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Evaluation of Common Bean (*Phaseolus vulgaris* L.) Genotypes of Diverse Growth Habit under Sole and Intercropping with Maize (*Zea mays* L.) in Southern Ethiopia

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Abstract: Seven released, one local and two potential, totally 10, common bean (*Phaseolus vulgaris* L.) genotypes representing three growth habit groups were tested under sole cropping and in association with hybrid maize (*Zea mays* L.). The experiments were conducted during the 2005 and 2006 cropping seasons in southern Ethiopia to compare genotypes and growth habit groups of common bean and to identify genotypes that give maximum intercropping advantage. A split-plot design with three replications was used with cropping system and genotype as main and sub plot factors, respectively. The bean genotypes varied significantly in productivity under both cropping systems. Determinate and bush types performed better than indeterminate and semi-climbing types, respectively. The mean yield from all bean genotypes was used for standardizing and specific genotype combinations showed a mean land equivalent ratio as high as 1.34. Grain yields and ranks of the bean genotypes were positively correlated between the two cropping systems. Furthermore, there was no significant genotype by cropping systems interactions indicating that genotypes selected for performance under sole cropping could perform well in association with hybrid maize. Using improved bush bean cultivars such as DOR-554 and AFR-772 in association with hybrid maize could enhance intercropping advantage.

Key words: Growth habit, maize, *Phaseolus vulgaris*, yield, yield components

INTRODUCTION

In southern Ethiopia, 46.5% of farmers have an average land holding of 0.1 to 0.5 ha with a further 25.4% having 0.51 to 1 ha (CACC, 2003). This acute land scarcity necessitates farmers to use other alternatives to improve their productivity. Intercropping systems play an important role in subsistence and food production in developing countries (Tsubo and Walker, 2002). Tefera and Tana (2002), Agegnehu *et al.* (2006), Gebeyehu *et al.* (2006) and Ghosh *et al.* (2006) have shown the advantage of intercropping over sole cropping in the tropics.

Multiple cropping is common in Southern Ethiopia with diverse associations comprised of maize (*Zea mays* L.), *tef* (*Eragrostis tef* (Zuc.) Trotter), rapeseed (*Brassica carinata* A. Braun), common bean (*Phaseolus vulgaris* L.), sweet potato (*Ipomoea batatas* (L.) Lam.), *enset* (*Ensete ventricosum* (Welw.) Cheeseman), coffee (*Coffea* sp.) and banana (*Musa acuminate* Colla) (Worku, 2004). The dominant association, among these, is maize-common bean intercropping. Suitable cultivars should be identified in order to maximize the benefit from multiple cropping. For instance, Yadav and Yadav (2001) reported that higher advantage from intercropping was obtained when clusterbean was intercropped with the shorter and early maturing HHB 67 pearl millet rather than with the tall and late maturing cultivar MH 179. The choice of compatible cultivars would be very important in a crop like common bean where there is great variation in the growth habit and morphology of cultivars.

Differences in growth habit and vegetative traits among genotypes may lead to differential performance under sole and intercropping systems. For instance, Tefera and Tana (2002) suggested that the significant variation among groundnut (*Arachis hypogaea* L.) cultivars in yield and yield components under intercropping with sorghum (*Sorghum bicolour* L. Moench) cultivars revealed that sole cropping may not provide the appropriate environment for selecting varieties intended for use in intercropping. Also, Gebeyehu *et al.* (2006) reported a similar finding from maize-bean intercropping involving climbing types. On the other hand, Santalla *et al.* (2001) working on bush bean cultivars, suggested that the evaluation of bean genotypes for agronomic and quality traits under sole cropping provide sufficient information to select varieties efficiently for intercropping systems with maize.

The number of released bean cultivars has been increasing in Ethiopia. However, their performance under intercropping system has not been tested rigorously. This is also true for maize where the more robust hybrids are gaining acceptance by farmers and are increasingly replacing open pollinated varieties. Aims of this research were to (1) examine the relative performance of common bean genotypes in sole stands and in association with hybrid maize, (2) observe if there is genotype by cropping systems interaction, (3) investigate differences within and between the three growth habit groups under the two cropping systems and (4) identify the most suitable bean genotypes for intercropping with hybrid maize.

MATERIALS AND METHODS

The experiment was conducted in Southern Ethiopia during the 2005 and 2006 cropping seasons at Awassa, which is located 7°05'N and 38°30'E and asl 1660 m.

Design and treatments: Treatments were made from a combination of two factors: cropping systems and common bean genotypes. The cropping systems consisted of sole cropping and intercropping with maize. The maize cultivar, Pioneer 3253 was planted in 2005 and BH 540 was planted in 2006. Both are recommended for the experimental area. The second factor involved seven released, one local and two potential genotypes of common bean representing three different growth habit groups. There were four determinate and six indeterminate types out of which eight were bush and two were semi-climbing types. One of the cultivars, Red Wolaita, is a popular local cultivar widely used for sole cropping and intercropping among farmers.

The factorial combinations of the ten bean genotypes and the two cropping systems (Sole and intercropping) comprising twenty treatments were arranged in a split plot design with three replications. Cropping systems was the main plot factor while common bean genotypes were assigned as a sub-plot factor. Also, sole maize plots were planted in three replications.

Agronomic management: Plantings of intercropped maize, sole maize and sole common bean were carried out on 15 and 14 April in 2005 and 2006, respectively. A pre-planting dose of phosphorus was applied on the intercrop and maize sole plots at a rate of 46 kg P_2O_5 ha^{-1} as a one time application while nitrogen was applied on the same plots at the rate of 54 kg ha^{-1} as split application. Half of the rate of nitrogen dose applied with phosphorus and the remaining half was given four and two weeks after emergence in 2005 and 2006, respectively. Sole common bean plots received phosphorus at the rate of 23 kg P_2O_5 ha^{-1} and nitrogen at the rate of 9 kg ha^{-1} and were applied as a single dose just before planting. Intercropped common bean plots were planted four weeks after maize emergence on 22 May in 2005 while they were planted two weeks after emergence, on 9 May in 2006. There was no additional fertilizer applied for intercropped common bean. The planting date for intercropped common bean was shifted in 2006 based on the fact that the advanced maize growth, which was near canopy closure, affected the common bean stand in 2005.

The intercropping was an additive type where the two components were combined with their full sole crop populations. The arrangement of intercropping was a row type where two common bean rows were planted between successive maize rows. The row arrangement was made east-west to allow better light penetration. Intercropped and maize plots were 4.8 m wide and 3 m long. Sole plots of common bean were planted on 2 m wide and 3 m long plots.

Maize seeds were hand planted with two seeds per hill with 80 cm inter-row and 30 cm intra-row spacing. The stand was thinned to a population of 41,666 plants ha^{-1} a week after emergence. Both the sole and intercrop common bean plots were hand sown with two seeds hill^{-1} with an inter-row and intra-row spacing of 40 and 10 cm, respectively. The stand was thinned to a density of 250,000 plants ha^{-1} a week after emergence. Both sole and intercrop maize took 135 and 140 days from emergence to physiological maturity in 2005 and 2006, respectively.

Data collection and analysis: Grain yield of intercropped and sole maize was determined from plants harvested of the two central rows (4.8 m^2). Number of rows per ear and number of seeds per row were determined from six randomly taken cobs. Similarly, grain yield of intercropped and sole common bean was determined from the two central rows (2.4 m^2). Number of pods per plant was determined from eight randomly selected plants while number of seeds per pod was determined from 15 randomly picked pods. Grain yield of both maize and common bean was adjusted to 13% moisture content.

A combined analysis of variance was done using the General Linear Models of the Statistical Analysis System (SAS, 1999). Year was considered as a random effect while cropping system and genotype were taken as fixed effects. The F-test was used to check for homogeneity of error variances between the two years (Gomez and Gomez, 1984). Responses of bean genotypes were also contrasted to examine the distribution of variation among genotypes between and within the different growth habit groups. The efficiency of the intercropping system as compared to sole cropping was analysed using the Land Equivalent Ratio (LER) method (Mead and Willey, 1980).

$$\text{Total LER} = \frac{Y_{ij}}{Y_{ii}} + \frac{Y_{ji}}{Y_{jj}}$$

where, Y_{ij} and Y_{ii} are intercrop and sole crop yields of component i, respectively while Y_{ji} and Y_{jj} are intercrop and sole crop yields of component j, respectively.

Land equivalent ratio evaluates the productivity by considering relative performance under the sole and intercropping rather than the yield per se of a given cultivar. This implies that larger LER values may arise not only from larger intercrop yields but also from smaller sole crop yields. This may lead to a choice of cultivars with medium or poor performance as long as they show better relative performance. Thus, the mean of the sole crop yields of all the genotypes was used as standardization factor for estimating partial LER of the common bean genotypes instead of individual sole crop yields (Mead and Stern, 1980; Oyejola and Mead, 1982; Santalla *et al.*, 2001).

RESULTS

There was a difference in rainfall amount and distribution between the growing seasons of 2005 and 2006 while there was no marked variation in temperature. Amount of rainfall received during the 2006 growing season (656 mm) was larger by 17% compared to the amount in 2005 (561 mm) and by 18% compared to the ten years average (554 mm) for the same period. There was also a better distribution in 2006 whereby only 31% of the days during the growing period received no rainfall while it was 57% of the days in 2005. This variation could be one of the contributing factors for the differences observed between the two years in the response of parameters to the study factors, especially in common bean.

The common bean component: Grain yield was significantly affected by year, cropping system and genotype (Table 1). The difference in grain yield among genotypes is distributed all over the computed contrasts except within semi climbing (Table 1). Yield increased by 22% in 2006 compared to 2005 (Table 2). On the other hand, intercropping with maize reduced bean grain yield by 80% compared to its sole counter part. On a group basis, the bush and determinate types produced 67 and 16% more yield compared to semi climbing and indeterminate types, respectively (Table 2). Within the determinates, Melke and AFR-772 produced the highest yields which were also the overall top yielders (Table 3). Within indeterminates, DOR-554 and Roba are the highest yielders.

Year, cropping system and genotype have shown a significant effect on the first yield component, pod number per plant (Table 1). The difference among genotypes for number of pods per plant is attributed to the same contrasts that showed variation for grain yield except determinate vs. indeterminate. Pod number per plant increased by 35% in 2006 compared to 2005. On the other hand, it dropped by 71% under intercropping compared to sole cropping, following the grain yield trend (Table 2). Bush genotypes produced more pods per plant than semi climbing types (Table 2). The within group comparison showed that genotypes with superior performance were not necessarily the highest ranking in pod number per plant though most are in the top category (Table 3). This could be explained by the fact that trends for pod number per plant and seed weight were variable among genotypes. For instance, the determinate types produced relatively smaller number of pods per plant and seeds per pod but remarkably heavier seeds while the reverse were true for indeterminates (Table 3).

Table 1: Combined analyses of variance on yield, yield components and maturity of common bean genotypes under sole and intercropping with maize at Awassa, in 2005 and 2006

		Mean square				
Source	df	Yield ($t\ ha^{-1}$)	Pod $plant^{-1}$	Seed pod^{-1}	100 seed weight (g)	Days to mature
Year	1	2.91**	14.31***	12.56**	60.12*	130.20
Replication within year	4	0.09	0.43	0.35	3.09	24.08*
Cropping systems	1	133.91*	1996.02*	53.32	8.95	492.07
Year×cropping systems	1	0.66	12.57	9.06*	4.06	33.05
Error a	4	0.17	2.21	0.49	14.93	34.75
Genotype	9	1.61*	16.25*	6.25***	1547.23***	83.16**
Determinate vs. indeterminate	1	1.73*	8.69	33.79***	1023.15***	67.83
Within determinate	3	1.42*	16.70*	1.21***	1213.41***	98.18**
Within indeterminate	5	1.71*	17.49*	1.20***	14.16	77.22*
Bush vs. semi climbing	1	8.89***	35.34*	1.82**	1358.32***	10.80
Within bush	7	1.15*	15.63*	5.40***	1792.63***	75.38*
Within semi climbing	1	0.32	1.45	3.43***	18.83	210.04**
Year×genotype	9	0.32	3.68	2.47*	17.94**	13.04
Cropping system×genotype	9	0.46	5.24	1.16***	12.17	9.50
Error b	72	0.24	2.64	0.18	6.52	6.91

*, **, *** indicate significance at 0.05, 0.01 and 0.001 probability levels, respectively

Year and genotype influenced the second yield component, seed number per pod (Table 1). The difference in seed number per pod among the genotypes was distributed all over the computed contrasts: between and within group contrasts. Relatively larger number of seeds per pod was produced in 2006 compared to 2005 (Table 2). There were a year×cropping system, a year×genotype and a cropping system×genotype interactions. However, the interactions were not large and consistent enough to be remarkably different from the main effect.

There was a significant variation between years and among genotypes for seed weight (Table 1). The variation among genotypes was located in all computed group contrasts, except for the within indeterminate and the within semi climbing contrasts. Seeds were heavier in 2005 compared to 2006, which may be attributed to the restricted number of pods in 2005 due to water stress leaving fewer pods to compete for assimilates (Table 2). A remarkable variation was observed for seed weight among the group comparisons in that determinates produced seeds larger by 96% compared to indeterminates while bush types produced seeds larger by 41% compared to semi climbing types (Table 2). There was also a significant year by genotype interaction for grain weight. This interaction did not alter the main effect considerably in that genotypes fall in a similar seed weight category in either year except minor change in ranking within their class.

Days to maturity were influenced by genotype and this variation was located under within group contrasts (Table 1). Maturity period was similar among the different growth habit groups. Maturity period did not vary significantly between cropping systems, either (Table 2).

Simple correlation coefficients of yield with various parameters were made separately for each cropping system or year and for the data pooled over cropping systems or years. Grain yield of common bean genotypes under sole cropping has shown a positive correlation with their yield under intercropping for 2006 (r = 0.62*) and for the pooled data (r = 48*) but not for 2005 (r = 0.55, p = 0.10). Correlations between ranks for bean grain yield under the two cropping systems were also significant for 2006 (r = 0.63*) and for the pooled data (r = 0.58**) but not for 2005 (r = 0.52, p = 0.11). Number of pods per plant made a positive correlation with grain yield under sole cropping (r = 0.61*), intercropping (r = 0.62*) and for the pooled data (r = 0.95***). Number of seeds per pod made positive relationship for the pooled data only (r = 0.60**) while seed weight did not make significant association either for each cropping system or for the pooled data.

Table 2: Means of year, cropping systems and contrasts for grain yield, yield components and maturity of common bean genotypes from a maize-common bean intercropping at Awassa

	Parameters				
Years and treatments	Yield ($t\ ha^{-1}$)	Pod No. $plant^{-1}$	Seed No. pod^{-1}	100 seed weight (g)	Days to mature
2005	1.41	6.34	4.22	27.88	78.5
2006	1.72	8.53	4.82	26.44	78.8
$LSD_{0.05}$	0.156	0.335	0.300	0.892	NS
Sole	2.62	11.51	5.16	26.90	76.4
Intercropping	0.51	3.36	3.88	27.45	80.9
$LSD_{0.05}$	1.88	7.01	NS	NS	NS
Determinate	1.71	7.10	3.70	38.47	79.4
Indeterminate	1.47	7.60	4.90	19.64	78.2
Bush	1.70	7.70	4.40	28.85	78.8
Semi climbing	1.02	6.80	4.60	20.44	78.4

NS: Not Significant, $LSD_{0.05}$: Least Significant Difference at 0.05 probability level

Table 3: Means of yield, yield components and maturity of common bean genotypes intercropped with maize, at Awassa

Genotypes		Yield ($t\ ha^{-1}$)	Pod No. $plant^{-1}$	Seed No. pod^{-1}	100 seed weight (g)	Days to mature
Determinate						
AFR-772	(BU)	1.93	7.73	3.74	43.47	81.90
Melke	(BU)	2.07	6.53	3.96	41.38	81.50
FIN-7	(BU)	1.52	7.82	4.35	23.60	78.60
FOI-55	(BU)	1.33	5.35	3.25	45.45	75.80
Indeterminate						
DOR-554	(BU)	1.81	8.78	5.04	20.34	80.30
Tabor	(BU)	1.69	7.08	5.25	19.46	77.80
RWR-719	(BU)	1.51	8.56	4.74	18.94	75.80
Roba	(BU)	1.76	8.81	5.18	18.22	78.80
Blneeb RR2	(SC)	1.20	6.60	4.54	21.33	75.90
Red Wolaita	(SC)	0.84	6.10	4.86	19.56	81.00
$LSD_{0.05}$		0.53	1.77	0.77	3.92	3.46

BU: Bush, SC: Semi Climbing

The maize component: Grain yield was not significantly varied between the two years and when intercropped with the 10 common bean genotypes (Table 4). The overall mean grain yield of intercropped maize averaged across common bean genotypes was no different compared to the mean of the sole counter part (Table 5).

Unlike grain yield, harvest index and yield components including number of rows per cob, number of seeds per row and seed weight were significantly different between years (Table 4). Intercropping with the various common bean genotypes did not influence any of the yield components. The plants carried no more than one cob per plant under all treatments, on average (Table 5). However, number of rows per cob, number of seeds per row and harvest index were higher in 2005 compared to 2006 while the reverse was true for seed weight.

Intercropping efficiency: The partial Land Equivalent Ratio (LER) for the maize component was not varied much between the two years (1.01 for 2005 and 1.02 for 2006)

Table 4: Combined analyses of variance on yield, yield components and harvest index of maize intercropped with different genotypes of common bean at Awassa, in 2005 and 2006

		Mean square					
Source	df	Yield (t ha^{-1})	Cob No. plant^{-1}	Row No. cob^{-1}	Seed No. row^{-1}	100 seed weight (g)	Harvest index
Year	1	0.00	0.026	92.50**	34.35*	391.93***	0.0955**
Rep. within year	4	1.00	0.010	1.06	2.98	0.97	0.0011
Genotype	9	1.78	0.006	2.03	5.09	5.18	0.0010
Year×genotype	9	1.08	0.010	1.30	5.16	2.80	0.0010
Error	36	1.54	0.010	1.05	5.89	3.87	0.0006

*, **, ***, indicate significance at 0.05, 0.01 and 0.001 probability levels, respectively.

Table 5: Means of year, contrasts and cropping systems for yield, yield components and harvest index of maize from a maize-common bean intercropping at Awassa

	Parameters					
Means for	Yield (t ha^{-1})	Cob No. plant^{-1}	Row No. cob^{-1}	Seed No. row^{-1}	100 seed weight (g)	Harvest index
2005	10.79	1.10	15.68	39.26	37.13	0.292
2006	10.80	1.15	13.19	37.75	42.50	0.213
LSD$_{0.05}$	NS	NS	0.74	1.24	0.71	0.024
Maize grown with						
Determinate	10.52	1.12	14.52	38.36	39.34	0.250
Indeterminate	10.97	1.13	14.38	38.44	39.70	0.250
Bush	10.80	1.12	14.33	38.60	39.92	0.250
Semi climbing	11.18	1.15	14.83	38.75	39.72	0.250
Sole^{a}	10.76	1.19	14.85	37.60	38.78	0.243
Intercrop^{a}	10.79	1.12	14.43	38.50	39.69	0.254

NS: Not Significant; LSD$_{0.05}$: Least Significant Difference at 0.05 probability level; ^{a}: Means of sole versus intercropping for comparison

Table 6: Means of partial LER and total LER from intercropping maize with different genotypes of common bean at Awassa

		Partial LER		
Genotypes		Maize	Common bean	Total LER
Determinate				
AFR-772	(BU)	1.03	0.29	1.32
Melke	(BU)	0.98	0.31	1.29
FIN-7	(BU)	1.05	0.14	1.20
FOI-55	(BU)	1.00	0.12	1.12
Indeterminate				
DOR-554	(BU)	1.06	0.27	1.34
Tabor	(BU)	1.04	0.24	1.28
RWR-719	(BU)	0.98	0.14	1.11
Roba	(BU)	1.05	0.20	1.25
Blneeb RR2	(SC)	1.04	0.10	1.15
Red Wolaita	(SC)	1.04	0.10	1.13

BU: Bush, SC: Semi Climbing

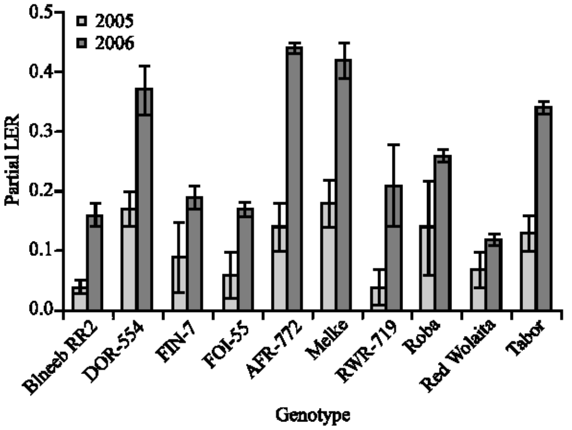

Fig. 1: Genotype×year for bean partial land equivalent ratio (LER) from a maize-common bean intercropping at Awassa

and among the four growth habit groups (between 1.01 and 1.04). Partial LER of maize when intercropped with the 10 genotypes was nearly one or greater (Table 6) indicating that there was no yield loss for the maize component when associated with the beans.

The partial LER for the bean component varied between the two years which were 0.11 for 2005 and 0.27 for 2006 showing a 145% increase in 2006 compared to 2005. As a group, determinate types gave a higher partial LER (0.21) than the indeterminates (0.17) while bush genotypes showed a greater partial LER (0.21) than semi climbing types (0.10). Within the determinate category partial LER values for Melke (0.31) and AFR-772 (0.29) were the highest while within the indeterminate group, DOR-554 (0.27) and Tabor (0.24) produced the highest values (Table 6). The two determinate bush types, Melke and AFR-772 gave the highest overall bean partial LER values. A significant year×genotype for bean partial LER showed that the magnitude of partial LER differences between the two years for each genotype was not similar (Fig. 1). However, the three top genotypes for partial LER remained the same in both years except a change in ranking.

Total LER reflected the trend of the bean partial LER in that it was influenced by genotype (Table 6). The bush types produced the highest mean total LER (1.23) as compared to semi climbing types (1.14) while there was no much difference between the determinates and indeterminates, as a group. Total LER for specific combinations were best for AFR-772 (1.32) and Melke (1.29) within determinates and for DOR-554 (1.34) and Tabor (1.28) within indeterminates (Table 6). Over all, DOR-554, AFR-772, Melke and Tabor showed the best intercropping advantage in that order.

DISCUSSION

The common bean component: Grain yield varied among the common bean genotypes both between and within groups. Determinate genotypes were superior to indeterminates while bush types were better than semi climbing types. The better performance of the determinate and the bush types, in the absence of growth duration differences and staking, could be attributed to better light distribution throughout their canopy as a result of their upright growth. Such distribution improves light utilization. For instance, Davis *et al.* (1984) reported that staking increased yield in climbing types while no response was observed for bush types. Furthermore, in rice, Setter *et al.* (1997) observed that lodged plants showed sub optimal stratified light interception of the canopy and reduced assimilation rate compared to erect plants, due to self-shading. On the other hand, Clark and Francis (1985) observed greater yield potential under monoculture for climbing compared to bush cultivars. However, their climbing types have longer maturity duration than the bush group. Occurrence of significant variation within each group requires examination of performance of each genotype separately and this indicated that there were productive genotypes within each category, except within semi climbing.

There was no significant genotype by cropping systems interaction for grain yield indicating that performance of genotypes did not vary considerably under the two cropping systems. Also, grain yields and ranks of common bean genotypes under sole cropping have shown a significant positive correlation with their yield and ranks under intercropping. These showed that selection of common bean cultivars for sole cropping could sufficiently identify suitable genotypes for intercropping with hybrid maize. Similarly, from maize-bean intercropping involving determinate and indeterminate bush genotypes, Santalla *et al.* (2001) and Francis *et al.* (1978) observed significant correlations between sole and intercrop yields and suggested that the evaluation of agronomic traits for sole cropping provide sufficient information for maize-bean intercropping systems. On the other hand, Gebeyehu *et al.* (2006) working on maize-bean intercropping involving climbing genotypes and Hauggaard-Nielsen and Jensen (2001) working on barley (*Hordeum vulgare* L.) intercropped with determinate and indeterminate pea (*Pisum sativum* L.) genotypes, observed significant genotype by cropping systems interactions and advocated for a separate selection scheme to develop appropriate cultivars for specific adaptation to intercropping. Differences in growth habit and morphology of the component cultivars involved may have contributed to reported differences in the response of genotypes to cropping systems. For instance, significant genotype by cropping system interactions are more consistently observed with climbing beans compared to bush beans (Francis, 1985).

Grain yield of common bean decreased remarkably under intercropping compared to sole cropping and this was associated with very low pod number per plant. Considerable yield reductions of the legume component were reported in various studies. For instance, Fininsa (1997) and Gebeyehu *et al.* (2006) reported 67 and 75-91% reduction in common bean yield when intercropped with maize, respectively while Hauggaard-Nielsen and Jensen (2001) reported a 35 to 64% yield reduction for determinate pea when intercropped with barley. Yield of the shorter legume component like bean could be reduced from shading by the tall cereal component like maize, depending on the density of the cereal, among other things. According to Gardiner and Craker (1981), at 55000 maize plants per hectare, the associated bean intercepted 20% of light and yield was decreased by 70% compared to the sole bean.

The maize component: Intercropping of maize with common bean did not reduce maize yield during both years. This shows that the bean component did not exert much competition on the maize component either because of the competitiveness of the maize hybrids and/or the less aggressive nature of the bean genotypes. Similarly, Gebeyehu *et al.* (2006) reported comparable yields between sole and intercropped hybrid maize cultivar in association with climbing bean genotypes and ascribed it to the competitive ability of the maize.

Intercropping efficiency: All associations involving the various genotypes showed a LER value of greater than one indicating the superior productivity of the combinations rather than growing the two crops separately. However, specific combinations which showed LER values of 1.3 and above would be recommended which is considered practically acceptable for intercropping production (Onwueme and Sinha, 1991).

Maize, with the higher partial LER and greater yield contribution is the more competitive component in the system. Ofori and Stern (1987) indicated that the cereal component, with relatively higher growth rate, height advantage and a more excessive root system is favoured in the competition with the associated legume. Lima Filho (2000), in maize-cowpea replacement intercropping, indicated that intercropped maize maintained higher values of leaf water potential, stomatal conductance, transpiration and photosynthesis than as sole crop.

As a group, bush genotypes produced a higher bean partial LER and total LER compared to semi climbing types. This may be because, the erect bush types could be in a better position to intercept light that is filtered through the tall maize component more uniformly throughout their canopy, as indicated in a previous section. Whenever the semi climbing types use the maize stalk for support, most of their leaves will be directly underneath the maize canopy where available light is at its lowest. Also, the two semi climbing genotypes used in this experiment are comparatively low yielders under sole cropping and since the mean of all the genotypes were used for standardization, they lost the advantage which otherwise could have gained. Due to significant differences within the bush group, it is important to look for specific genotype combinations, which offer the best LER.

Most of the productivity in the intercrop mixture, 79%, was contributed by the maize component while 21% is contributed by the bean component. However, the magnitude of the intercropping advantage was influenced by the legume component. The contributing factors for the intercropping advantage could be related to resource acquisition and efficiency of its utilization. From a maize-cowpea replacement intercropping, Lima Filho (2000) reported that intercropped cowpea maintained higher leaf water potential than the sole crop because of reduced evapotranspiration. This was caused by decreased radiation load on the legume component due to shading by the taller maize component. Regarding the resource use efficiency, the shaded legume component usually uses intercepted light more efficiently. For instance, Marshall and Willey (1983) reported that the intercropped groundnut intercepted 27% less radiation, but used it with 48% greater efficiency under intercropping with sorghum.

CONCLUSION

The experiments indicated that determinate genotypes were superior in grain yield compared to indeterminate ones while bush types were better than the semi climbing types. This was also reflected in the intercropping advantage of these growth habit groups. There was a positive correlation for grain yield and ranks of bean genotypes under sole cropping and intercropping. Unlike the bean component, hybrid maize did not suffer yield reduction when grown in association with bean genotypes. Absence of yield reduction in hybrid maize when associated with the bean component should encourage more farmers to practice intercropping, as maize is the principal crop of the area. Farmers could get more out of maize-bean intercropping by using improved bean genotypes such as DOR-554, AFR-772 and Melke than Red Wolaita. For similar growth period categories, bush types provide a better intercropping advantage. Due to absence of significant genotype by cropping systems interactions, it is possible to use determinate and indeterminate bush genotypes that are isolated as superior for sole cropping as components for intercropping with hybrid maize. Further research aimed at investigating the physiological basis of differences in performance among genotypes of the various growth habit groups under sole and intercropping would be worthwhile.

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REFERENCES

Agegnehu, G., A. Ghizaw and W. Sinebo, 2006. Yield performance and land-use efficiency of barley and faba bean mixed cropping in Ethiopian highlands. Eur. J. Agron., 25: 202-207.

Central Agricultural Census Commission (CACC), 2003. Statistical Report on Socio-Economic Characteristics of the Population in Agriculture House Holds, Land Use and Area and Production of Crops: Country Level, Part I. Addis Ababa, Ethiopia.

Clark, E.A. and C.A. Francis, 1985. Bean-maize intercrops: A comparison of bush and climbing bean growth habits. Field Crops Res., 10: 151-166.

Davis, J.H.C., L. van Beuningen, M.V. Ortiz and C. Pino, 1984. Effect of growth habit of beans on tolerance to competition from maize when intercropped. Crop Sci., 24: 751-755.

Fininsa, C., 1997. Effects of planting pattern, relative planting date and intra-row spacing on a haricot bean/maize intercrop. Afr. Crop Sci. J., 5: 15-22.

Francis, C.A., M. Prager, D.R Laing and C.A. Flor, 1978. Genotype×environment interactions in bush bean cultivars in monoculture and associated with maize. Crop Sci., 18: 237-242.

Francis, C.A., 1985. Variety development for multiple cropping systems. Crit. Rev. Plant Sci., 3: 133-168.

Gardiner, T.R. and L.E. Craker, 1981. Bean growth and light interception in a bean-maize intercrop. Field Crops Res., 4: 313-320.

Gebeyehu, S., B. Simane and R. Kirkby, 2006. Genotype×cropping system interaction in climbing bean (*Phaseolus vulgaris* L.) grown as sole crop and in association with maize (*Zea mays* L.). Eur. J. Agron., 24: 396-403.

Ghosh, P.K., M. Mohanty, K.K. Bandyopadhyay, D.K. Painuli and A.K. Misra, 2006. Growth, competition, yield advantage and economics in soybean/pigeon pea intercropping system in semi-arid tropics of India. I. Effect of sub soiling. Field Crops Res., 96: 80-89.

Gomez, K.A. and A.A. Gomez, 1984. Statistical Procedures for Agricultural Research. 2nd Edn. John Willey and Sons, Inc., New York, ISBN: 0-471-87931-2, pp: 704.

Hauggaard-Nielsen, H. and E.S. Jensen, 2001. Evaluating pea and barley cultivars for complementarity in intercropping at different levels of soil N availability. Field Crops Res., 72: 185-196.

Lima Filho, J.M.P., 2000. Physiological responses of maize and cowpea to intercropping. Pesq. Agropec. Bras., 35: 915-921.

Marshall, B. and R.W. Willey, 1983. Radiation interception and growth in an intercrop of pearl millet/groundnut. Field Crops Res., 7: 141-160.

Mead, R. and R.D. Stern, 1980. Designing experiments for intercropping research. Exp. Agric., 16: 329-342.

Mead, R. and R.W. Willey, 1980. The concept of a land equivalent ratio and advantages in yield from intercropping. Exp. Agric., 16: 217-228.

Ofori, F. and W.R. Stern, 1987. Cereal-legume intercropping systems. Adv. Agron., 41: 41-90.

Onwueme, T.C. and T.D. Sinha, 1991. Field Crops Production in Tropical Africa. CTA., Netherlands.

Oyejola, B.A. and R. Mead, 1982. Statistical assessment of different ways of calculating land equivalent ratios (LER). Exp. Agric., 18: 125-138.

Santalla, M., A.P. Rodino, P.A. Casquero and A.M. de Ron, 2001. Interactions of bush bean intercropped with field and sweet maize. Eur. J. Agron., 15: 185-196.

SAS, 1999. The SAS System, SAS Version 8e, Cary, NC: SAS Institute.

Setter, T.I., E.V. Laureles and A.M. Mazaredo, 1997. Lodging reduces yield of rice by self shading and reduction of photosynthesis. Field Crops Res., 49: 95-106.

Tefera, T. and T. Tana, 2002. Agronomic performance of sorghum and groundnut cultivars in sole and intercrop cultivation under semiarid conditions. J. Agron. Crop Sci., 188: 212-218.

Tsubo, M. and S. Walker, 2002. A model of radiation interception and use by a maize-bean intercrop canopy. Agric. For. Meteorol., 110: 203-215.

Worku, W., 2004. Maize-*tef* relay intercropping as affected by maize planting pattern and leaf removal in southern Ethiopia. Afr. Crop Sci. J., 12: 359-367.

Yadav, R.S. and O.P. Yadav, 2001. The performance of cultivars of pearl millet and clusterbean under sole cropping and intercropping systems in arid zone conditions in India. Exp. Agric., 37: 231-240.