect of Haramaya on maize might have resulted in production of smaller leaves. On the other hand, the less competing common bean variety, Anger resulted in production of larger leaves.

Days to maturity of Gibe-2 significantly increased during the cropping season of 2012 while decreased for BH543 and BH661. Medium (BH543) and late (BH661) maturing hybrids reached physiological maturity three to four days earlier in 2011, whereas Gibe-2 was earlier in 2012 (Figure 2). Days to maturity of maize intercropped with Haramaya was prolonged by 4 days, assumed due to its large biomass protecting the soil from direct sun heat and conserved soil moisture particularly during the early cessation of rainfall. The justification seems reasonable because intercropping with common bean variety of determinate growth habit as well as sole maize took less number of days to maturity. In an intercropping with bush common bean varieties, days to maturity of maize was unaffected (Santalla *et al.*, 2001) confirming that days to maturity of maize can differentially be affected when intercropped with bean varieties of different growth habit.

Main effects due to variety and cropping system were significant for maize biomass and grain yield (Table 1). The highest maize biomass (19877 kg ha^{-1}) and grain yield (7810 kg ha^{-1}) were obtained when maize was intercropped with common bean variety Anger (Table 2). Compared to the second season (2012), biomass and grain yield showed increment for Gibe-2 whereas a declining trend for the other two maize varieties, BH 543 and BH 661 (Table 2). Intercropping reduced biomass weight and grain yield of maize by 7% while thousand seed weight was not affected by the cropping system. On the other hand, main effect due to variety was significant for thousand seed weight. The highest (325 g) and the lowest (300 g) TSW were obtained when maize varieties were intercropped with bean varieties, Nassier and Haramaya, respectively (Table 2). Intercropping effects on yield of maize are experiment and site specific affected by the varieties and cultural practices used. For example, Cardoso *et al.* (2007) reported a 17% reduction in maize yield due to maize/common bean intercropping whereas Walelign (2008) found no effect of intercropping on maize grain yield; the latter used only one maize variety, which might have competitive and shading effect on common bean varieties. The competitive effect of Anger and Haramaya on maize depends on their growth habit. As a result, maize intercropped with less competing variety, Anger showed better endurance and produced highest biomass and grain yield.

Common bean component

In both years, main effect due to variety was significant for common bean LAI and plant height; while the latter was influenced also by cropping system (Table 3). Common bean intercropped with Gibe-2 produced the highest LAI of 3.70 whereas intercropping with BH543 resulted in the lowest LAI of 2.61. Under intercropping, Haramaya had the highest (4.20) LAI (Fig. 3) and the tallest plants in both cropping seasons (Table 5). Days to maturity of common bean was affected by the main effects of variety and cropping system. Intercropping the common bean varieties with BH661 and Gibe-2 led to delayed physiological maturity of common beans compared to the associated culture with BH 543. Haramaya intercropped with maize took significantly longer days to maturity and maize/common bean intercropping significantly prolonged maturity by 14 days (Table 5). Maize variety, Gibe-2 has relatively erect leaf morphology and low biomass weight hence its influence on growth and performance of common bean is expected to be less compared with BH543, a maize variety characterized by droopy leaf canopy, which might have high competitive effect on common bean growth and performance. Similarly, common bean varieties grown in association with BH543, droopy maize might have been dominated and forced to complete their life cycle earlier (mechanism of escaping resource insufficiency) they do under intercropping with maize varieties of erect morphology. The variety x cropping system interaction effect was significant for the number of pods per plant and biomass weight. Haramaya intercropped with Gibe-2 produced the highest (20) number of pods per plant whereas all common bean varieties intercropped with BH 543 produced the lowest (10 to 12) number of pods per plant (Table 4). Similar result by Setegn *et al.* (2006) indicated pods per plant was reduced by 65% and 55% when climbing bean was intercropped with maize varieties, BH540 (similar morphology with BH543) and Guto, respectively. Haramaya intercropped with Gibe-2 produced significantly highest biomass of 2871 kg ha^{-1} whereas the lowest biomass of 1030 kg ha^{-1} was obtained from the intercropping of BH 543 and Anger (Table 4). Morphologically, Haramaya is an indeterminate prostrate common bean whereas Gibe-2 is semi-erect maize variety, which is less competitive with common beans like Haramaya. Indeed, Haramaya demonstrated highest productivity potential when intercropped with less competing maize variety like Gibe-2.

Table 1. Mean squares of selected parameters of maize intercropped with common bean varieties of distinct morphologies at Bako, western Ethiopia, during 2011 and 2012 main cropping seasons.

Source of variation	DF	Leaf area index	Days to Maturity	Grain yield kg ha^{-1}	Biomass kg ha^{-1}	TSW G
Year	1	0.1040 ns	26.7407**	64066.67 ns	132016.7 ns	1048.96 ns
Replication	2	2.5840	4.3889	2440420.91	30339710.9	3816.52
Sole maize (SM)	2	1.3211**	1269.39**	17726271.63**	60357921.7**	3853.91**
Maize with bean (MB)	2	1.0204**	85.72**	2297072.57**	16118493.4**	2760.24*
SM x MB	4	0.2001 ns	12.28**	1371379.71**	5207583.5*	1214.74 ns
SM x Year	2	0.24035ns	72.35**	146405.56 ns	4407599.4 ns	8.57 ns
Error	34	0.1328	1.8444	164359.81	1403554.8	575.45
Maize vs. cropping system (CS)						
Maize	2	1.1166*	1259.01**	17108618.78**	76690135.7**	995.42 ns
CS	1	0.2577 ns	210.04**	4685495.23**	27595426.0**	327.57 ns
Maize x CS	2	0.4542 ns	0.68 ns	864728.78 ns	15536445.9**	1871.87 ns
Error	22	0.2665	8.7231	379282.14	2957495.7	709.78

,=significant and highly significant at 5% level of probability, respectively; ns=non-significant.*

Common bean seed yield was affected both by variety and cropping system (Table 3). Seed yields of common bean intercropped with Gibe-2 (816 kg ha^{-1}) and with BH 661 (785 kg ha^{-1}) were significantly higher than the associated cropping with BH 543 (582 kg ha^{-1}).

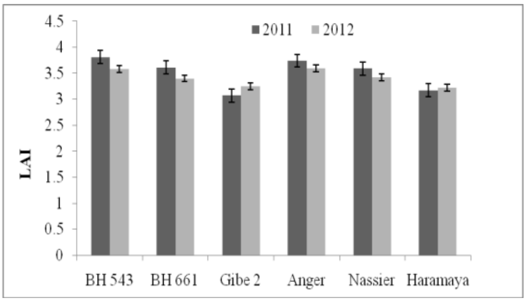

Figure 1. Leaf area index of maize as affected by associated common bean varieties grown in an intercropping system at Bako, western Ethiopia during 2011 and 2012 cropping seasons.
Vertical bars represent ± S.E of three replications

Common bean varieties with indeterminate growth habits (Haramaya and Nassier) produced significantly higher yields than the one with determinate growth habit, Anger (Table 5). The usefulness of common bean varieties for intercropping with maize depends on the growth habit of the common bean variety. Seed yield in pure stand was 70% higher than common bean yield obtained from the intercropping with maize. Similar study by Walelign (2008) indicated maize/common bean intercropping reduced seed yield by 80%. In this study, seed yield appeared to be less affected by the differences in growth habit of the common bean varieties and was rather influenced by the type of maize with which they were associated. Similar to other growth and yield parameters, seed yield of common bean was affected by maize/common bean intercropping. The yield reduction of common bean is more manifested by intercropping with maize variety, BH 543. The droopy nature of the variety might have more competitive effect compared with varieties of erect leaf morphology.

Table 2. Biomass, grain yield and thousand seed weight of three maize varieties intercropped with common bean varieties of distinct morphologies at Bako, western Ethiopia during 2011 and 2012 main cropping seasons.

Factor	Biomass (kgha^{-1})			Grain yield (kg ha^{-1})			1000 seed weight (g)		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
Sole maize									
BH 543	19767	19099	19433	7839	7703	7771	327	334	331
BH 661	20540	19866	20203	8343	8137	8240	300	309	304
Gibe 2	16195	17239	16717	6267	6403	6335	301	311	306
LSD (5%)	1147.4	1660	1137.4	455	556.9	359.94	NS	NS	18.64
Maize with bean									
Anger	20150	19603	19877	7881	7738	7810	311	320	316
Nassier	18402	18126	18264	7456	7426	7441	321	328	325
Haramaya	17949	18475	18212	7113	7078	7096	295	306	300
CV (%)	6.10	8.95	6.31	6.08	7.58	5.44	8.57	9.17	7.65
LSD (5%)	1147.4	NS	1137	454.8	556.9	359.94	NS	NS	18.64
Cropping system									
Sole	20205	20210	20214	8047	8043	8038	319	319	319
Intercropping	18834	18809	18784	7483	7466	7449	309	312	311
CV (%)	3.63	9.22	12.64	3.87	6.47	13.59	4.84	5.77	9.01
LSD (5%)	744.69	1105	1314.7	315.3	506	561.04	NS	NS	NS

System productivity and economic benefit

Significantly highest LER of 1.28 and highest RCC of 6.75 were obtained from the intercropping of BH 661 with common bean variety Haramaya (Table 6). Compared with other maize varieties, BH 661 associated with all common bean varieties produced the highest RCC, which ranged from 2.89 to 6.75 (Table 6). Among maize/common bean intercrop combinations, Gibe-2 intercropped with Haramaya produced LER and RCC less than 1.0, implies intercropping with Gibe-2 is disadvantageous. Niringye *et al.* (2004) found partial LERs as high as 1.11 and 0.43 for maize and bean, respectively. The finding was in line with this result identifying that no two partial LERs with highest value produced the highest combined LER. In an additive series experiment (100% maize population+50% common bean population), which had almost similar proportions of plant population with this experiment, maize yield was unaffected and produced maize partial LER of 1.00 and 0.36 for common bean (Yilmaz *et al.*, 2008). Besides relative suitability of BH661 and Haramaya for maize/common bean intercropping, 28% of a hectare of land was saved to grow both crops in pure stand to produce the grain yields obtained by their association.

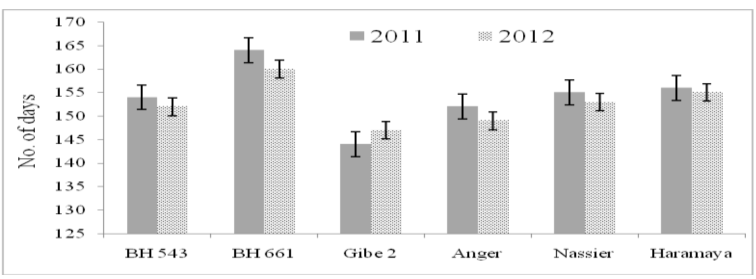

Figure 2. Days to maturity of maize as affected by associated common bean varieties grown in an intercropping system at Bako, western Ethiopia during 2011 and 2012 cropping seasons.
Vertical bars represent ± S.E of three replications.

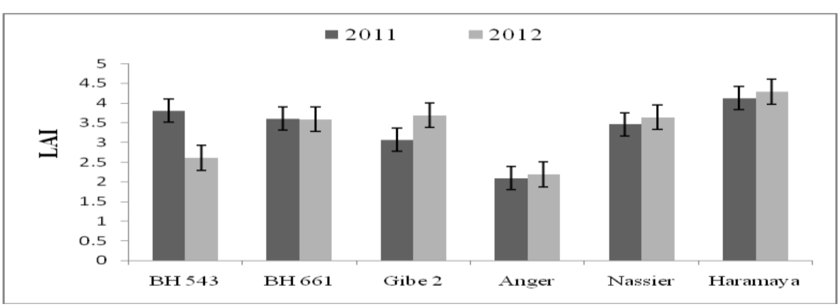

Figure 3. Leaf area index of common bean varieties as affected by associated maize varieties of distinct morphologies grown in an intercropping system at Bako, western Ethiopia during 2011 and 2012 cropping seasons. Vertical bars represent ± S.E of three replications.

Table 3. Mean squares of selected parameters of common bean intercropped with maize varieties of distinct morphologies at Bako, western Ethiopia, during 2011 and 2012 main cropping seasons.

Source of variation	DF	LAI	Days to maturity	Pods per plant	Plant Height (cm)	Biomass Weight (kg ha^{-1})	Seed yield (kg ha^{-1})
Year	1	0.2889ns	115.57**	851.45**	318.76**	12702247**	4298.72ns
Replication	2	0.2112	23.35	4.62	1018.80	322467	55623.96
Bean	2	20.0748**	1690.5**	14.411**	169376**	1490263**	260443**
Bean with maize	2	6.4586**	34.79**	80.52**	1922.79**	810192**	290745**
Bean x Maize	4	0.3846ns	4.1018ns	3.58ns	229.91*	406204*	13374.29ns
Bean x Year	2	0.0074ns	2.3518ns	12.46**	2.9274ns	533070**	839.2ns
Error	34	0.3453	3.0379	2.1258	66.7985	61060.42	5490.421
Bean vs. cropping system (CS)							
Bean	2	4.99**	343.19**	0.65	22398**	614514	62323
CS	1	0.03	73.31**	0.13	65414**	338992704 **	11619806**
Bean x CS	2	0.19	20.76**	18.92*	7146**	269471	32304
Error	22	0.21	1.64	3.33	129.96	666349	184746

*, **= significant and highly significant at 5% level of probability, respectively; ns=non-significant.

Average of two years net benefit of BIRR 1179 ha^{-1} was obtained by intercropping common bean variety, Haramaya with hybrid maize variety, BH 661 compared with sole grown maize variety BH 661. Dominance analysis showed that acceptable and higher MRR of 209% was recorded for changing from producing BH661 with Anger to intercropping BH661 with Haramaya (Table 7). For additional 1.00 Birr invested on production of BH661 associated with Haramaya, the return was Birr 2.09. As indicated in (Table 7), MRR as high as 956% was recorded for changing from producing sole Gibe-2 to sole BH543. However, considering the lowest acceptable MRR as 100%, and efficient resource (land) utilization, treatment contained maize/common bean intercropping with acceptable MRR is selected. This finding is supported by (CIMMYT, 1988), indicating that the recommendation is not necessarily based on the highest MRR nor the highest net benefit, nor treatment with the highest yield; because farmers will continue to invest as long as the return to each extra unit invested (MRR) are higher than the cost of the extra unit (minimum acceptable rate of return) invested. Sensitivity analysis indicated that intercropping of BH 661 with Haramaya remain profitable even if the output price falls by 20% and cost raises by 10%. Based on this finding, growing these varieties (BH 661 and Haramaya) in maize/common bean intercropping system is economically profitable and agronomically acceptable.

Table 4. Number of pods per plant and biomass (kg ha^{-1}) of Common bean varieties as affected by the interaction of maize and common bean varieties of distinct morphologies at Bako, western Ethiopia, during 2011 and 2012 main cropping seasons.

	Number of pods per plant			Biomass kg ha^{-1}		
Maize x bean	Anger	Nassier	Haramaya	Anger	Nassier	Haramaya
BH 543	10.18	10.44	12.31	1030	1541	1694
BH 661	15.68	14.54	17.03	1353	1596	2129
Gibe 2	13.60	15.08	20.06	1477	1763	2871
CV (%)	11.20			19.65		
LSD (5%)	2.52			427.73		

Table 5. Days to maturity, plant height and yield of three common bean varieties intercropped with maize varieties of distinct morphologies at Bako, western Ethiopia, during 2011 and 2012 main cropping season.

Factor	Days to maturity			Plant height (cm)			Seed yield kg ha^{-1}		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
Bean with maize									
BH543	97	101	99	110	116	113	575	589	582
BH661	101	102	102	131	136	133	775	794	785
Gibe-2	99	102	101	123	127	125	806	826	816
LSD (5%)	1.43	NS	1.35	9.01	11.28	7.12	82.16	95.71	59.71
Bean variety									
Anger	92	94	93	56	60	58	595	601	598
Nassier	95	98	97	76	80	78	742	756	749
Haramaya	109	113	111	232	238	235	819	852	835
CV (%)	1.44	2.105	1.78	7.43	9.03	6.61	11.44	13.13	10.19
LSD (5%)	1.43	2.12	1.35	9.01	11.28	7.12	82.16	95.71	59.71
Cropping system									
Sole	85	87	86	83	85	84	2376	2459	2418
Intercropping	99	102	100	121	126	124	718	736	727
CV (%)	1.33	2.13	4.19	11.36	15.09	11,76	28.81	21.37	19.55
LSD (5%)	1.36	7.44	8.72	12.16	14.78	9.86	468.2	541.1	589.3

able 6. Land equivalent ratio (LER) and relative crowding coefficient (RCC) of intercropping maize and common bean varieties with distinct morphologies at Bako, western Ethiopia, during 2011 and 2012 main cropping seasons.

No	Variety		Land equivalent ratio			Relative crowding coefficient
	Maize	Bean	2011	2012	Mean	
1	BH543	Anger	1.08	1.11	1.10	2.39
2	BH543	Nassier	1.10	1.10	1.10	1.94
3	BH543	Haramaya	1.06	1.08	1.07	1.60
4	BH661	Anger	1.19	1.19	1.19	4.67
5	BH661	Nassier	1.18	1.19	1.19	2.89
6	BH661	Haramaya	1.27	1.29	1.28	6.75
7	Gibe-2	Anger	1.00	1.02	1.01	1.05
8	Gibe-2	Nassier	1.04	1.07	1.06	1.41
9	Gibe-2	Haramaya	0.96	0.99	0.98	0.96
CV (%)			5.02	7.72	6.89	4.67
LSD (5%)			0.06	1.09	1.03	1.24

Table 7. Economic evaluation of intercropping maize and common bean varieties with distinct morphologies at Bako, western Ethiopia, during 2011 and 2012 main cropping seasons.

Treatments	Total cost that vary (Birr ha^{-1})	Gross benefit (Birr ha^{-1})	Net benefit (Birr ha^{-1})	Dominance analysis	Marginal rate of return
Gibe-2 sole	1553	18674	17121		
BH543 sole	1941	22772	20831		9.56
BH661 sole	2142	24291	22149		6.54
Gibe-2 + Anger	2646	20735	18089	Dominated	
Gibe-2 + Nassier	2715	21627	18912	Dominated	
Gibe-2 + Haramaya	2769	18460	15691	Dominated	
BH543 + Anger	3044	24231	21187	Dominated	
BH543 + Nassier	3056	23984	20928	Dominated	
BH661 + Anger	3124	25997	22873		0.74
BH661 + Nassier	3126	25448	22322	Dominated	
BH543 + Haramaya	3198	24677	21479	Dominated	
BH661 + Haramaya	3342	26670	23328		2.09

Conclusions

Considering the compatibility and relative performance of varieties of the component crops as manifested in the combined yield, LER and monetary advantages, intercropping BH661 (a maize variety with erect morphology) with Haramaya (an indeterminate common bean variety) is recommended to maximize land use efficiency and ensure economic benefit in the Bako area of western Ethiopia. Maize and common bean breeding programs in the area need to revisit their strategies to consider morphology of the two crops as selection criteria in developing varieties that can be used across range of cropping systems.

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