Agronomic Performance and Compatibility of Common Bean Genotypes Intercropped with Maize

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Abstract

Common bean (Phaseolus vulgaris L.) is one of the most important nutritious food and cash crops grown in Ethiopia. This study evaluated the compatibility of common bean genotypes to intercropping with maize and assessed land use efficiency of mixed cropping for sustainable intensification of maize-legume based farming systems. Twenty-five common bean genotypes were evaluated under sole and intercropping with a maize hybrid, BH540, in 2011 and 2012 at Bako. Significant variations were observed among the common bean genotypes for most studied traits under sole and intercropping conditions. On average, about 88% yield reduction was recorded for the common bean genotypes intercropped with maize as compared to sole cropping. Genotypes MEXICO235 X PAN-182 and UBR(92)25-13-1 had higher seed yield under both cropping systems and also showed relatively lower yield reduction due to intercropping, indicating the compatibility of these genotypes for mixed cropping. Seed yield had positive and significant correlation only with seeds per pod and harvest index under sole cropping, but it had strong positive association with days to maturity, plant height, pods per plant, harvest index and number of primary braches under intercropping. Maize-common bean intercropping slightly increased land use efficiency and land productivity. Genotypes ICTAJU-95-28, UBR (92)25-13-1 and MEXICO235XPAN-182 exhibited relatively higher total land equivalent ratio (LER) and relative crowding coefficient (RCC) under intercropping. In general, common bean genotypes used in this study were highly affected by the competition imposed by maize, indicating the need for further research to develop more compatible varieties of component crops and adjust the time of common bean intercropping with maize.

Key words: Common bean, intercropping, Land Equivalent Ratio (LER), relative crowding coefficient (RCC)

Introduction

Common bean *(Phaseolus vulgaris* L.) is the most important food, export and cash crop in major producing regions of Ethiopia. It is also the source of protein for the majority of peoples in the country (Dereje *et al.,* 1995). The two major common beans producing regions of the country are Oromia (169,600 tons) and Southern Nations, Nationalities and People's Region (SNNPR) (106,700 tons) that makes up to 81% of the total production of common bean in the country (CSA, 2011). Area and production of low land pulses in Ethiopia concentrates around the Rift Valley and lake areas (EARO, 2000).

Increasing production and productivity so as to satisfy the ever increasing human need for food could only be attained through intensifying crop land and increasing agricultural productivity per unit area. One of the most attractive intensive land use systems that increases productivity and labor efficiency per unit area of available land is the use of intercropping (Ullah *et al.*, 2007). Cereal-legume intercropping is an advanced agro-technique of cultivating two or more crops on the same area at the same time and it has shown higher combined yield than sole cropping because of the better use of growth resources (Maluleke *et al.,* 2005). According to Seran and Brintha, 2010, intercropping also minimizes risks, reduce weed competition and stabilize grain yield.

Some of the major factors that influences maize-bean intercropping are the use of compatible crop and/or variety (Setegn *et al.*, 2006), time of crop maturity, planting density, drought, time of planting, pest and disease incidences (Chemeda, 2003). The vast majority of common bean varieties currently grown in intercropping have been developed for sole cropping. But hardly any varieties have been released for intercropping in the country. Therefore, the lack of bean cultivars adapted to intercropping situations with a concurrent progress in the availability of improved maize production packages presently have paved the way for maize mono-cropping to flourish (Setegn *et al.*, 2006).

Screening and selecting the most promising genotypes for crops like beans which are able to grow in more than one cropping system depends on the magnitude of variety-by-cropping system interaction which can be determined by the relative performance of different genotypes under two or more cropping systems. Such information is lacking in all bean growing regions of Ethiopia in general and western region of the country in particular (Setegn, 1997). On the other hand, development and use of crop species or varieties suitable for mixed cropping can avert the risk of crop failure and rejoin the ever increasing demand for compatible common bean varieties for maize-legume intercropping so that farmers' could have a multiple choice of varieties that best fit to their farming systems and needs. The present study was, therefore, designed to identify compatible common bean genotypes for intercropping with maize and assess land use efficiency of the intercropping for sustainable intensification of maize-legume based farming systems.

Materials and Methods

Experimental site

Field experiments were conducted at Bako Agricultural Research Center (BARC) (1650 m.a.s.l, 9°06 N; 37°09' E which is located at 257 km west of Addis Ababa,) for two consecutive cropping seasons (2011and 2012). Long-term average annual rainfall of the center is about 1260 mm, while the rainfall received during the experimental years, 2011 and 2012, was 1428 and 885 mm per annum, respectively. The minimum, maximum and average air temperature was 13.5, 27.3 and 20.4 C° in 2011 and 13.6, 28.8 and 21.2 C° in 2012, respectively. The soil type is Alfisols, texturally classified as clay soil, and acidic in reaction (Wakene *et al.*, 2001).

Germplasm, experimental design and field measurement

Twenty four common bean genotypes were evaluated along with one local check under sole and intercropping with a maize hybrid (BH540) in adjacent blocks. Among the common bean genotypes, 23 of them were selected from the set of regional variety trials obtained from Melkasa Agricultural Research Center and evaluated at Bako Agricultural Research Center (BARC) during the 2009/10 cropping season. The selection was made based on *per se* performance and desirable performances for seed yield and agronomic traits under sole cropping condition. A variety released by BARC, Loko, was used as standard check while a farmers' variety, Burre, was used as local check. The hybrid maize, BH540, is one of the most popular maize hybrid varietiy which is widely grown around Bako and similar agro-ecologies with medium plant height and medium maturity group (145 days).

The trials were laid out in 5 x 5 triple lattice design, with three replications. In the intercropping trial, the standard check variety was replaced by sole maize treatment and considered as missing genotype during data analysis; hence only 24 common bean genotypes were used. The plot size for sole bean cropping was four rows of 5.1m each; with spacing of 0.40m between rows and 0.1m between plant stands. On the other hand, each plot of the intercropping sets consisted of four rows of 5.1m long and the beans were sown between a 0.75m spaced maize rows, with spacing of 0.1m between plants. To attain the desired maize population of 44,444 plants ha^{-1}, the space between maize plants within a row was adjusted to 0.3m distance. Common bean genotypes were planted after twenty one days of maize planting. Common bean population in the intercropped plots were adjusted to 50% of the recommended population. Fertilizer rates used were 18 kg ha^{-1} N and 46 kg ha^{-1} P_2O_5 for sole common bean; and 100 kg ha^{-1} N and 100 kg ha^{-1} P_2O_5 for maize-bean intercropping, which is the recommended amount for maize. For the intercropped trial, Urea was applied in two splits, one-half at planting of maize and the remaining half at about 35 days after maize planting. Other agronomic practices were applied uniformly as per research recommendations of the specific area. Ten individual plants of both crops were selected randomly per plot from the two central rows of sole and intercropping, marked before flowering and/or tasseling, and used as samples to measure quantitative traits.

Measurements for the common bean genotypes were taken for seed yield and various agronomic traits. Days to flowering and maturity were recorded as the number of days from emergence to the stage when 50% of the plants in each plot had flowers, and when 75% of the plants in a plot reached physiological maturity, respectively. Plant height was measured as above ground length of the plant from the base to the top. Number of pods per plant was counted as an average number of pods per plant for five randomly selected plants while number of seeds per pod was taken as an average number of seed from ten randomly selected pods of five plants. Pod length was measured as the average length of ten randomly taken pods from five plants. Number of primary branches per plant was counted as average number of primary branches from ten randomly selected plants. Hundred seed weight was recorded as the weight of hundred seeds randomly taken from the bulk of shelled seeds after adjusted to 10% moisture content. Biological yield was recorded as the total above ground biomass weight after sun-dried until constant weight was maintained, and used to calculate harvest index. Seed yield was measured as the total weight of the seed from all plants of the two central rows of each plot after adjusted to 10% moisture content. Harvest index was recorded as the ratio of seed yield to biological yield. For the maize hybrid, grain yield was measured from all the ears of each experimental plot, adjusted to 12.5% moisture content and expressed in ton ha^{-1}.

Data analysis

Combined analyses of variance over years were conducted separately for sole and intercropped trials using SAS (SAS, 2004) computer software. Genotypic means adjusted for incomplete block effects generated from individual cropping systems analyses according to the lattice design were used to perform combined analyses across cropping systems. Relative reductions in seed yield and all other agronomic traits under intercropping condition was calculated as $1-MV_{intercropping}/MV_{sole\ cropping}$; where $MV_{intercropping}$ and $MV_{sole\ cropping}$ are mean trait values obtained in paired experiments under sole and intercropping conditions. Pearson correlation coefficients were calculated between pairs of traits of common bean genotypes using over years means to determine their relationships. This analysis was done separately for the sole and intercropping experiments.

Land equivalent ratio (LER) and the relative crowding coefficient (RCC) were calculated for grain yield data of both crops to compare the relative efficiency of bean-maize intercropping. LER is used to assess the performance of an intercrop relative to the corresponding sole crop and calculated following the formula suggested by Mead and Willey (1980):

$$\text{Bean Partial LER} = \frac{Ybi}{Ybs}$$

$$\text{Maize Partial LER} = \frac{Ymi}{Yms}$$

$$\text{Total LER} = \frac{Ybi}{Ybs} + \frac{Ymi}{Yms}$$

Where Y_{bi} and Y_{bs} are the seed yield of common bean grown under intercropping and sole cropping, respectively. Whereas, Y_{ms} and Y_{mi} are the grain yield of maize grown under sole and intercropping, respectively.

RCCs were computed to estimate the productivity of respective crops whether they gave higher or lower yield than the expected following the formula suggested by de Wit (1960) as:

$$CCab = \frac{(Yab \times Zab)}{(Yaa - Yab)Zab},$$

$$CCba = \frac{(Yba \times Zba)}{(Ybb - Yba)Zba}$$

Where, 'a' refers to maize crop and 'b' to bean crop; 'CCab' and 'CCba' are crowding coefficient of species 'a' and 'b'; 'Yaa' and 'Ybb' are pure stands of yield of species 'a' and 'b'; 'Yab' and 'Yba' are mixture yield of species 'a' (in combination with 'b') and vice- versa; and 'Zab' and 'Zba' are sown proportion of species 'a' (in mixture with species 'b') and vice versa.

Results and Discussion

Analysis of variance and mean performances of common bean genotypes

Sole cropped common bean

Year effect on the performances of genotypes was highly significant for all studied traits (Table 1). This indicated the existence of significant variability between the two evaluation years in determining the performance of common bean genotypes. Mean squares due to genotypes were significant for all traits except for harvest index, indicating the existence of variations among the genotypes studied, which makes selection of preferable genotypes possible. Similar to the current findings, significant genotypic variations among common bean genotypes were previously reported by Santala *et al*. (2001) and Setegn *et al*. (2006). Genotype x year interaction effects were significant for most traits; but not for days to flowering, seeds per pod, hundred seed weight and number of branches per plant.

Table 1. Combined analysis of variance and means for seed yield and agronomic traits of common bean genotypes evaluated under sole cropping at Bako in 2011 and 2012.

Sources of variation	df	SY t ha^{-1}	DF days	DM days	PH cm	NPB No.	PPP No.	SPP No.	PL cm	HSW gm	HI ratio
Year (Y)	1	135.4**	674.2**	537.7**	47053**	290.9**	15702**	8.7**	57.0**	937.5**	118.8**
Replication (R)/Y	4	11.7	58.02	53.40	93.53	6.72	6.62	1.01	0.37	31.14	0.01
Block (R x Y)	24	17.5**	27.69**	157.74**	931.5**	2.99	48.62**	1.22**	1.22**	111.9**	0.04**
Genotype (G)	24	19.1**	13.34**	166.11**	959.99**	5.88**	41.77**	1.76**	2.99**	174.8**	0.02
G x Y	24	13.3**	8.86	72.84**	529.61**	3.42	41.08**	0.64	1.37**	50.5	1.43**
Error	72	3.5	5.54	13.36	130.68	1.93	9.48	0.54	0.34	24.47	0.13
Mean		2.75	36.9	84.8	60.6	7.7	14.9	5.6	8.3	20.8	0.56
CV(%)		21.6	6.39	4.32	18.9	18.2	20.71	13.24	7.08	23.05	20.6
R^2		0.79	0.78	0.88	0.89	0.77	0.84	0.64	0.85	0.79	0.73
$LSD_{5\%}$		0.68	2.70	4.19	13.11	1.59	3.53	0.84	0.67	5.67	0.13

** = Significant at $P \leq 0.01$, * = Significant at $P \leq 0.05$

df = degrees of freedom, DF = Days to flowering, DM=days to maturity, HSW= hundred seed weight, HI= Harvest index, NPB = number of primary branches per plant, PH = plant height, PL= pod length, PPP = pods per plant, SPP = seeds per pod, SY = seed yield.

Seed yield for all genotypes ranged from 1.54 to 3.84 t ha^{-1}, with a mean of 2.75 t ha^{-1} (Table 3). Genotypes UBR(92)25-13-1 (3.84 t ha^{-1}), AN-92-12123 (3.52 t ha^{-1}), FEB-147 X EAP-4 (3.51 t ha^{-1}), SK-93846 (3.43 t ha^{-1}), and MEXICO235 X PAN-182 (3.32 t ha^{-1}) showed higher seed yield. Days to flowering ranged from 33 to 40 days with a mean of 37 days whereas mean days to maturity was 85 days with a range of 74 to 96 days. Most of the higher yielding genotypes tend to mature later (Table 3). It is a general belief among breeders that later maturing genotypes do yield higher than the earlier maturing ones, as late materials have the opportunity to draw nutrients and photosynthesize over a longer period. Plant height ranged from 36.0 to 91.3 cm with a mean of 60.6 cm. The highest yielding genotype, UBR(92)25-13-1, had the tallest plant height. Number of primary branches ranged from 6.0 to 10.0, with a mean of 7.7, whereas pods per plant ranged from

11.2 to 21.1 with a mean of 14.9. Seeds per pod ranged from 3.7 to 8.1 with a mean of 5.6, whereas pod length ranged from 7.2 to 9.6 cm with a mean of 8.3 cm. Genotypes with higher seed yield had larger number of seeds per pod and longer pods, but not necessarily larger number of pods per plant as compared to medium and low yielding genotypes. Hundred seed weight ranged from 13.9 to 33.8 gm with a mean of 20.8 gm.

Common bean intercropped with maize

Results of analysis of variance and mean performances of common bean genotypes intercropped with one of the most popular maize hybrids, BH540, are presented in Tables 2 and 3. Significant year effects were observed for all studied traits except for plant height (Table 2). Genotypic effects were also significant for most traits except for days to flowering, indicating the existence of genetic variability among common bean genotypes for intercropping compatibility. According to Setegn *et al.* (2006), the availability of bean cultivars that best fit into the dynamic cropping system not only contributes to the aversion of growing challenge posed by maize mono-cropping on the ecology as well as the socio-economic circumstances of subsistent farmers but also could help in conserving crop diversity through traditional multiple cropping systems. Genotype x year interaction effects were also significant for most traits except for days to flowering, indicating that performances of the genotypes evaluated were not consistent across the two years. Significant variation was not observed in grain yield of the maize hybrid due to the use of single maize variety for both sole cropping and intercropping with various common bean genotypes, indicating that maize-bean intercropping had no effect on maize yield. This might be attributed to the competitive and shading effect of the maize hybrid on bean varieties. In line with the current study, Walelign (2008) found no effect of maize-common bean intercropping on maize grain yield.

In the intercropped experiment, seed yield ranged from 0.20 to 0.65 t ha^{-1} with a mean value of 0.33 t ha^{-1} (Table 3). Genotypes UBR(92)25-13-1 (0.65 t ha^{-1}), MEXICO235 X PAN-182 (0.57 t ha^{-1}), AN-92-12123 (0.49 t ha^{-1}), FEB-147 X EAP-4 (0.45 t ha^{-1}), and SEN-4L (0.42 t ha^{-1}) had higher Seed yield than all other genotypes. Days to flowering ranged from 36.8 to 43.3 with a mean of 40.4 days, while mean days to maturity was 86.5 days with a range of 81.3 to 95.3 days. High yielding genotypes tend to mature later as compared to most low and medium yielding genotypes. Plant height ranged from 37.0 to 134.4 cm with a mean value of 59.2 cm. Similar to the sole cropping trial, the highest yielding genotype, UBR(92)25-13-1, showed the tallest plant height. Pods per plant ranged from 3.5 to 9.2 with a mean of 5.9; seeds per pod ranged from 2.8 to 6.3 with a mean of 5.61, whereas pod length ranged from 6.5 to 9.1 cm with a mean of 7.9 cm. Hundred seed weight ranged from 14.5 to 40.0 gm with a mean of 20.8 gm, whereas number of primary branches ranged from 3.3 to 5.5 with a mean number of 4.3 branches per plant. The local check, Burre, showed the highest hundred seed weight among all genotypes evaluated. Harvest index ranged from 0.28 to 0.45 with a mean value of 0.37; genotypes with higher seed yield also showed higher harvest index.

Effects of maize-common bean intercropping on performances of common bean genotypes

Combined analysis of seed yield and other agronomic traits of common bean genotypes evaluated under sole cropping and intercropping with maize showed highly significant genotypic and year main effects for all studied traits (Table 4). Mean squares due to cropping system main effects were significant for most of the traits except for plant height and hundred seed weight. Genotype × year effects were significant for all traits, whereas genotype × cropping system interaction effects were significant for most traits except for seeds per pod and pod length. Genotype × year × cropping system interaction effect was also significant for most traits, but not for pod length and hundred seed weight. Significant interactions of genotypes with years and cropping systems indicated that the performances of common bean genotypes evaluated under this study were not consistent across years and cropping systems. Similar findings were previously reported by Santala *et al*. (2001) and Setegn *et al*. (2006).

Table 2. Combined analysis of variance and means for seed yield and agronomic traits of common bean genotypes evaluated under intercropping with a maize hybrid, BH540, at Bako in 2011 and 2012.

Sources of variation	df	SY t ha^{-1}	DF days	DM days	PH cm	NPB No.	PPP No.	SPP No.	PL cm	HSW gm	HI ratio
Year (Y)	1	0.04*	6.67*	61.36*	116.6ns	378.3**	33.9**	18.13**	24.75**	249.3**	0.196**
Replication (R)/Y	4	0.05**	70.86**	32.14ns	317.4*	1.72ns	5.6*	2.92*	1.23ns	113.4**	0.001ns
Block (R x Y)	24	0.04**	16.8ns	84.28**	2828.6**	1.14ns	4.1*	0.046ns	0.54ns	48.8ns	0.005ns
Genotype (G)	23	0.06**	15.26	55.65**	2427.8**	1.62**	9.5**	2.99**	2.4**	155.2**	0.008**
G x Y	23	0.03**	14.05ns	58.86**	498.6**	1.55**	5.9**	1.63**	0.94*	53.91**	0.01**
Error	68	0.009	9.39	13.51	95.4	0.62	1.61	0.71	0.53	21.45	0.003
Mean		0.33	40.4	86.5	59.2	4.3	5.9	4.9	7.9	20.8	0.37
CV(%)		29.1	7.58	4.25	16.5	18.2	21.6	17.19	9.3	22.2	15.38
R^2		0.76	0.52	0.72	0.90	0.89	0.74	0.67	0.69	0.74	0.69
$LSD_{5\%}$		0.11	3.51	4.21	11.2	0.90	1.45	0.97	0.84	5.31	0.06

** = Significant at $P \leq 0.01$, * = Significant at $P \leq 0.05$

df = degrees of freedom, DF = Days to flower, DM=days to maturity, HSW= hundred seed weight, HI= Harvest index, NPB = number of primary branches per plant, PH = plant height, PL= pod length, PPP = pods per plant, SPP = seeds per pod, SY = seed yield.

Table 3. Mean seed yield and other traits of top-yielding common bean genotypes evaluated under sole and intercropping with maize hybrid at Bako in 2011 and 2012.

Entry No.	Genotype	SY t ha^{-1}	DF days	DM days	PH cm	NPB No.	PPP No.	SPP No.	PL cm	HSW gm	HI ratio
Sole Cropping											
17	UBR(92)25-13-1	3.84	39.0	92.6	91.3	7.1	12.7	6.0	9.6	29.2	0.68
6	AN-92-12123	3.52	36.2	86.2	62.7	7.9	11.6	5.9	7.8	20.7	0.65
13	FEB-147 X EAP-4	3.51	38.1	86.6	71.5	7.9	14.7	6.0	9.5	24.7	0.69
20	SK-93846	3.43	37.8	89.3	53.4	10.0	19.8	5.4	7.4	17.9	0.71
19	MEXICO235 X PAN-182	3.32	39.8	94.9	88. 6	6.6	12.7	6.0	9.4	22.1	0.58
1	SEN-4L	3.29	35.1	83.0	47.5	6.5	13.4	5.2	8.3	20.1	0.59
2	SEN-46	3.00	34.5	76.4	55.6	7.7	13.3	5.4	8.7	23.1	0.54
24	Local check (Burre)	1.71	34.3	74.3	42.7	8.3	11.2	4.7	9.5	28.8	0.55
	Mean	2.75	36.9	84.8	60.6	7.7	14.9	5.6	8.3	20.8	0.56
	Minimum	1.54	33.3	74.3	36.0	6.0	11.2	3.7	7.2	13.9	0.45
	Maximum	3.84	39.8	95.9	91.3	10.0	21.1	6.1	9.6	33.8	0.71
Intercropping											
17	UBR(92)25-13-1	0.65	42.8	95.3	134.4	4.6	9.2	5.0	8.0	27.8	0.45
19	MEXICO235 X PAN-182	0.57	43.3	95.3	122.5	5.5	7.7	5.1	8.7	22.8	0.44
6	AN-92=12123	0.49	40.3	86.8	57.8	4.1	6.7	5.9	7.6	19.2	0.41
13	FEB-147 X EAP-4	0.45	40.0	88.2	65.5	4.4	5.9	5.5	9.1	22.8	0.41
1	SEN-4L	0.42	37.5	86.3	53.0	5.2	5.9	6.3	8.3	21.5	0.37
2	SEN-46	0.36	40.2	84.0	52.6	4.1	6.6	4.5	7.5	22.5	0.36
20	SK-93846	0.35	41.2	87.7	52.8	4.8	6.7	4.7	6.5	17.5	0.36
24	Local check (Burre)	0.21	42	81.83	42.87	4.27	3.5	3.47	9.08	40	0.28
	Mean	0.33	40.4	86.5	59.2	4.3	5.9	4.9	7.9	20.8	0.37
	Minimum	0.20	36.8	81.3	37.0	3.3	3.5	2.8	6.5	14.5	0.28
	Maximum	0.65	43.3	95.3	134.4	5.5	9.2	6.3	9.1	40.0	0.45

DF = Days to flower, DM=days to maturity, HSW= hundred seed weight, HI= Harvest index, NPB = number of primary branches per plant, PH = plant height, PL= pod length, PPP = pods per plant, SPP = seeds per pod, SY = seed yield.

Mean common bean seed yield in intercropping was reduced by 87.9%, as compared to mean seed yield under sole cropping (Table 4). The range of yield reduction among all genotypes was between 82.3 and 92.2% (Table 5), indicating differences in responses of common bean genotypes to intercropping with maize. Genotypes ICTAJU-95-28 (82.3%), MEXICO235 X PAN-182 (83.0%) and UBR(92)25-13-1 (83.1%) showed relatively lower yield reduction when intercropped with maize (Table 5), indicating the compatibility of these genotypes for intercropping. In addition, MEXICO235 X PAN-182 and UBR(92)25-13-1 were among the top yielding genotypes under both sole and intercropping, and can be recommended for both conditions. Even though ICTAJU-95-28 showed the lowest yield reduction under intercropping, it was among the lowest yielding genotypes both under sole and intercropping; and hence, cannot be recommended for further use.

Several genotypes showed higher percentage of seed yield reduction under intercropping. For instances, ICTAJU-95-56 (91.0%), AN-9123342 (89.8%), FEB-190 (91.6%), ROBA X FEB-147 (92.2%) and SK-93846 (89.9%) showed about 90% or more reduction in seed yield under intercropping.

Table 4. Combined analysis of variance and means for seed yield and agronomic traits of common bean genotypes evaluated under sole and intercropping with a maize hybrid, BH540, at Bako in 2011 and 2012.

Sources of variation	df	SY t ha^{-1}	DM days	PH cm	NPB No.	PPP No.	SPP No.	PL cm	HSW gm
Year (Y)	1	64.7**	509.3**	25170.2**	670.7**	1042.3**	26.8**	72.6**	951.6**
Replication (R) (Y x CS)	8	6.1	72.7	190.8	3.5	7.4	3.3	1.4	34.8
Genotype (G)	23	16.1**	248.1**	3829.1**	4.4**	46.3**	3.8**	5.0**	262.3**
Cropping system (CS)	1	4201**	201.7**	171.4	803.7**	5968.7**	34.2**	10.7**	0.19
G x Y	23	6.7**	95.93**	714.87*	2.92**	25.83**	1.23**	1.74**	82.04**
G x CS	23	10.2**	58.19**	599.7**	3.66**	21.45**	0.79	0.55	42.24**
G x Y x CS	23	8.8**	40.89**	114.52**	2.06**	45.1**	1.02**	0.58	21.67
Error	96	1.9	14.07	116.26	1.34	5.62	0.61	0.44	21.58
Mean		1.54	85.62	59.91	6.01	10.42	5.3	8.10	20.77
CV (%)		28.3	4.38	17.99	19.21	22.75	14.86	8.29	29.36
R^2		0.94	.81	0.89	0.88	0.91	0.66	0.76	0.72
$LSD_{0.05}$		0.10	.087	2.51	0.26	0.55	0.18	0.15	1.08
Sole mean		2.75	84.8	60.6	7.7	14.9	5.6	8.3	20.8
Intercropped mean		3.33	86.5	59.2	4.3	5.9	4.9	7.9	20.8
Relative reduction (%)		87.9	-2.0	2.4	43.3	60.7	12.2	4.6	0.0

** = Significant at P $\leq$ 0.01, * = Significant at P $\leq$ 0.05

df = degrees of freedom, DM=days to maturity, HSW= hundred seed weight, NPB = number of primary branches per plant, PH = plant height, PL= pod length, PPP = pods per plant, SPP = seeds per pod, SY = seed yield.

Similar studies conducted by Walelign (2008), Tolera *et al*. (2005) and Chemeda (1997) indicated that intercropping of bean with maize has negative effect on yield and yield components of bean. These studies reported bean seed yield reduction ranging from 26 to 67% as compared to that of sole cropping. Egbe and Kalu (2009) reported that intercropping pigeon pea with sorghum reduced the dry seed yield of pigeon pea by about 41.5%. Santala *et al.* (2001) also reported that intercropping of common beans with field maize reduced bean yield by 55%, and intercropping with sweet maize reduced bean yield by 44%.

Pods per plant and biomass yield were reduced under intercropping by 60.7 and 77.9%, respectively. Intercropping maize with bean resulted into reductions of seeds per pod and primary branches per plant by 12.2 and 43.3%, respectively. Mean plant height (2.4%) and pod length (4.6%) were not significantly reduced due to intercropping. On the other hand, maize-common bean intercropping slightly increased days to flowering (9.5%) and days to maturity (2.0%). The slight increase in plant height for the intercropped bean could be attributed to strong competition for sun light and growth of tendrils using maize as a staking material.

Phenotypic correlation among traits

Assessment of relationships among traits measured using Pearson correlation coefficients (Table 6) indicated positive and significant correlation of seed yield with seeds per pod and harvest index under sole cropping. Under intercropping, seed yield showed strong positive association with days to maturity, plant height, pods per plant, harvest index and number of primary braches per plant. In line with this finding, Kassaye (2006) and Alemneh (2009) found positive association of seed yield with several yield components. Under sole cropping, positive and significant correlation coefficients were observed among some agronomic traits, such as days to flowering, days to maturity, plant height, pods per plant, harvest index and number of primary branches per plant, and between pod length and hundred seed weight. Under intercropping, positive and significant correlation coefficient were observed between plant height and days to maturity, seeds per pod and days to maturity, pod length and plant height, pod length and number of primary branches per plant. Strong positive association among these traits indicated the presence of common genetic elements that control their expressions. According to Kearsey and Pooni (1996), significant positive correlation could be observed either due to the strong coupling linkage between the genes or as the result of pleiotropic effects of genes that controlled these characters in the same direction.

No significant negative correlation was observed between pairs of traits under sole cropping trial, except between seeds per pod and hundred seed weight. Under intercropping, however, hundred seed weight had negative and significant correlation coefficient with days to maturity, pods per plant and seeds per pod. Negative and significant correlation was also observed between pod length and number of pods per plant as well as number of primary branches and plant height. Significant negative correlation coefficients observed between pairs of traits indicate that both traits could not be simultaneously improved. No correlation was observed among most of the traits studied, indicating the lack of functional relationship between these group of traits.

Intercropping efficiency

Common bean partial LER values were generally low, ranging from 0.08 to 0.20, with a mean value of 0.12 (Table 7). Smaller partial LER values indicated lower productivity of the bean genotypes under intercropping condition. TLER ranged between 0.86 and 1.14, and averaged 1.05. Genotype ICTAJU-95-28 showed higher partial and total LER of 0.20 and 1.13, respectively, whereas both MEXICO235 X PAN-182 and UBR (92) 25-13-1 had the highest TLER value of 1.14. In general, LER analysis in this study showed that maize-common bean intercropping increased land use efficiency by an average of 5.0%, and a maximum of 14%. Santala *et al.* (2001) reported LER, which averaged 1.12 for intercropping; and Chemeda (1997) reported 2-28% of relative yield advantage of maize-bean intercropping over sole cropping.

Table 5. Seed yield (t ha^{-1}) of common bean genotypes evaluated at under sole and intercropping in 2011 and 2012; and percent seed yield reduction due to intercropping.

Entry no.	Genotype	Sole crop seed yield (t ha^{-1})	Intercrop seed yield (t ha^{-1})	% reduction in seed yield
1	SEN-4L	3.29	0.42	87.3
2	SEN-46	3.00	0.36	87.9
3	SEN-53	2.10	0.27	87.2
4	ICTAJU-95-56	2.62	0.24	91.0
5	TB-94-02	2.88	0.32	88.9
6	AN-92=12123	3.52	0.49	86.2
7	ICTAJU-95-1-07	1.87	0.20	89.3
8	AN-9123342	3.12	0.32	89.8
9	ICTAJU-95-28	1.54	0.27	82.3
10	FEB-190	3.14	0.26	91.6
11	ROBA X FEB-147	3.26	0.26	92.2
12	ATENDABA X EAP-4	2.65	0.36	86.5
13	FEB-147 X EAP-4	3.51	0.45	87.2
14	ECAB-06-01	2.91	0.33	88.6
15	557-FIN-1	2.84	0.31	89.1
16	DB-190-84-1	2.95	0.31	89.4
17	UBR(92)25-13-1	3.84	0.65	83.1
18	BAT-1198 XBAT-1248	1.55	0.23	85.5
19	MEXICO235 X PAN-182	3.32	0.57	83.0
20	SK-93846	3.43	0.35	89.9
21	MEXICO-23 X BAT-338-1C-10	2.21	0.23	89.5
22	BAT-1198 X BAT-1248-6	2.08	0.28	86.8
23	BAT-448 X PAN-182-2	2.63	0.31	88.4
24	Local check (Burre)	1.71	0.21	87.5

Relative crowding coefficient (RCC) calculated to assess the efficiency of maize-common bean intercropping showed very low RCC for all bean genotypes and high RCC for the maize hybrid. (Table 7). Genotypes ICTAJU-95-28, UBR (92)25-13-1 and MEXICO235XPAN-182 exhibited relatively higher RCC values of 0.061, 0.054 and 0.051, respectively. Bean-maize RCC ranged from 0.19 to 1.56, with a mean of 0.66. Bean genotypes with higher RCC were UBR (92)25-13-1 (1.56), MEXICO235 X PAN-182 (1.40), SEN-46 (1.38) and MEXICO-23 X BAT-338-1C-10 (1.08). Higher RCC values indicate higher yield advantage of the two crops when grown in mixed cropping. In other words, the genotypes resisted competition effect exerted by the companion crop and are well adapted to intercropping and efficient in utilization of growth resources. According to de Wit (1960) and Setegn (1997), bean genotypes that have RCC of less than one in combination with maize variety indicated that they have produced lower yield than expected and adversely dominated by maize variety. Hence, most of the bean genotypes of the present study could not withstand the influence and intensity of competition exerted by the maize hybrid as evident from the low RCC values of common bean genotypes (Table 7). The RCC value of maize was much greater than that of bean genotypes indicating that the maize hybrid showed higher competition intensity than that of common beans. The current study indicated that bean genotypes used for the intercropping were highly sensitive to competition imposed by the maize hybrid.

Table 6. Phenotypic correlation coefficients among traits of common bean genotypes grown under sole (above diagonal) and intercropping with maize (below diagonal) at Bako in 2011and 2012 main cropping seasons.

Traits	SY $t\ ha^{-1}$	DF days	DM days	PH cm	NPB No.	PPP No.	SPP No.	PL cm	HSW gm	HI ratio
SY		0.25	0.25	0.28	0.12	0.13	0.45^{*}	0.20	0.00	0.80^{**}
DF	0.34		0.60^{**}	0.54^{**}	0.23	0.24	-0.16	0.35	0.31	0.03
DM	0.81^{**}	0.81^{**}		0.88^{**}	0.45^{*}	0.73^{**}	0.37	0.18	-0.03	0.52^{**}
PH	0.82^{**}	0.57^{**}	0.62^{**}		0.46^{*}	0.67^{**}	0.11	0.24	0.23	0.63^{**}
NPB	0.52^{**}	0.02	-0.02	-0.44^{*}		0.63^{**}	-0.03	-0.29	-0.29	0.17
PPP	0.73^{**}	0.37	0.37	-0.22	0.39		0.34	-0.26	-0.22	0.40
SPP	0.39	0.46^{*}	0.43^{*}	0.38	0.03	0.18		0.10	-0.50^{*}	0.26
PL	0.16	0.08	-0.02	0.44^{*}	0.18	-0.45^{*}	0.14		0.52^{**}	0.03
HSW	0.13	-0.45^{*}	-0.43^{*}	0.11	0.23	-0.63^{**}	-0.51^{*}	0.49^{*}		-0.14
HI	0.68^{**}	0.06	0.00	0.15	0.27	-0.10	0.21	0.27	0.30	

** = Significant at $P \leq 0.01$, * = Significant at $P \leq 0.05$

DF = Days to flower, DM=days to maturity, HSW= hundred seed weight, HI= Harvest index, NPB = number of primary branches per plant, PH = plant height, PL= pod length, PPP = pods per plant, SPP = seeds per pod, SY = seed yield.

Table 7. Land Equivalent Ratio (LER) and Relative Crowding Coefficients (RCC) for Common bean-maize intercropping at Bako in 2011 and 2012.

Common bean genotypes	BLER	MLER	TLER	BRCC	MRCC	BMRCC
SEN-4L	0.13	0.94	1.07	0.04	15.69	0.59
SEN-46	0.12	0.97	1.10	0.04	38.99	1.38
SEN-53	0.12	0.84	0.97	0.03	5.39	0.19
ICTAJU-95-56	0.09	0.97	1.07	0.03	36.15	0.93
TB-94-02	0.11	0.97	1.08	0.03	30.35	0.97
AN-92=12123	0.15	0.95	1.10	0.04	20.95	0.90
ICTAJU-95-1-07	0.10	0.96	1.05	0.03	21.44	0.59
AN-9123342	0.10	0.90	0.99	0.03	8.69	0.23
ICTAJU-95-28	0.20	0.93	1.13	0.06	13.37	0.81
FEB-190	0.08	0.96	1.04	0.02	27.37	0.59
ROBA X FEB-147	0.08	0.79	0.86	0.02	3.68	0.08
ATENDABA X EAP-4	0.13	0.93	1.06	0.04	13.38	0.48
FEB-147 X EAP-4	0.13	0.91	1.04	0.04	9.88	0.37
ECAB-O6-01	0.11	0.90	1.01	0.03	8.66	0.27
557-FIN-1	0.11	0.88	1.00	0.03	7.54	0.24
DB-190-84-1	0.10	0.92	1.02	0.03	11.34	0.32
UBR(92)25-13-1	0.17	0.97	1.14	0.05	30.59	1.56
BAT-1198 XBAT-1248	0.13	0.96	1.09	0.04	24.77	0.91
MEXICO235 X PAN-182	0.18	0.96	1.14	0.05	26.03	1.40
SK-93846	0.10	0.84	0.94	0.03	5.10	0.14
MEXICO-23 X BAT-338-1C-10	0.11	0.97	1.08	0.03	33.86	1.08
BAT-1198 X BAT-1248-6	0.13	0.92	1.05	0.04	10.82	0.42
BAT-448 X PAN-182-2	0.12	0.96	1.09	0.03	27.57	0.95
Local check	0.12	0.92	1.04	0.04	11.34	0.40
Average	0.12	0.93	1.05	0.04	18.46	0.66

BLER= common bean land equivalent ratio, BMRCC = bean and maize crowding coefficient, BRCC= bean crowding coefficient, MRCC = maize crowding coefficient, MLER= maize land equivalent ratio, TLER= total land equivalent ratio.

Conclusion

Significant variations were observed among the common bean genotypes for various traits under both sole and intercropping conditions indicating the possibility of selecting desirable genotypes. Genotypes UBR (92)25-13-1 and MEXICO235 X PAN-182 showed higher seed yield under both growing conditions; and exhibited lower percent of reduction in seed yield and other important yield related traits when intercropped with maize. These genotypes also showed higher values of RCC and LER, indicating their compatibility and suitability for intercropping with maize that need to exploited in mixed cropping system. The level of yield reduction observed for most common bean genotypes used in the current study was unexpectedly higher. This recalls further evaluation and identification of compatible genotypes using larger number of the common bean genotypes. Besides, the date of common bean planting under intercropping condition should also be adjusted to enhance their competitiveness capacity for sun light and other growth nutrients for better productivity.

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