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Performance variation among improved common bean (*Phaseolus vulgaris* L.) genotypes under sole and intercropping with maize (*Zea mays* L.)

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Periodic assessment of released common bean cultivars is essential to screen genotypes that offer superior intercropping advantage to farmers when grown in association with maize. Thus, comparative performance of improved genotypes representing commonly used growth habit and market classes were investigated under sole and intercropping system at Halaba special district, Southern Ethiopia. Treatments consisted of a factorial combination of seven common bean genotypes and two cropping systems, which were arranged in a split plot design replicated three times. Cropping system and genotype were assigned as main and sub plot factors, respectively. Cropping system by genotype interaction was significant for bean grain yield and two of the yield components causing moderate changes in ranking. Relative yield reduction due to association with maize varied from 26% for genotype Sari-1 (Type II) to 67% for Awash Melka (Type III), while maize suffered a smaller reduction, 7%. The total Land Equivalent Ratio (LER) values under intercropping with maize ranged from 1.34 for the improved Hawassa Dume (Type II) to 1.01 for the local cultivar, Red Wolayita (Type III). Genotypes with greater LER were not necessarily all top yielders under sole cropping, because of the genotype by cropping system interaction. Bush and semi bush (Type I and II) types produced the highest intercropping advantage, as a group. The two export bean types, which have a semi climbing (Type III) growth pattern, had the lowest LER values among the improved genotypes. Genotypes such as Hawassa Dume and Sari-1 are preferred to the conventionally used cultivars for maximizing intercropping advantage. Developing bush type export genotypes may help broaden their expansion outside their traditional zones since better performance under intercropping could attract more farmers to adopt them.

Key words: Bush types, genotype, interaction, intercropping efficiency, semi climbing types.

INTRODUCTION

Intercropping, the agricultural practice of cultivating two or more crops in the same space at the same time is an old and commonly used cropping practice which aims to match efficiently crop demands to the available growth

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resources and labor (Lithourgidis et al., 2011). Intercropping has been found to be advantageous in maximizing land use efficiency through efficient use of resources like moisture (Coll et al., 2012), nutrients and light (Awal et al., 2006) and also reduced pest and disease problems (Theunissen and Schelling, 1996). It is also a viable strategy to stabilize yield through risk minimization of crop failure from unfavorable environmental conditions. Intercropping has been shown to produce higher and more stable yields in a wide range of crop combinations, while the system is characterized by minimal use of inputs such as fertilizers and pesticides, emphasizing the production of healthy, safe, and high quality food in the context of environmentally sound production (Lithourgidis et al., 2011). Intercropping may contribute to reduction of greenhouse gas emissions thereby allowing a more sustainable production system by mitigating climate change. Reduced greenhouse gas emissions have been reported from cereal-legume intercrops compared to their sole counterparts (Dyer et al., 2012; Huang et al., 2013). Thus, intercropping can be considered as one of the strategies of climate smart agriculture to achieve nutrient and food security under changing climate particularly to those small farmers constrained by land scarcity.

Intercropping for food grain production is widely practiced by small farmers who significantly contribute to food security but constrained by land and inputs in Africa (Dakora, 1996; Tsubo et al., 2005). Intercropping is a common practice in many areas of Africa as part of traditional farming systems commonly implemented in the area due to declining land sizes and food security needs (Dakora, 1996). In Ethiopia, it is a familiar practice of crop production in densely populated areas such as southern Ethiopia. Arable land scarcity is an acute problem in southern Ethiopia due to high population pressure where 49% of farmers have an average land holding of 0.1 to 0.5 ha with a further 21% having 0.51 to 1 ha (CSA, 2015). Two of the popular component crops for intercropping in the region are maize and common bean as principal and subsidiary crops, respectively.

The advantages of intercropping can easily be constrained depending on various factors such as suitability of cultivars for intercropping, soil moisture levels, component interactions and competition for resources (Dakora, 1996). 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 (Worku, 2008). According to Davis et al. (1986), bush bean is less competitive, easy to harvest and suitable for both sole and intercropping while climbers are more aggressive and reduce maize yield.

Many studies have shown yield reduction when beans are grown with maize under intercropping (Gebeyehu et al., 2006; Tana et al., 2007; Worku, 2008). On the other hand, the magnitude of intercropping efficiency depends largely on the performance of the associated beans. Thus, it is necessary to screen and select suitable bean genotypes in order to maximize advantage from intercropping. In southern Ethiopia, a semi climbing red seeded local bean cultivar has been the favorite component among farmers for intercropping with maize. More than 30 improved bean genotypes of diverse growth habit have been released in the country. Adoption of some of the varieties has been gaining momentum under sole cropping while the local cultivar is still widely used for intercropping. It is, thus, important to investigate how the improved varieties perform under sole and intercropping environments in order to screen for compatible genotypes. As is common in most breeding programs, the cultivars have been tested and selected for their performance under sole cropping environment. Plant genotypes are rarely developed for mixed cropping systems despite the potential of these systems to provide multiple ecosystem services (Isaacs et al., 2016). Significant cropping system by genotype interactions have been reported from maize-bean intercropping (Hauggaard-Nielsen and Jensen, 2001; Atuahene-Amankwa et al., 2004; Gebeyehu et al., 2006) whereas Worku (2008) has not observed a significant interaction. Differences in growth habit and morphology of the component bean genotypes involved may have contributed to reported differences in the response of genotypes to cropping systems (Worku, 2008). Thus, this investigation was conducted to assess the response of released common bean genotypes to component performance and intercropping efficiency and identify suitable genotypes, under intercropping with maize.

MATERIALS AND METHODS

Description of the study site

The experiment was conducted on a farmer's field at Halaba special district, during the 2013 cropping season under rainfed condition. The site is located at 7° 3" N latitude and 38°10"E longitude with an elevation of 1788 m above sea level. The mean annual rainfall of the area ranges from 857 to 1085 mm while annual mean temperature varies from 17 to 20°C.The experimental crops received a well distributed total rainfall of 780 mm, which was greater by 38% against the long term average (Table 1). As a result, the season was conducive for the growth of both crops in terms of moisture and temperature. Analysis of soil sample before planting indicated that the soil has clay loam texture with a pH of 6.4, which are not limiting for growth of the component crops.

Treatments and experimental design

The treatments were made from a combination of two factors: cropping systems and common bean genotypes. Cropping systems consisted of intercropping and sole cropping while the genotypes included six improved varieties and one popular local variety (Red Wolayita) and consisted of determinate and indeterminate bush and indeterminate semi climber types (Table 2). A late maturing maize hybrid variety, Shone Pioneer, and the seven common bean genotypes were factorially combined under the two cropping

Table 1. Weather condition and mean rainfall of the experimental site during the crop growth period[(a).]

Month	Temperature (°C)		Rainfall (mm)	
	Minimum	Maximum	2013	2003-2012
April	15.1	29.9	132.3	129.5
May	14.6	28.0	123.1	98.2
June	15.4	26.1	167.4	92.0
July	16.6	24.6	131.4	125.2
August	17.6	24.9	178.1	118.5
September	17.4	28.2	138.8	112.8
October	16.7	29.0	118.9	49.3

[(a)]The crop growth period was from 27 April to 07 October 2013.

systems. The experiment was laid out in a split plot design with three replications. Cropping systems and common bean genotypes were assigned as main plot and sub-plot factors, respectively. Also, sole maize crop was included for standardization under each replication.

Experimental procedures and crop management

Both maize and common bean crops were planted together on 27th of April 2013. Common bean seeds were obtained from Hawassa Agricultural Research Centre except the local variety which was obtained from farmers in the study site. The maize variety was obtained from Halaba Agriculture and Rural Development Office. Maize seeds were sown at 0.8 m inter-row and 0.3 m intra-row spacing under intercropping and sole cropping systems. Common bean varieties were planted at 0.4 and 0.1 m inter-row and intra-row spacing, respectively under both cropping systems. The spatial arrangement was 1:2, where two rows of common bean were planted between successive rows of maize. The two components were associated with their full sole density, which were, 41,666 plants ha^{-1} for maize and 250,000 plants ha^{-1} for common bean. The distances that separated sub plots, main plots and blocks were 0.5, 1 and 1.5 m, respectively. The plot sizes for intercrop and sole crops were 4.8 m wide and 3 m long (14.4 m^2).

Intercropped and maize sole crop plots received nitrogen and phosphorus fertilizers recommended for sole maize production. The common bean component did not receive any additional fertilizer. Intercropped and sole maize plot received phosphorus fertilizer at a rate of 20 kg P ha^{-1} just before planting. Also, nitrogen was applied at the rate of 64 kg ha^{-1} as split application: 18 kg ha^{-1}at planting and the remaining 46 kg ha^{-1} at knee height. Sole common bean plots received 20 kg ha^{-1} P and 18 kg ha^{-1} N as a single dose during sowing. Urea (46-0-0) and Di-ammonium phosphate (18-46-0) were used as sources of N and P nutrients. Weeds were removed as often as required. Stalk borer infestation of maize was controlled by spraying Lambda Cyhalotrin (karate) 5% EC at the rate of 16 g a.i. in 300 L water ha^{-1}, twice at fifteen days interval before tasseling.

Data collection and analyses

Yield and yield components

Common bean: Average number of mature pods was counted at harvest from six randomly taken plants. Number of seeds per pod was determined from 15 randomly selected pods. Hundred randomly taken seeds were used to determine seed weight. Grain yield was determined from eight central rows (3.2 m × 3 m = 9.6 m^2) and was adjusted to 10.5% seed moisture content.

Maize: Number of ears per plant, number of seed rows per ear and number of seeds per row were recorded from six randomly taken plants from the central harvested rows. Hundred randomly taken seeds were used to determine grain weight. Four central rows (3.2 m × 3 m = 9.6 m^2) were used to determine grain yield, which was adjusted to 12.5% seed moisture content.

Intercropping efficiency

The land equivalent ratio (LER) method was used to assess the efficiency of the intercropping system (Mead and Willey, 1980).

Total LER = Yim/Ysm + Yib/Ysb

where *Yim* and *Yib* are intercrop yields of maize and common bean, respectively and *Ysm* and *Ysb* are yields of maize and common bean grown as sole crop, respectively.

Land equivalent ratio indicates relative land area under sole crop required to produce the same yield as obtained under intercropping system at the same level of management. To minimize unwanted variation among the ratios and identify the most productive association, yield of the best sole crop bean genotype was used as standardization factor instead of individual sole crop yields of genotypes (Mead and Willey, 1980; Oyejola and Mead, 1982; Gebeyehu et al., 2006).

The main and interaction effects of genotypes and cropping systems on yield, yield components and intercropping efficiency of component crops were determined by analysis of variance using SAS Software (SAS, 2008). Least significant difference (LSD) test was used to separate the means when the analysis of variance indicated presence of significant differences (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Common bean

Grain yield

Both main effects and interaction between genotype and cropping system significantly influenced grain yield

Table 2. Agro-morphological characteristics of common bean genotypes used in the experiment.

Genotypes	Year released	Growth habit[(b)]	Days to maturity	Purpose of production	Seed size	Seed color
Sari-1	2011	Indeterminate bush (Type II)	85-95	Domestic consumption	Small	Dark red
Hawassa Dume	2008	Indeterminate semi bush (Type II)	85-90	Domestic consumption	Small	Dark red
Ibbado	2003	Determinate bush (Type I)	85-90	Domestic consumption	Large	Speckled red
Omo-95	2003	Indeterminate semi climber (Type III)	90-120	Domestic consumption	Small	Dark red
Awash Melka	1998	Indeterminate semi climber (Type III)	90-100	Export	Small	White
Awash-1	1990	Indeterminate semi climber (Type III)	90-100	Export	Small	White
Red Wolayita (Local)	1974[(a)]	Indeterminate semi climber (Type III)	90-100	Domestic consumption	Small	Red

[(a)]Recommended; [(b)]Based on Singh (1982).

(Table 3). As a result, there were moderate changes in performance rankings of genotypes under sole and intercropping systems (Table 4). The genotype Hawassa Dume was the top yielder followed by Ibbado and Awash-Melka, with the latter two having similar yields, under sole cropping. Performance of Hawassa Dume was equivalent to Sari-1 under intercropping and this was followed by Ibbado and Omo-95. The least performers rank included Sari-1, Awash-1 and Red Wolayita for sole cropping while Awash-Melka, Awash-1 and Red Wolayita were the lowest for the intercropping system. The genotype that showed exceptional characteristic was Sari-1, which had a top yield under intercropping in spite of its place in the lower group of genotypes under sole cropping. Relative yield losses under intercropping compared to sole cropping varied from 26% for Sari-1 to 67% for Awash Melka. The observed yield loss could be attributed to the severe impact of shading by the taller maize plant. The favorable environment in terms of one of the vital resources, moisture, may have contributed to the vigorous maize growth leading to severe shading. For instance, Tsubo and Walker (2003) reported that the taller maize canopy at a density of 6.67 plant m^{-2} reduced incident radiation on the top of intercropped bean canopies by up to 90% decreasing total dry matter of beans by 67% at the end of the growing season.

Distribution of growth habit groups among the performance rankings showed variation between the two cropping systems. There was a more equitable distribution of genotypes from the different growth habit groups under sole cropping while some patterns were observed under intercropping. Accordingly, the bush and semi bush types dominated the top and medium performance ranks while the poor performers cluster was made from semi climbing types under intercropping. Similarly, Worku (2008) has observed that bush types were better than semi climbing types and suggested that their improved performance could be attributed to better light distribution throughout their canopy as a result of their upright growth. Moreover, semi climbing types tend to twine on maize when intercropped and this makes them grow beneath the maize leaves where shading is at its severest. Also, Davis et al. (1986) observed that bush beans are less competitive, easy to harvest and suitable for both sole and intercropping while climbers are more aggressive and reduce maize yield.

Genotype by cropping system interactions have been reported in maize-groundnut (Tefera and Tana, 2002), maize-common bean (Davis and Gracia, 1983; Atuahene-Amankwa et al., 2004; Gebeyehu et al., 2006) and barley-pea (Hauggaard-Nielsen and Jensen, 2001) intercropping systems. Padi (2007) and Worku (2008) in sorghum-cowpea and maize-bean intercropping have not observed significant interaction respectively. 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. Genotype by cropping systems interactions may basically indicate the necessity of screening bean cultivars specifically for the intercropping environment though it is necessary to examine how large and important the interaction is.

Yield components

Number of pods per plant, number of seeds per pod and seed weight varied significantly among genotypes but only number of pods per plant and seed weight have been significantly influenced by cropping systems and its interaction with

Table 3. Analysis of variance on yield and yield components of common bean genotypes under sole and intercropping with maize at Halaba.

Source of variation	DF	Grain yield (t ha^{-1})	Pod no. plant^{-1}	Seed No. pod^{-1}	Hundred seed weight (g)	Total biomass (t ha^{-1})
Replication	2	0.0532^{ns}	0.880^{ns}	0.285^{ns}	2.590^{ns}	0.30^{ns}
Cropping syst. (CS)	1	18.586***	814.8***	1.928^{ns}	104.02*	138.2**
Error a	2	0.0332	0.1666	0.2857	1.63	0.377
Genotype (GEN)	6	1.272***	31.706***	2.261***	1085.78***	3.81***
CS×GEN	6	0.299***	41.88***	0.039ns	4.78*	6.36***
Error b	24	0.0295	2.496	0.2579	1.72	0.48

*, **, ***Indicate significance at 5, 1 and 0.1% probability levels, respectively; ns, non-significant.

Table 4. Grain yield (t ha^{-1}) of common bean genotypes under sole cropping and intercropping with maize.

Cropping system	Genotypes						
	Hawassa Dume	Sari-1	Ibbado	Omo-95	Awash Melka	Awash-1	Red Wolayita
Sole	3.60	2.09	2.82	2.48	2.78	1.97	1.95
Intercrop	1.83	1.55	1.29	1.25	0.92	0.85	0.68
% Reduction	49	26	54	50	67	57	65
$Lsd_{5\%}$ = 0.34	-	-	-	-	-	-	-

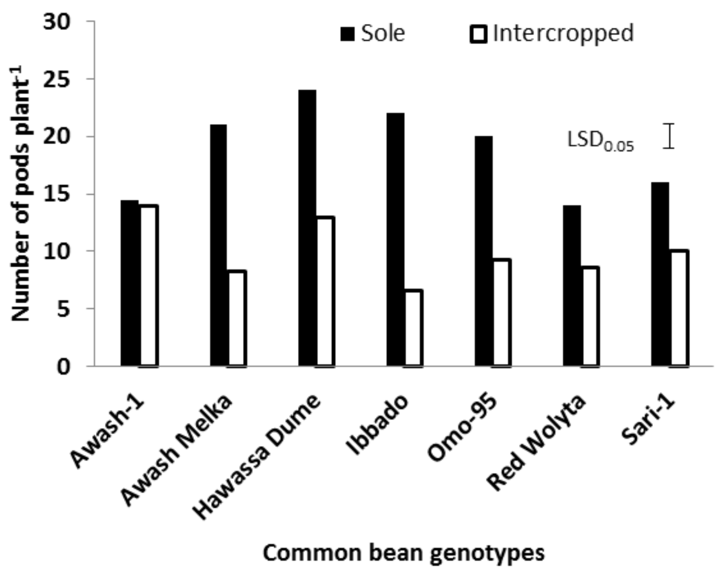

Figure 1. Interaction effect of common bean genotypes and cropping system on number of pods plant^{-1}.

genotype (Table 3). All genotypes except Awash-1, suffered a significant reduction in number of pods per plant when grown under intercropping ranging from 38% for Sari-1 to 70% for Ibbado (Figure 1). The relationship between grain yield and number of pods per plant was significant under sole cropping (r = 0.86***), while it was not under intercropping. Thus, rankings for pod number per plant followed mostly that of grain yield under sole cropping.

The determinate bush genotype, Ibbado, had the smallest seed number and the heaviest seed weight (Data not shown). The other genotypes produced

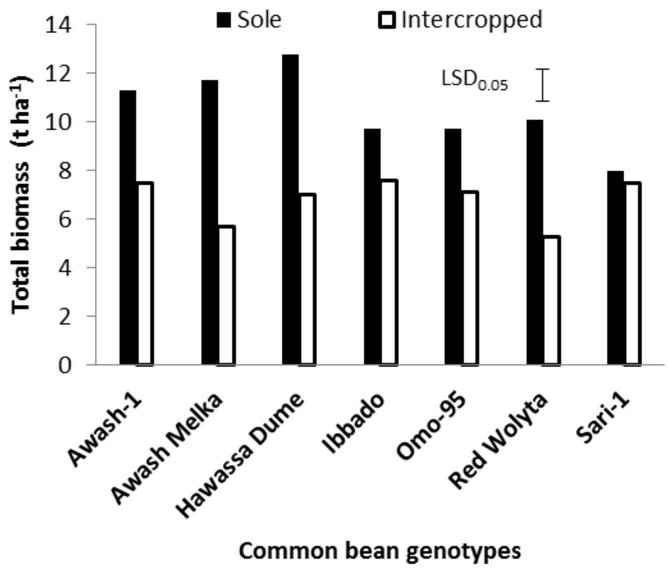

Figure 2. Effect of genotype by cropping system interaction on total biomass of common bean.

similarly greater number of seeds per pod but smaller seed size. Intercropping slightly depressed seed weight compared to sole cropping, though the extent varied among genotypes (Data not shown). The variation among common bean genotypes for number of seeds per pod and seed weight could be attributed to genetic differences. Both seed weight and seed number per pod were less influenced by intercropping when compared with number of pods per plant.

Total biomass

Total biomass was significantly influenced by genotype, cropping systems and their interaction (Table 3). Greater biomass was obtained from genotypes Awash Melka and Hawassa Dume under intercropping while the lowest came from Red Wolayita (Figure 2). The other genotypes gave an intermediate amount of biomass under a similar cropping system. All genotypes suffered loss of biomass when intercropped except Sari-1. However, the magnitude of the effect varied remarkably differing from 51% loss for Awash Melka to 22% for Ibbado. Overall, those cultivars with better productivity under sole cropping suffered a much severe loss when intercropped.

Maize

Grain yield and yield components

Maize grain yield was reduced significantly due to its association with common bean (Table 5). The mean yield loss amounted to 7%. The yield loss was related with a concomitant drop in yield components such as number of seeds per row and seed weight (Table 6). The influence of the associated bean on maize yield did not vary significantly among the genotypes.

All the genotypes showed a moderate impact on maize performance with absence of either over-aggressive or non-competitive types. Reports on the impact of intercropping on maize performance are mixed. The result agrees with the findings of Worku (2014) who recorded a 16% yield loss from simultaneous intercropping with bean in a sub-humid environment. David and Gracia (1983) reported a 15% loss in a wetter area while the decline was as much as 30% in a drier area for a similar simultaneous intercropping. Muraya et al. (2006) and Worku (2008) did not observe significant yield reduction from a maize-common bean simultaneous intercropping. The bean component may not have exerted 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 (Muraya et al., 2006). In other studies, maize yield did not suffer from intercropping when the bean was planted a month after maize emergence (Gebeyehu et al., 2006) and from relay planting (Davis and Gracia, 1983; Worku, 2014). The long growth duration of maize and its dominant nature provided by its architecture may have lessened a strong competition from common bean. Absence of severe maize yield loss under intercropping might be attributed to the favorable growth environment especially in terms of a well distributed and adequate rainfall. The magnitude of maize yield loss may vary depending on the competitive ability of the associated

Table 5. Mean square values for yield and yield components of maize grown as sole and intercropped with common bean genotypes at Halaba, in 2013.

Source of variation	DF	No. of ears plant^{-1}	No. of rows ear^{-1}	No. of seeds row^{-1}	100 seed weight (g)	Grain yield (t ha^{-1})
Replication	2	0.001^{ns}	0.320^{ns}	2.725^{ns}	0.438^{ns}	0.218^{ns}
Genotype	7	0.002^{ns}	1.246^{ns}	9.236*	2.752*	0.593**
Error	14	0.003	0.683	2.547	0.975	0.131

*, **Significant at 5 and 1% probability levels, respectively; ns, non-significant.

Table 6. Grain yield and yield components of maize under sole and intercropping with maize at Halaba.

Associated bean genotype	Grain yield (t ha^{-1})	No. of ears plant^{-1}	No. of rows ear^{-1}	No. of seeds row^{-1}	100 seed weight (g)
None (sole maize)	8.02^{a}	1.0^{a}	17.4^{a}	36.1^{a}	38.3^{a}
Hawassa Dume	6.70^{b}	1.1^{a}	15.7^{a}	31.1^{b}	35.2^{b}
Ibbado	7.09^{b}	1.2^{a}	16.4^{a}	31.9^{b}	36.5^{b}
Sari-1	7.11^{b}	1.0^{a}	16.7^{a}	31.9^{b}	36.5^{b}
Omo-95	7.01^{b}	1.0^{a}	16.4^{a}	31.6^{b}	36.5^{b}
Awash-1	6.82^{b}	1.0^{a}	15.4^{a}	30.7^{b}	35.8^{b}
Awash Melka	6.93^{b}	1.0^{a}	16.1^{a}	31.4^{b}	36.2^{b}
Red Wolayita	6.55^{b}	1.1^{a}	15.8^{a}	30.7^{b}	35.4^{b}
$LSD_{5\%}$	0.63	0.14	1.44	2.79	1.73
CV	5.1	5.0	5.1	4.9	2.7

Means within a column followed by different letters are significantly different at p<0.05.

bean and maize varieties, the bean introduction time and the availability of growth resources. Fininsa (1997) indicated that earlier planting of the associated bean components depressed maize yield while it favoured that of the bean yield. It seems safe to say that it is possible to limit maize yield loss from intercropping by choosing less aggressive bean genotypes and through agronomic management such as adjusting the bean planting date and avoiding stress for main growth resources.

Intercropping efficiency

Partial and total land equivalent ratio

Partial LER of maize did not vary when it was grown with the different common bean genotypes (Table 7). A mean partial LER of 0.86 was obtained for maize (Table 8). The partial LER gives an indication of the relative competitive abilities of the components of an intercropping system. The species with higher partial LER is considered to be more competitive for growth limiting factors than the species with lower partial LER (Willey, 1979). Thus, the high partial LER value recorded for maize in all treatments indicated the presence of greater competitive capacity of maize against common bean.

The various common bean genotypes had significantly different partial LER values (Table 7). The highest partial LER (0.51) was recorded from genotype Hawassa Dume followed by Sari-1 (0.43) while lower values were obtained from Awash-1 (0.23) and Red Wolayita (0.19) (Table 8). Bush and semi bush types had greater partial LER values compared to semi climbing ones. This may be related to their capacity to intercept more light because of their erect growth. The semi climbing types could use the maize stalk for support but this puts most of their leaves directly underneath the maize canopy where available light is at its lowest thus leading to poor performance. Comparison of the genotypes in terms of their utility had showed that none of the two genotypes used for export had a partial LER in the top group. This might be related to their growth habit, which is semi climbing type. Performance under sole cropping did not reflect their competitive ability under intercropping for more than half of the varieties tested because of genotype by cropping system interaction for grain yield.

Total LER had showed significant difference among common bean genotypes (Table 7). The top intercropping advantages were obtained from associations with genotypes Hawassa Dume and Sari-1 (Table 8). The yield advantage of the intercrop over sole crop for genotype Hawassa Dume was 34%, Sari-1 (32%),

Table 7. Mean square values of partial and total LER from a maize-common bean intercropping at Halaba, in 2013.

Source of variation	DF	Partial LER		Total LER
		Maize	Common bean	
Replication	2	0.0108*	0.0005^{ns}	0.0078^{ns}
Genotype	6	0.0020ns	0.0389***	0.0469***
Error	12	0.0021	0.0009	0.0029

*, **, ***Indicate significance at 5, 1 and 0.1% probability levels, respectively; ns, non-significant.

Table 8. Partial and total land equivalent ratio from a maize-common bean intercropping at Halaba, in 2013.

Genotype	Partial LER		Total LER
	Maize	Common bean	
Hawassa Dume	0.83^{a}	0.51^{a}	1.34^{a}
Ibbado	0.88^{a}	0.36^{c}	1.24^{bc}
Sari-1	0.89^{a}	0.43^{b}	1.32^{ab}
Omo-95	0.87^{a}	0.34^{c}	1.22^{c}
Awash-1	0.86^{a}	0.23^{de}	1.08^{de}
Awash Melka	0.85^{a}	0.25^{d}	1.12^{d}
Red Wolayita	0.82^{a}	0.19^{e}	1.01^{e}
Mean	0.86	0.33	1.19
$LSD_{5\%}$	0.08	0.05	0.09
CV	5.4	9.2	4.5

Means within a column followed by different letters are significantly different at p<0.05.

Ibbado (24%), Omo-95 (22%), Awash-1 (8%), Awash Melka (12%) and 1% for Red Wolayita. This means that sole cropping requires more land than intercropping to produce equal yields indicating the greater land use efficiency from intercrops. Between the two genotypes that recorded the highest total LER only one is the top yielder under sole cropping while the other was one of the poor yielders. Thus, intercropping advantage from genotypes may not necessarily reflect performance under sole cropping indicating the need for evaluating genotypes under intended cropping systems. Yield advantages from maize-bean associations have been reported in several studies (Gebeyehu et al., 2006; Muraya et al., 2006; Worku, 2008, 2014; Workayehu and Wortmann, 2011). Though most of the contribution was derived from the dominant component, maize, differences in intercropping advantage appeared due to variability among the associated bean genotypes.

In this maize-bean association, while the bean is strongly and negatively affected, the effect on maize was slight. This type of association would be important in southern Ethiopia and elsewhere where the maize component is considered as the principal crop and the associated bean is used as a subsidiary crop. The intercropping advantage in such systems could be maximized by selecting appropriate bean genotypes that would not be aggressive on maize but strong enough to perform well under intercropping. Above all, such relationships could be maintained as long as severe shortages for moisture and nutrients are avoided because such environments tend to favor the dominated species (bean) at the expense of the dominant species (maize).

Conclusion

The genotype by cropping system interaction caused a moderate reranking of genotype performance between the two cropping systems leading to differences in choice. The genotype Hawassa Dume is the best choice followed by Ibbado and Awash-Melka under sole cropping while genotypes like Hawassa Dume and Sari-1 are equally good choices under intercropping. The traditionally used local cultivar did not perform well either in sole or intercropping systems suggesting the need for its replacement. Moreover, the more recent releases were found to be more efficient under intercropping than the variety identified previously (Ibbado), indicating the need for periodic assessment. Given the costly nature of plant breeding, the modest ranking changes observed for productivity between the two cropping systems do not warrant a separate variety development program for intercropping since there are genotypes with overlapping performance. Bush and semi bush types had better compatibility under intercropping while performance under sole cropping did not fall to a specific growth habit category. Though, one of the two export genotypes has showed good performance under sole cropping, none performed well under intercropping. This may be related to their growth habit since both are semi climbing types. Developing bush type export genotypes may help broaden their expansion outside their traditional zones since better performance under intercropping could attract more farmers to adopt them.

Conflict of Interests

The authors have not declared any conflict of interests.

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