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Agronomic Performance and Productivity of Common Bean (*Phaseolus vulgaris* L.) Varieties in Double Intercropping with Maize (*Zea mays* L.) in Eastern Ethiopia

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Abstract: Selection of appropriate varieties of component crops is important to maximize the productivity of double intercropping. Field experiments were conducted at Alemaya in 2003 and 2004 and at Hirna in 2004, eastern Ethiopia, to evaluate the agronomic performance of common bean (*Phaseolus vulgaris* L.) varieties in double intercropping with maize (*Zea mays* L.), select suitable common bean varieties for double intercropping and assess the productivity of the system. Common bean varieties were double intercropped with maize in *Belg* (short rainy season) and *Meher* (long rainy season). The common bean varieties on the average matured 15 days earlier during the *Belg* compared with the *Meher* season. Bean variety *MAM-25* matured at the earliest while *TY3396-12* was late and produced the highest number of nodules (78.3) per plant. Bean varieties grown in intercropping with maize showed significant differences in seed yield (kg ha^{-1}) in *Belg*. Sole cropped bean showed significantly higher leaf area index during *Meher* season in 2004 and higher number of nodules, pods and seed yield (kg ha^{-1}) than intercropped bean. The common bean varieties had no significant effect on LAI, height, number of ears and grain yield (kg ha^{-1}) of the associated maize, but harvest index at Alemaya in 2003. The total LERs indicated 25 to 66% yield advantage of double intercropping over sole cropping at Alemaya and 6 to 46% at Hirna. Double intercropping of common bean variety *Gofta* with maize gave the highest gross monetary value (6054.8 ETB ha^{-1} at Alemaya, 8097.1 ETB ha^{-1} at Hirna). The study proved the agronomic and economic feasibility of double intercropping of common bean with maize under smallholder farming system of eastern Ethiopia.

Key words: Double intercropping, land equivalent ratio, *Phaseolus vulgaris*, *Zea mays*

INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) is a food and cash crop grown under sole and various intercropping systems in the east and the great lakes region of Africa (Allen *et al*., 1989; Wortmann and Allen, 1994). It is an important and fast expanding legume that provides an essential part of the daily diet of most Ethiopians (Simane *et al*., 1989) and foreign earnings. The Hararghe highland in eastern Ethiopia is one of the major common bean production centers in Africa (Wortmann and Allen, 1994).

Intercropping, the simultaneous growing of two or more crops in space and time on the same land, is an important feature of cropping systems in the tropics (Francis, 1986; Connolly *et al*., 2001). Double intercropping is the growing of the associated crops or one of them twice in succession in a cropping season on the same field. The common bean and maize (*Zea mays* L.) intercropping is a common feature of crop production in densely populated areas of eastern Africa such as the highlands of Hararghe. The system is important for intensification of crop production and contributes to increased returns to smallholder farmers in the highlands of Hararghe having a limited land holdings (0.6 ha per household size of 5.4 members) (CACC, 2001).

The highlands of Hararghe have a bimodal rainfall distribution and a typical sub-humid, high altitude agro-climatic zone. The short *(Belg)* rainy season extends from April to June and receives 25% of the annual rainfall, whereas the long (*Meher*) rainy season extends from July to October and accounts for about 45% of the annual rainfall (Simane *et al*., 1998). In the Hararghe highlands of eastern Ethiopia, 91% of common bean and 64% of maize are grown in intercropping systems (Fininsa and Yuen, 2001). The productivity of such cropping system could further be improved by double intercropping of the common bean component in association with maize, as two harvests of common bean are possible during the growth period of maize.

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The short growth cycle (80-120 days) of common bean makes it best for double intercropping with maize. Increased productivity of common bean when intercropped once with maize than sole cropping in the Hararghe highlands (Fininsa, 1997; Tamado and Eshetu, 2000), efficient use of resources, minimized soil erosion and increased soil fertility of cereal-legume double cropping have been reported (Tanner *et al*., 1994; Buxton *et al*., 1998). In double intercropping, selection of appropriate varieties of the component crops is important to maximize complementary effects and productivity (Davis and Woolley, 1993). Common bean variety suitable for double intercropping should be able to mature in time to provide adequate period for succeeding variety. However, the performance of double intercropping and common bean varieties that are compatible with the season and which exhibit biological complementarity have not been determined, as the performance of varieties in double intercropping could be different than in sole cropping. The objectives of this study, therefore, were to evaluate the agronomic performance of common bean varieties in double intercropping with maize; select suitable common bean varieties for the system; and assess the productivity of the system.

MATERIALS AND METHODS

Description of experimental sites: Field experiments on common bean-maize double intercropping were conducted at Alemaya (in 2003 and 2004) and at Hirna (in 2004), experimental stations of Alemaya University, Ethiopia during the *Belg* and *Meher* seasons. The Alemaya (9° 26′N, 42° 3′E, 1980 m asl, average temperature 17°C, average annual rainfall 790 mm, fluvisol) is in eastern Hararghe zone while Hirna (9° 15′N, 41° 6′E, 1870 m asl, average temperature 24°C, average annual rainfall 1045 mm, vertisol) is in western Hararghe zone of eastern Ethiopia.

Test varieties: Seven best performing common bean varieties namely; *Ayenew*, *Roba-1*, *Gofta*, *MAM-25*, *A-197*, *TY3396-12* and *Red Wolaytta* (local check) were used. The varieties have bush type growth habit; vary in seed color and seed size. Under sole cropping, the varieties vary in their maturity period (78-110 days). A late maturing maize variety *Rarre-1* with white kernel and released for highlands of eastern Ethiopia was used as an associate cereal.

Treatments, trial design and management: Field trials were arranged in randomized complete blocks design in three replications. Each common bean variety was sown in double intercropping with maize. Respective double sole crops of the common bean varieties and the maize were included.

The maize variety was sown in mid-April at both locations and years on a plot size of 5.1×3.75 m (19.125 m^2) at 0.75 m inter- and 0.3 m intra-row spacings. Simultaneously, the common bean varieties were sown in between the maize rows at 0.11 m intra-row spacing. The bean-maize intercropping consisted of five rows of maize at rate of 44444 plants ha^{-1} (100% of sole maize population) and four rows of bean at rate of 125000 plant ha^{-1} (50% of sole bean population) as recommended for the sites (Tamado and Eshetu, 2000). Sole bean was sown at 0.4 m inter-row and 0.1 m intra-row spacing.

In *Meher*, the respective common bean varieties were sown on the same plot in July immediately after the harvest of the *Belg* sown bean in both sole and intercropping. Old and dead lower leaves (3-5) of maize were defoliated during the *Meher* common bean sowing to reduce the shading effect of maize on the bean. The central three rows of maize and four rows of common bean, in both sole and intercropping, were harvested in both seasons.

At time of maize sowing in *Belg*, all plots received a basal application of diammonium phosphate (DAP, 18% N, 20% P) at the rate of 100 kg ha^{-1}. At knee high growth stage of maize, N in the form of urea (46% N) was applied at the rate of 50 kg ha^{-1} to all plots except the sole common bean plots assuming the common bean would benefit from self-fixed N. Stalk borer (lepidopterous species) incidence on maize was managed by the application of cypermethrin 1% granules once at knee high (50-75 cm height). Hand weeding and frequent hoeing were done.

Belg sown common bean was harvested in mid July at Alemaya and late July at Hirna while *Meher* sown common bean was harvested in mid November at both locations. Maize was harvested in mid October at Alemaya and early November at Hirna. The maize grain yield was adjusted to 12.5% moisture level and that of common bean to 10%.

Data collection on common bean: For common bean varieties Leaf Area Index (LAI), number of nodules per plant, days to maturity (DM), number of pods per plant, number of seed per pod, 100 seed weight and seed yield were recorded. LAI was calculated as the ratio of total leaf area to ground area occupied by the plant. In determining LAI, all leaves on five randomly selected plants were detached at 50% flowering and their areas were determined using CID-202 leaf area meter (CID, Inc., USA). Ground area per plant was 400 cm^2 for sole bean and 800 cm^2 for intercropped bean.

Number of nodules and pods per plant were recorded from a count of 10 randomly sampled plants per plot at flowering and at harvest, respectively. Number of seeds per pod was recorded from 10 randomly sampled pods per plot at harvest. Hundred-seed weight was determined from randomly taken seeds at harvest by adjusting to 10% moisture content.

Data collection on maize: Maize height was measured from five randomly sampled plants per plot from ground level to terminal stem at tasseling. The leaf area was determined as leaf length (L) x maximum leaf width (W) x 0.733 as described by McKee (1964). Then LAI was calculated as the ratio of total leaf area (cm^2) of the plant to the ground area (2250 cm^2). Thousand Kernel Weight (TKW) was determined after weighing 1000 kernels at 12.5% moisture content. The seeds were counted using electronic seed counter from a sample of threshed seeds from each plot after harvest. Harvest index was calculated as the ratio of grain yield to above ground dry biomass.

Productivity and monetary value of the system: Land Equivalent Ratio (LER), the relative land area required as sole crop to produce the same yield as an intercrop, was used to assess the productivity of the double intercropping to that of sole cropping using the formula described by Willey (1979). Land equivalent ratio

$$(LER) = \sum_{i}^{n} \frac{YiI}{Yim}$$

where n is the number of crop species, YiI is the yield of ith species in intercropping and Yim is the yield of ith species in sole cropping. The *Meher* sole bean yield was considered as a basis for comparison due to the fact that bean is normally grown in *Meher* season in eastern Ethiopia and the main research question was to compare the productivity of double intercropping of bean with the standard farmers' practice.

Gross Monetary Value (GMV) was calculated from the yield of maize and bean by multiplying yields of the component crops by their respective market price. During December 2004, the prices for maize and common bean were 1.3 and 1.5 Ethiopian Birr (ETB) per kg, respectively at Harar grain market (1 ETB ≈ 0.12 USD in December 2004).

Data analysis: Analysis of variance (ANOVA) was performed using STATISTICA computer software (StatSoft, 1999) for all data collected in different seasons and locations separately as the seasons and locations are quite different. Least Significance Difference (LSD) test at 5% probability level was used for mean comparison when the ANOVA showed significant difference.

RESULTS

Days to maturity, LAI and nodulation of common bean: Days to maturity (DM) was not significantly affected by cropping system. However, it varied significantly ($p<0.05$) among varieties in intercropping in *Belg* at Alemaya and in *Meher* at Hirna (Table 1). Bean variety *MAM-25* matured at the earliest (80 days in *Belg* at Alemaya and 89 days in *Meher* at Hirna) while the variety *TY3396-12* matured late at both sites and seasons. On average, the varieties matured 15 days earlier in *Belg* compared with the *Meher* season at Hirna. However, it was not possible to determine the days to maturity of bean at Alemaya in 2004 due to frost occurrence towards maturity of bean.

The varieties did not show significant differences in their LAI in both locations and seasons except during *Meher* season at Alemaya where the bean variety *TY3396-12* gave the highest LAI of 1.56 in intercropping (Table 1). Sole cropped bean showed significantly ($p<0.05$) higher LAI than intercropped bean during *Meher* season both at Alemaya and Hirna in 2004.

Mean number of nodules counted in *Belg* season were lower than that of the *Meher*. Although nodulation was not significantly affected by cropping system in seasons and locations, higher number of nodules were counted from sole cropped bean than intercropped bean. The varieties were also not significantly different in their number of nodules when grown in intercropping except in *Meher* season at Alemaya in 2004. Bean variety *TY3396-12* produced the highest number of nodules (78.3) per plant in *Meher* at Hirna.

Yield and yield components of common bean: Common bean seed yield (kg ha^{-1}) significantly ($p<0.05$) varied among varieties in *Belg* and between sole and intercropped bean in both seasons in 2003 at Alemaya (Table 2). The yield of the varieties under the intercropping ranged from 318.0 kg ha^{-1} for *Gofta* to 581.3 kg ha^{-1} for *Red Wolaytta* in *Belg* season. In contrast, *Meher* season and total yields were not significantly different among the varieties. However, sole cropped bean gave significantly higher *Belg*, *Meher* and total yields (Table 2). Number of pods $plant^{-1}$ and number of seed pod^{-1} were not significantly different among the varieties and between cropping systems in both seasons.

In 2004, *Belg*, *Meher* and total yields at Alemaya as well as *Belg* season yield at Hirna were significantly different among the varieties grown in intercropping with maize (Table 3). However, the performance of the varieties over seasons and locations was not consistent. For instance, variety *A-197* yielded the highest (996 kg ha^{-1})

Table 1: Days to maturity, LAI and number of nodules per plant of common bean varieties grown in intercropping with maize (M) and in sole crop during *Belg* and *Meher* seasons of 2004 at Alemaya and Hirna

	Days to maturity		Leaf area index		No. of nodules	
Treatments	*Belg*	*Meher*	*Belg*	*Meher*	*Belg*	*Meher*
Alemaya						
Varieties of bean						
M + *MAM-25*	79.7	NR	1.62	0.82	9.4	18.1
M + *Ayenew*	89.0	NR	1.38	0.60	16.9	24.7
M + *Roba-1*	89.0	NR	1.63	0.95	4.7	26.4
M + *A-197*	83.7	NR	1.27	1.06	12.7	11.4
M + *Gofta*	85.0	NR	1.40	0.99	5.6	15.5
M + *TY3396-12*	94.7	NR	1.46	1.56	5.5	25.3
M + *Red Wolaytta*	88.3	NR	2.26	0.74	8.7	21.4
LSD (0.05)	7.7	NR	ns	0.52	ns	9.4
Cropping system						
Sole bean	86.6	NR	1.67	2.39	10.0	23.6
Intercropped bean	87.1	NR	1.57	0.96	9.1	20.4
LSD (0.05)	ns	NR	ns	1.30	ns	ns
Hirna						
Varieties of bean						
M + *MAM-25*	75.3	89.0	1.74	2.14	7.1	27.3
M + *Ayenew*	75.0	91.7	2.29	1.65	11.1	58.9
M + *Roba-1*	78.0	91.0	1.96	2.22	6.9	41.5
M + *A-197*	73.7	91.7	1.57	1.67	6.1	33.5
M + *Gofta*	75.7	91.7	1.72	1.09	5.1	38.4
M + *TY3396-12*	80.0	96.0	2.71	1.59	15.4	78.3
M + *Red Wolaytta*	79.0	92.3	1.14	1.54	12.3	54.8
LSD (0.05)	ns	1.5	ns	ns	ns	ns
Cropping system						
Sole bean	78.1	92.4	2.17	2.32	9.7	57.5
Intercropped bean	76.7	92.0	1.88	1.70	9.1	47.5
LSD (0.05)	ns	ns	ns	0.51	ns	ns

NR = Not Recorded

Table 2: Number of pods per plant, number of seeds per pod and seed yield of common bean varieties grown in intercropping with maize (M) and in sole crop during *Belg* and *Meher* seasons of 2003 at Alemaya

	No. of pods		No. of seeds		Seed yield (kg ha^{-1})		
Treatments	*Belg*	*Meher*	*Belg*	*Meher*	*Belg*	*Meher*	Total
Varieties of bean							
M + *Ayenew*	17.7	5.0	5.0	4.0	373.3	563.3	936.7
M + *Roba-1*	16.0	5.7	6.3	3.7	524.7	290.0	814.7
M + *A-197*	11.7	6.7	4.7	3.7	414.0	564.7	978.7
M + *Gofta*	10.7	5.7	6.0	4.0	318.0	428.3	746.3
M + *TY3396-12*	16.7	7.3	5.3	4.0	472.0	530.3	1002.3
M + *Red Wolaytta*	14.7	6.0	4.7	4.0	581.3	497.0	1078.3
LSD (0.05)	ns	ns	ns	ns	202.4	ns	ns
Cropping system							
Sole bean	14.6	7.8	5.3	4.1	677.7	1153.3	1763.3
Intercropped bean	13.8	6.1	5.0	3.9	521.0	478.9	926.2
LSD (0.05)	ns	ns	ns	ns	144.6	313.1	661.9

in *Belg* but ranked 6th in *Meher* season at Alemaya. Variety *Gofta* showed relatively higher yield performance both in *Belg* and *Meher* seasons at Hirna. Similarly, variety *TY3396-12* showed consistently better performance in the *Meher* season at both sites. At both locations and seasons, sole cropped bean gave significantly higher yields (Table 3). Likewise, the varieties revealed significant differences in their hundred seed weight showing that seed weight is a varietal character which is less influenced by management practices. In contrast, number of pods plant^{-1} was not significantly different among the varieties and between cropping systems except during *Meher* season at Hirna where variety *TY3396-12* produced the highest number of pods per plant (11.6) compared to other varieties.

Maize component: The LAI of the maize variety *Rarre-1* grown in association with the common bean varieties during the *Belg* and *Meher* seasons at both locations was not significantly different (Table 4). However, sole cropped maize had higher LAI (mean = 4.08) than intercropped maize (mean = 3.41). Similarly, the common bean varieties grown in association had no significant effect on the height of maize in both years and

Table 3: Number of pods per plant, hundred seed weight and seed yield of common bean varieties grown in intercropping with maize (M) and in sole crop during *Belg* and *Meher* seasons of 2004 at Alemaya and Hirna

	No. of pods		Hundred seed weight (g)		Seed yield (kg ha^{-1})		
Treatments	*Belg*	*Meher*	*Belg*	*Meher*	*Belg*	*Meher*	Total
Alemaya							
Varieties of bean							
M + *MAM-25*	12.2	10.5	38.7	37.7	776.0	787.0	1563.0
M + *Ayenew*	12.9	12.0	43.3	41.7	640.3	825.3	1465.7
M + *Roba-1*	15.1	14.2	20.0	17.3	680.7	502.3	1183.0
M + *A-197*	10.3	10.1	55.0	38.7	996.0	453.0	1449.0
M + *Gofta*	11.3	8.9	40.3	38.3	884.0	592.7	1476.7
M + *TY3396-12*	13.1	13.5	24.3	25.3	493.0	792.0	1285.0
M + *Red Wolaytta*	12.5	11.8	27.0	20.0	788.7	430.0	1218.7
LSD (0.05)	ns	ns	9.1	12.0	132.7	217.4	287.3
Cropping system							
Sole bean	13.1	13.7	32.8	31.4	1680.5	2081.5	3762.0
Intercropped bean	12.5	11.6	35.5	31.3	751.2	626.1	1377.3
LSD (0.05)	ns	ns	ns	ns	274.4	174.1	345.5
Hirna							
Varieties of bean							
M + *MAM-25*	14.1	7.0	37.3	44.0	413.3	652.7	1066.0
M + *Ayenew*	15.5	8.1	41.3	47.0	571.0	755.3	1326.3
M + *Roba-1*	14.0	7.6	24.7	22.0	822.3	649.7	1472.0
M + *A-197*	8.5	6.0	48.3	61.3	675.3	527.3	1202.7
M + *Gofta*	14.2	8.3	35.3	41.0	912.3	770.3	1682.7
M + *TY3396-12*	15.9	11.6	26.0	33.0	513.0	945.0	1458.0
M + *Red Wolaytta*	15.0	9.1	21.0	23.7	460.7	625.0	1085.7
LSD (0.05)	ns	3.5	5.4	3.6	366.7	ns	ns
Cropping system							
Sole bean	13.9	15.5	32.3	36.3	972.9	3035.6	4008.6
Intercropped bean	12.6	8.2	33.4	38.9	624.0	798.9	1422.9
LSD (0.05)	ns	5.4	ns	ns	145.3	348.6	430.8

Table 4: Leaf area index, days to maturity and plant height of maize (M) grown in intercropping with common bean varieties and in sole crop at Alemaya and Hirna in 2004

	Leaf area index		Days to maturity		Plant height (cm)	
Treatments	Alemaya	Hirna	Alemaya	Hirna	Alemaya	Hirna
M + *MAM-25*	3.11	3.97	138.0	148.0	173.7	187.7
M + *Ayenew*	2.85	3.42	140.7	148.0	158.3	189.3
M + *Roba-1*	3.52	3.12	142.3	150.0	167.3	179.3
M + *A-197*	2.85	3.55	141.0	148.0	162.0	181.7
M + *Gofta*	3.02	4.03	142.3	146.3	185.7	197.0
M + *TY3396-12*	3.26	4.40	141.3	146.3	176.0	190.0
M + *Red Wolaytta*	3.12	3.56	142.3	147.0	190.3	196.3
Sole maize	3.87	4.29	138.0	148.0	170.7	194.3
LSD (0.05)	ns	ns	2.3	ns	ns	ns

locations (Table 4 and 5). The maize matured within 138 to 150 days and it was significantly different at Alemaya in 2004 where sole maize and maize grown in association with early maturing bean variety *MAM-25* matured early (138 days).

In 2003, number of maize ears and grain yield (kg ha^{-1}) were not significantly affected by the associated common bean varieties except the harvest index (HI). The highest HI (0.47) was obtained from maize grown in intercropping with bean variety *TY3396-12* and the lowest HI (0.32) was from sole cropped maize (Table 5). In 2004, the associated bean varieties did not have significant effect on thousand kernel weight (TKW) and HI of maize (Table 6). However, the associated bean varieties had a significant effect on maize grain yield at Hirna (Table 6). At both years and locations sole maize gave higher yields than growing in intercropping (Table 5 and 6).

Productivity and monetary values of double intercropping: Productivity of double intercropping was evaluated using total LER as index. In 2003, the total LER among the various intercropping combinations was not significant. However, in 2004 the total LER values were significantly different at both locations (Table 7). In 2003, the total LERs ranged from 1.28 (for *Roba-1*) to 1.66 (for *Red Wolaytta*) indicating 28 to 66% relative yield advantage of double intercropping over sole cropping of the component crops, while in 2004 the relative yield advantage ranged from 25 to 53% at Alemaya and from

Table 5: Plant height, number of ears per plant, grain yield and harvest index of maize (M) grown in intercropping with common bean varieties and in sole crop at Alemaya in 2003

Treatments	Plant height (cm)	No. of ears per plant	Grain yield (kg ha^{-1})	Harvest index
Varieties of bean				
M + *Ayenew*	196.00	2.00	1990.0	0.35
M + *Roba-1*	175.00	2.00	2163.3	0.38
M + *A-197*	201.00	2.33	2140.0	0.36
M + *Gofta*	179.00	2.00	2436.7	0.41
M + *TY3396-12*	196.67	2.00	2170.0	0.47
M + *Red Wolaytta*	199.33	1.67	2793.3	0.44
Sole maize	199.00	2.33	3778.3	0.32
LSD (0.05)	ns	ns	ns	0.08

Table 6: Thousand kernel weight, grain yield and harvest index of maize (M) grown in intercropping with common bean varieties and in sole crop at Alemaya and Hirna in 2004

	Thousand kernel weight (g)		Grain yield (kg ha^{-1})		Harvest index	
Treatments	Alemaya	Hirna	Alemaya	Hirna	Alemaya	Hirna
M + *MAM-25*	418.7	378.3	1725.67	3650.00	0.42	0.26
M + *Ayenew*	382.3	403.3	2512.00	4300.00	0.38	0.33
M + *Roba-1*	408.3	363.7	2387.33	3824.00	0.29	0.31
M + *A-197*	400.3	382.3	2644.00	3447.67	0.44	0.25
M + *Gofta*	421.7	397.0	2953.67	4287.00	0.47	0.30
M + *TY3396-12*	415.7	383.0	2803.00	3649.00	0.45	0.24
M + *Red Wolaytta*	407.3	370.0	2765.67	3416.00	0.37	0.31
Sole maize	420.0	366.0	3550.67	4875.33	0.44	0.32
LSD (0.05)	ns	ns	ns	893.33	ns	ns

Table 7: Total land equivalent ratios (LER) and monetary value of maize and common bean grown in intercropping and sole cropping at Alemaya in 2003 and 2004 and at Hirna in 2004

	Total LER			Monetary value (ETB ha^{-1})*		
Treatments	Alemaya 2003	Alemaya 2004	Hirna 2004	Alemaya 2003	Alemaya 2004	Hirna 2004
M + *MAM-25*	-	1.25	1.12	-	4587.9	6344.0
M + *Ayenew*	1.39	1.40	1.32	4279.4	5464.1	7579.5
M + *Roba-1*	1.28	1.25	1.28	4346.8	4878.0	7179.2
M + *A-197*	1.47	1.44	1.11	4559.1	5610.7	6286.0
M + *Gofta*	1.37	1.53	1.43	4711.3	6054.8	8097.1
M + *TY3396-12*	1.50	1.40	1.46	4637.9	5571.4	7930.7
M + *Red Wolaytta*	1.66	1.36	1.06	5652.3	5423.4	6069.3
Sole maize	1.00	1.00	1.00	5457.6	4615.9	6337.9
Sole bean	1.00	1.00	1.00	2644.9	5643.0	6012.9
LSD (0.05)	ns	0.31	0.16	ns	ns	983.3

* 1 ETB ≈ 0.12 USD in December 2004

6 to 46% at Hirna in 2004. However, the varieties did not show consistency in total LER over locations, seasons and years. For instance, bean variety *Red Wolaytta* gave the highest LER (1.66) in 2003 at Alemaya, but gave the lowest LER (1.06) at Hirna in 2004. On the other hand, bean varieties *Gofta* and *TY3396-12* gave consistently higher LER while the early maturing bean variety *MAM-25* gave lower LER at both locations in 2004.

The monetary values of double intercropping were evaluated by considering the amount of money that can be generated by growing sole common bean, sole maize or double intercropping common bean with maize. In 2003, at Alemaya, double intercropping of bean variety *Red Wolaytta* with maize gave the highest GMV of 5652.3 ETB ha^{-1} followed by sole maize (Table 7). In 2004, at Hirna double intercropping of bean with maize had a significant effect on GMV (Table 7). At both sites double intercropping of common bean variety *Gofta* with maize gave the highest GMV (6054.8 ETB ha^{-1} at Alemaya, 8097.1 ETB ha^{-1} at Hirna). On the other hand, the lowest GMV of 4587.9 ETB ha^{-1} was recorded when maize was double intercropped with early maturing bean variety *MAM-25* at Alemaya. Double cropping of sole bean gave the lowest GMV of 2644.90 ETB ha^{-1} at Alemaya in 2003.

DISCUSSION

Maturity, leaf area index and nodulation of bean: The performance of common bean varied between locations, seasons and years. For example, in *Belg* season, the common bean varieties compared to *Meher* season, matured earlier, had higher LAI, but produced lower number of nodules. In general, the LAI and number of nodules from intercropped bean were lower than sole cropped bean possibly due to the shading effect from the

cereal component. This result is in agreement with the report of Karikari *et al.* (1999) where they observed higher LAI in sole Bambara groundnut as compared to Bambara groundnut intercropped with pearl millet and maize. Similarly, Tamado and Eshetu (2000) reported significantly lower number of nodules for common bean grown in intercropping with maize and sorghum as compared to sole cropped bean and attributed this to shading by the cereal components. The variation also depends on the amount of seasonal rainfall as seasonal rainfall affects the use of soil moisture by the component crops, days to maturity and transfer of assimilates (Morris and Garrity, 1993). In high rainfall season (*Meher*) the common bean tends to be more vegetative and hence matures late. The production of nodules could also be affected by the seasonal rain and temperature that may affect the growth and physiology of the *rhizobium* bacteria. The varieties matured earlier at Hirna than at Alemaya possibly due to the higher mean temperature at the former site (24°C vs 17°C) which might have hastened growth and development. At both locations and seasons, sole cropped bean gave significantly higher yields than intercropped bean possibly due to absence of competition for growth resources from the cereal component and higher population in the sole crops.

Effect on maize component: Growing of common bean in double intercropping with maize had no significant effect on maize LAI, height, number of ears and grain yield as also reported for single intercropping by Davis and Garcia (1987) and Harwood *et al.* (2000). In contrast, significant yield reductions of maize intercropped with common bean were reported by other workers (Francis *et al.*, 1982; Fininsa, 1997). It appears that the late maturing maize variety *Rarre-1* used in these trials is highly competitive under the highlands of Hararghe conditions to withstand the competition effect of double intercropped common bean for resources and root spaces. However, the magnitude of the effect of common bean varieties on the performance of maize differed in double intercropping.

Productivity and monetary values: The productivity of the double intercropping as determined by total LER, in all combinations, was superior compared to sole cropping in resource use efficiency. The relative yield advantage of the double intercropping as indicated by total LER ranged from 6 to 66% as compared to growing of single cropping of the associated crops separately. This implies that double intercropping intensified crop production both in space and time. The total LER revealed that it would require 0.06 to 0.66 more units of land with the farmers' practice of single cropping of bean and maize to produce comparable yield to double intercropping of common bean with maize. The yield advantages from such intercropping are reported to be due to better utilization of both underground and above ground growth resources such as light, soil moisture, nutrients by the intercrops than sole crops (Willey, 1979; Rao and Willey, 1980; Ofori and Stern, 1987).

Early maturity is one of the characters required for selecting common bean varieties for double intercropping system. However, the early maturing (75 to 89 days) bean variety *MAM-25* showed poor compatibility for double intercropping with maize as compared to the late maturing (80 to 96 days) bean variety *TY3396-12* due to its low yield. The latter variety has higher total LER and GMVs over locations and years (Table 7). In addition *TY3396-12* was reported for its multiple disease resistance against major common bean diseases (Fininsa and Tefera, 2006). In general, the performance of varieties *Gofta* and *TY3396-12* under double intercropping was relatively better compared to other bean varieties evaluated.

Gross Monetary Value (GMV) was calculated by multiplying the respective yields of the component crops by their market prices and then adding the values of the component crops. The highest LER (1.53) and GMV (6054.8 ETB ha^{-1}) in 2004 at Alemaya was recorded when bean variety *Gofta* was double intercropped with maize. However, at Hirna in 2004, bean variety *TY3396-12* gave the highest LER (1.46), but the highest GMV of 8097.1 ETB ha^{-1} was recorded when bean variety *Gofta* was double intercropped with maize. This shows difference between agronomic and economic advantages from the intercropping system due to the price differences between the component crops and proves the need for economic evaluation of intercrop systems. Tamado and Eshetu (2000) also reported such discrepancy in agronomic and economic advantages in maize, sorghum and bean intercropping study. Sole bean gave the lowest GMV at Alemaya in 2003 and at Hirna in 2004 which also confirms farmers' justification of growing common bean mainly as an intercrop in eastern Ethiopia (Fininsa and Yuen 2001).

The present study indicated field based empirical evidence that double intercropping of common bean with maize in the highlands of Hararghe, eastern Ethiopia is feasible, productive and increases household income. The system is also known to enhance biodiversity, conserve soil moisture, avert crop failure risks and diversify crop harvest. Common bean-maize intercropping was also reported to reduce incidence and severity of common bean common bacterial blight (caused by *Xanthomonas campestris* pv. *phaseoli*) and rust (caused by *Uromyces appendiculatus*) (Fininsa, 1996; Fininsa and Yuen, 2002) in Hararghe highlands.

Among the bean varieties evaluated for double intercropping with maize, varieties *Gofta* and *TY3396-12* were found to be compatible. As soil moisture has great significance in double cropping system, study related to soil moisture and possibility of early planting of common bean and late planting of maize to reduce the competition of maize component on the bean might be investigated as a planting schedule in double cropping system at both sites.

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