ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF AGRONOMY

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

OPEN ACCESS Journal of Agronomy

ISSN 1812-5379
DOI: 10.3923/ja.2017.1.11

Research Article
System Productivity as Influenced by Varieties and Temporal Arrangement of Bean in Maize-climbing Bean Intercropping

Zerihun Abebe, Chala Dabala and Tadesse Birhanu

Bako Agricultural Research Center, P.O. Box 03, West Shoa, Ethiopia

Abstract
Objective: Maize-legume intercropping is one of the best practices to avert mono cropping problems and ensure sustainable and diversified production systems. In recognition of this fact, the objective of the experiment was to identify compatible maize and climbing types of common bean varieties at appropriate time of bean planting in intercropping systems. **Methodology:** The experiment was conducted in 2013 and 2014 years at Bako and Billo Boshe sites. Three maize varieties (BH661, BH546 and Gibe 2), two climbing beans (Tibe and Dandessu) and bean temporal arrangements (same, 15 and 20 days after maize planting) were arranged in factorial combinations in randomized complete block design with three replications. **Result:** The highest significant maize yield (9 t ha^{-1}) was obtained when common bean was planted with BH661 simultaneously followed by 20 days after BH546 planting. Bean performance in BH546 was significantly decreased as the function of increasing from same date to 20 days after maize planting. Even though maximum bean yield could be obtained when intercropped with Gibe 2 at the same time, 31% yield reduction of the maize was observed. Maximum LER (1.53) was obtained when BH661 was planted simultaneously with beans. Positive value of agressivity index showed maize varieties, except Gibe 2 were the dominant. In contrast, climbing bean was significantly dominated by maize varieties except in simultaneous planting with Gibe 2. **Conclusion:** Simultaneous planting of climbing bean in BH661 maize variety is the best practices to get the highest net benefits. Alternatively, farmers could also prefer to use planting of the beans 15 days after BH546 variety of maize planted. Moreover, intercropping of bean after 20 or more days planting of Gibe 2 could be used to advise the farmers as other options where there are limited accesses to hybrid varieties.

Key words: Maize, climbing bean, time of planting, intercropping, land equivalent ratio

Received: August 04, 2016 Accepted: October 19, 2016 Published: December 15, 2016

Citation: Zerihun Abebe, Chala Dabala and Tadesse Birhanu, 2017. System productivity as influenced by varieties and temporal arrangement of bean in maize-climbing bean intercropping. J. Agron., 16: 1-11.

Corresponding Author: Zerihun Abebe, Bako Agricultural Research Center, P.O. Box 03, West Shoa, Ethiopia

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Maize is the main staple[1] in African countries. In eastern and southern Africa, the demand for maize is projected to increase by at least 40% over the next 10 years[2]. Maize is the most important staple in terms of calorie intake in rural Ethiopia. The 2004/5 national survey of consumption expenditure indicated that maize accounted for 16.7% of the national calorie intake followed by sorghum (14.1%) and wheat (12.6%) among the major cereals[3]. The popularity of maize in Ethiopia is partly because of its high value as a food crop as well as the growing demand for the stover as animal fodder and source of fuel for rural families[4]. Approximately 88% of maize produced in Ethiopia is as food, both in green cobs and grain.

In Ethiopia, maize is the second next to teff in production area and the first in its productivity. Of total grain cereal crop area, 79.4% (9,848,746 ha), maize took up 16.1% of cultivated areas and its national productivity reaches up to 3.24 t ha^{-1}. Oromiya state accounts about 54.3% of total production area to the nation and the productivity in this region is currently[5] 3.31 t ha^{-1}. However, Western parts of sub-humid regions are dominantly producing maize crop and accounts more than 60% of the total production of the region. Most of the Western parts of Oromiya in their area of production percentage includes Jima zone (13.8%), East Wollega (11.5%), West Shewa (9.2%), Ilu Aba-bor (8.7%), West Wollega (6.5%), Kelam Wollega (5.2%) and Horro Guduru (4.6%) zones[5]. The production area increased from year to year and from location to locations.

Even though maize covers the second largest production areas and first in its productivity compared to other cereal crops, there is still high yield gabs between the actual yield currently producing and the potential yield that documented by different research institutions. For instance, long maturing hybrid maize varieties will produce up to 9.5-12 t ha^{-1} at research field and 6-8.5 t ha^{-1} at on farm fields if the production and managements are done in integrated approaches[6]. Whereas, the national and regional current maize productivity is below half of the potential yield of most of hybrid seeds, 3.2 t ha^{-1}. This high yield gabs are most probably caused by many biotic and abiotic factors, of which continuous maize based mono cropping and poor soil fertilities are the major problems limiting the productivity of the crops particularly in sub-humid Western parts of the region.

Continuous cultivation of maize year after year is one of the main challenges affecting production and productivity of the crop. The practice is popular in Western parts of Oromiya where maize is dominantly producing. The result of baseline survey in Bako Tibe and Gobu Sayo districts depicted that experiences of growing crops by the farmers shows more than 94% of the respondents continuously practiced mostly on the same plots of maize productions for more than 17 years, where as they have no experiences in growing of legume crops like soybean, common bean and pigeon peas[7]. However, crop rotation practice is one of the best solutions to avert the problem, maize-legume intercropping is also another important practice to reduce the problem of mono cropping while intensifying to generate diverse food sources and incomes.

Enhancing vertical agriculture in maize based cropping systems is one of the main strategies to boost the production and productivity of the main stable crops in Western parts of Ethiopia, where continuous monoculture is the main challenges. Maize-legume intercropping systems are one of the best agronomic practices that ensure high production per unit area while averting the problem of monocultures. Restoring soil fertility through diversified cropping systems that mimic nature is also considered to be the best options for sustainable agriculture[8].

Intercropping is one means of production technology which could not only ensure efficient utilization of common resources that include water, nutrients, sun light and space[9,10] but also conserve it by reducing soil erosion, suppress weed growth as well as disease pressure and thereby helps in yield increment and maintain greater stability in crop yields[11].Yield advantage occurs in intercropping comparing to sole crops since growth resources are more completely absorbed and converted to crop biomass by the intercrop over time and space due to differences in competitive ability between the component crops, which exploit the variation of the mixed crops in characteristics such as variation in root and canopy development at different pick time of nutrient requirements, variations in photosynthetic adaptation of canopies to irradiance conditions[12].

Competition among mixtures is thought to be the major aspect affecting yield as compared with solitary cropping of cereals. Species or variety selections, seeding ratios, spacial and temporal arrangements and competition capability within row or mixtures intercropping may affect the growth of the species used in intercropping systems[10]. Legumes, such as common bean (bush and climbing types), soybean, groundnut faba bean and field pea are widely used to intercrop in major cereal crops like maize and sorghum. Identification of compatible varieties of maize and common beans (for both bush and climbing types) at appropriate time of planting is very crucial to get optimum yield of the companion crops without reducing the yield of the main crops. The objective of this study was to identify compatible maize and climbing types of common bean at appropriate time of bean planting in maize intercropping systems.

MATERIALS AND METHODS

The experiment was conducted at Bako and Billo Boshe research sub-sites during 2013 and 2014 cropping seasons. Both research sub-sites are located in sub humid areas of Western Ethiopia, which are found within 20 km radius. Bako s ub-site lies at a latitude of 9°6' N and longitude of 37°9' E and at an altitude of 1650 m a.s.l. Both locations have warm humid climate with annual mean minimum and maximum air temperatures of 13.5 and 29.7°C, respectively. The area received average annual rainfall of 1431 mm (2013) and 1067 mm (2104) with maximum precipitation being received in the months of May-August (Fig. 1). The soil of the experimental site was reddish-brown, nitosol, which is acidic with a pH range of 5.2-5.6. The area is a mixed farming zone and is one of the most important maize (*Zea mays* L.) growing belts in Ethiopia, in which cultivation of teff (*Eragrostis* (Zucc.) Trotter.) finger millet (*Eleusine corocana* (L.) Gaertn) and common bean (*Phaseolus vulgaris* L.).

The treatments consisted of three factors, namely, climbing types of two common bean varieties (Tibe and Dandessu), three types of maize varieties (BH661, BH546 and Gibe 2) and time of bean planting in maize (same, 15 and 20 days after maize planting). These factors were combined in 2×3×3 factorial arrangements and laid out as Randomized Complete Block Design (RCBD) with three replications. In addition, maize and common bean varieties were sown as sole with recommended agronomic practices as control. The distance between blocks and plots were 1 m and 50 cm, respectively. The size of each experimental plot was 3.75×3 m.

The experimental plots were plowed three times at different time intervals starting from mid May and leveled manually before the field layout was made. Rows were prepared with 75 cm recommended maize spacing. At the time of maize planting, recommended inorganic fertilizer, 110 N kg ha^{-1} and 46 P_2O_5 kg ha^{-1} was applied in the prepared rows. All maize varieties were planted with 30 cm between plants in early June. Two varieties of maize (BH661 and BH546) are hybrid types and one open pollinated variety, which are different in morphological characters and their maturity periods were used. The BH661 was three way cross hybrid and long maturing with higher plant height than BH546, which is two way cross and medium in maturity period and shorter in height. However, Gibe 2 is an open pollinated variety which is relatively shorter in maturity period and plant height than the hybrid varieties.

On the other hand, two varieties (Dandessu and Tibe) of climbing common bean were intercropped in maize at different bean planting times. Both varieties naturally need supporting materials since they are climbers. They produce more pods per plant when they grow on supporting materials. The bean varieties were intercropped at the same day, 15 and 20 days after maize planting, which were planted 10-15 cm away from maize rows. The distance between bean plants in an intercrops was 10 cm. Intercropped common bean plant population were 133,333 plants ha^{-1} where as

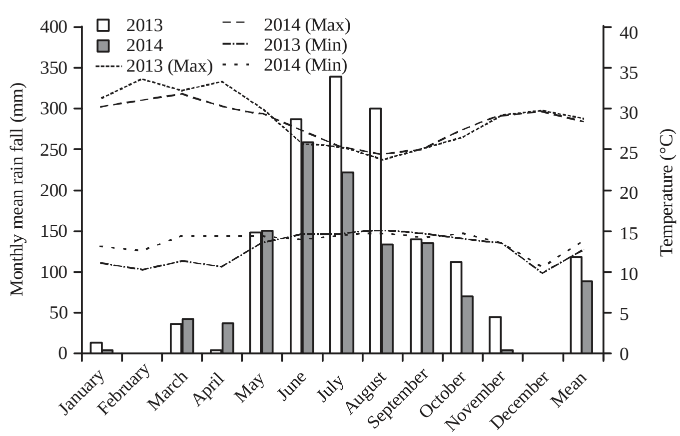

Fig. 1: Mean monthly rainfall and minimum and maximum temperature of Bako research site, 2013-2014

250,000 plants ha^{-1} for sole crops with spacing of 40 cm between rows and 10 cm between plants. However, the total plant population for both soles and intercrops of maize varieties were 44,444 plants ha^{-1} with 75×30 cm plant spacing. Two seeds per hole were planted for both crops and finally thinned to one vigor plant per hole after uniform germination for each crop. All other agronomic practices were uniformly applied to avoid external error variations.

At the time of harvesting, three middle rows of maize by excluding two border rows from each side (2.25×3 m) were harvested for both sole and intercropped maize. Similarly, common bean was harvested when it reached harvest maturity and the color of the pods turned yellow. Three rows of intercropped common bean were also harvested. For sole common bean, six rows from each central plot by excluding plants in border rows from each side were harvested. Net plot size for sole common bean crop was 2.8×3 m. Maize was harvested at the end of November.

Data collection: Grain yield of maize and seed yield of common bean components were collected. Total ear weight was taken from each plot and converted to grain yield by conversion factor (0.83). Finally, grain yield was adjusted to standard moisture contents of maize to 12.5% as described in:

$$\text{Adjusted yield} = \frac{\text{Actual yield}\times 100\text{-M}}{100\text{-D}}$$

where, M and D is the measured and standard moisture content, respectively. Similarly, bean yield was measured from each net plot and then converted to standard moisture contents of beans to 10%. Some models to measure efficiencies and competition indices were used to assess the competition efficiencies as well as compatibility of the intercropped component crops.

Land Equivalent Ratio (LER) and Aggressivity Index (AI) for component crops were also used to assess the productivity and competition efficiencies of the component crops in the systems.

Land Equivalent Ratio (LER): Land equivalent ratio was calculated from economic yield of common bean and maize components. The sum of the ratio of intercropped yield to sole yield of maize and common bean components gave LER. Land equivalent ratio for common bean was calculated as the yield of common bean varieties in intercropping divided by the sole yield, whereas LER of maize calculated as yield of maize in intercropping divided by the yield of sole.

The second index was aggressivity (AI) which is often used to determine the competitive relationship between two crops used in intercropping[13]. The aggressivity was calculated as follows:

$$AI_{\text{common bean}} = (Y_{CB}I/Y_{CB}S\times Z_{CB}I)-(Y_mI/Y_mS\times Z_mI)$$

$$AI_{\text{maize}} = (Y_mI/Y_mS\times Z_mI)-(Y_{CB}I/Y_mS\times Z_{CB}I)^{10}$$

where, $Y_{CB}I$ is yield of common bean in intercrops, $Y_{CB}S$ is yield of common bean in sole crop, Y_mI is yield of maize in intercrops, Y_mS is yield of maize in sole crop, $Z_{CB}I$ is proportion of common bean in intercrops and Z_mI is proportion of maize in intercrops.

Data analysis: To compare maize and bean yield effects of the tested cropping systems across the environments, combined analyses of variance (ANOVA) across sites were carried out using GenStat 15th editions software, underlying assumptions of using ANOVA. Least Significant Difference (LSD) test at $p<0.05$ was used for comparing treatment means. Thus data from each site and year was pooled for a combined analysis. Sigma plot version 10 was used for graphing and Microsoft excel was used for scatter plot. Economic analysis was also done[14].

RESULTS

The result of analysis of variance revealed that seasonal variations significantly affected only on intercropped bean yield where as locations showed highly significant variations on yield of companion crops (Table 1). But treatment

Table 1: Analysis of variances for grain of maize-common bean intercropping as affected by bean and maize varieties and time of bean planting

		P probability (p = 0.05)	
		Grain yield	
Source of variation	df	Maize	Common bean
Year	1	0.061	<0.001
Location	1	<0.001	<0.001
MV	2	<0.001	<0.001
BV	1	0.608	<0.001
TP	2	0.068	<0.001
MV×BV	2	0.539	0.241
MV×TP	4	<0.001	0.005
BV×TP	2	0.903	0.098
MV×BV×TP	4	0.463	0.131
CV (%)		14	23

df: Degree of freedom, BV: Bean variety, MV: Maize variety, TP: Time of bean planting in maize

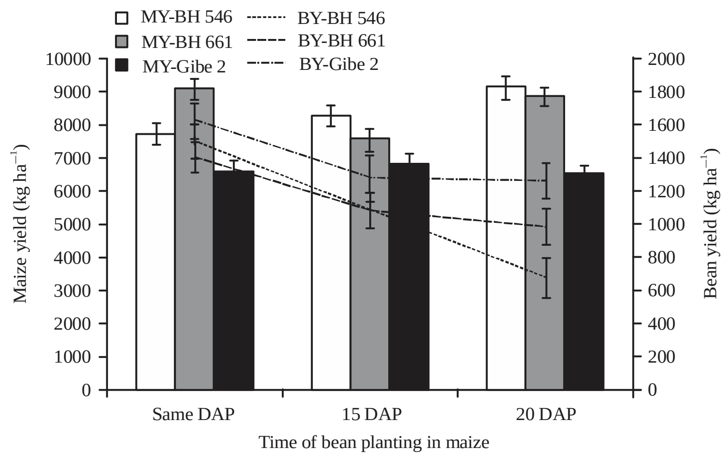

Fig. 2: Effect of maize varieties and time of bean planting on yield of maize and common bean varieties, MY-BH546: Maize yield for BH546, MY-BH661: Maize yield for BH661, MY-Gibe 2: Maize yield for Gibe 2, BY-BH546: Bean yield in BH546, BY-BH661: Bean yield in BH661 and BY-Gibe 2: Bean yield in Gibe 2, error bars indicate standard errors of means

responses at each site showed consistent responses. Both economic yield of maize and bean yield were highly ($p<0.001$) affected by maize varieties while the bean varieties showed significant difference on bean yield. However, time of bean planting in maize did not affect yield of the maize in the intercrop. The interaction effect of maize varieties by time of bean planting in main crop was significantly varied on yield of intercropped crops.

The result of maize varieties by time of bean planting indicated that the highest significant maize yield (9 t ha^{-1}) was obtained when climbing bean was planted simultaneously with BH661 and BH546 planted with bean after 20 days maize planting. More than 38 and 17% yield advantage could be obtained when BH661 was intercropped with bean varieties simultaneously compared to Gibe 2 and BH546, respectively (Fig. 2). However, the highest maize yield was recorded when bean was intercropped 20 days after BH546 variety was planted though comparable yield was also obtained from BH661. When the bean varieties were intercropped after 15 days of BH546, a significant yield (8278 kg ha^{-1}) was obtained compared to BH661 (7575 kg ha^{-1}) and the open pollinated variety (6827 kg ha^{-1}). Gibe 2 was significantly dominated by climbing bean when planted simultaneously and the yield was significantly reduced compared to hybrid varieties (Fig. 2).

Even though the highest yield performance for BH546 was recorded when bean was planted after 20 days of maize planting, the lowest significant bean yield (680 kg ha^{-1}) was obtained. Bean yield performance in BH546 was significantly decreased as the function of increasing from same date to 20 days after maize planting. However, significantly higher yield of BH546 variety and bean were obtained when the bean was intercropped in the maize after 15 days of maize planting than other temporal arrangement. Similarly, maximum bean yield could be obtained when intercropped with Gibe 2 variety at each time of bean planting though the highest bean yield was recorded when intercropped simultaneously. Significantly more than 1.3 t ha^{-1} yield of climbing bean could also be obtained when planted at same time of planting with BH661 variety. In addition, more than 1 t ha^{-1} of additional yield could be obtained when bean crop intercropped after 15 days of either BH661 or BH546 variety of the main crop without significant reduction of the main yield. Similar additional yield could also be obtained from intercropped common bean when planted 20 days after BH661 variety of planting (Fig. 2). Yield of BH546 and Gibe 2 was significantly reduced by 12 and 29%, respectively due to competition effect of companion crops while only 5% yield reduction was recorded when BH661 was used for intercropping compared to its sole crop (Fig. 3). However, maximum (31%) yield decrease of maize was recorded when common bean was planted simultaneously with Gibe 2 and followed by BH546 (19%). Both hybrid varieties (BH661 and BH546) were significantly at par in yield performance under sole crops, but Gibe 2 was significantly inferior either under intercrops or sole crops.

Significantly higher bean yields could be obtained when Tibe variety of common bean was used either in intercropping or sole cropping. More than 0.4 t of yield advantage could be obtained when Tibe variety was used in either of each system. But, in absence of this variety Dandessu could also give more than 1 and 2.4 t ha^{-1} of yield in an intercrops and sole crops, respectively.

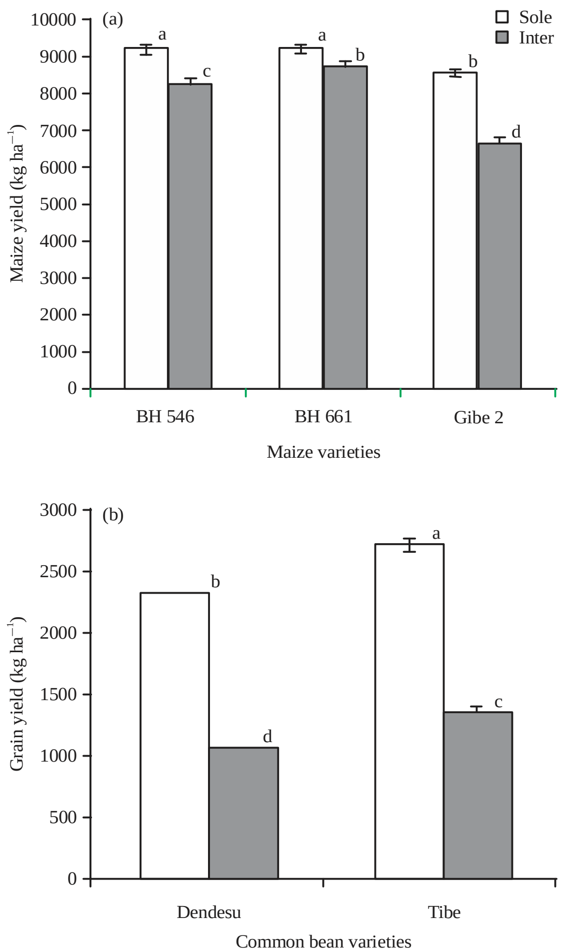

Fig. 3(a-b): (a) Yield performance of maize and (b) Common bean varieties in sole and intercropping systems

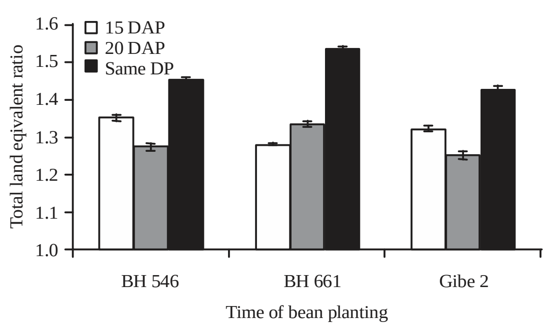

Fig. 4: Total land equivalent ratio of maize-common intercropping systems as affected by maize varieties and time of bean planting

Land productivity: Like grain yield of both companion crops, LER was significantly varied due to the effect of maize varieties by time of bean planting though main effect of maize and bean varieties as well as time of bean planting in maize showed highly (p<0.001) significant effects (Table 2).

Table 2: Analysis of variances for land equivalent ratio as affected by main effects of common bean and maize varieties and time of bean planting and their interactions

Source of variation	df	P probability (p = 0.05) TLER
Year	1	<0.001
Location	1	<0.001
MV	2	0.105
BV	1	0.020
TP	2	<0.001
MV×BV	2	0.281
MV×TP	4	0.021
BV×TP	2	0.639
MV×BV×TP	4	0.066
CV (%)		10

df: Dgree of freedom, MV: Maize variety, BV: Bean variety, TP: Time of bean planting in maize

Moreover, seasonal variations at each location also caused significant variations that might be variations in rain fall amount and distributions (Fig. 1).

Land productivity was also assessed based on total Land Equivalent Ratio (LER). The highest LER (1.53) was also recorded when BH661 of maize variety was planted simultaneously with bean variety and followed by 1.45 of LER when BH546 intercropped at the same time with bean varieties (Fig. 4). Even though the productivity of Gibe 2 intercropped simultaneously with bean considerably gave more than one (LER = 1.42), significant yield reduction by more than 31% of maize in intercropping systems was recorded compared to its sole crops. This practice is or may not be preferred by the farmers since they mainly focus on main yield than the companion ones. Similarly, more than 19% yield reduction of maize variety (BH546) could occur when intercropped with bean varieties though more than one LER (1.3-1.45) was recorded in different time of bean planting (Fig. 4).

Competition index: Regarding to competitions efficiencies, Aggressivity Index (AI) for both maize and bean varieties were assessed. In intercropping systems of maize and bean varieties with different temporal arrangements, positive AI_{maize} showed that maize varieties except Gibe 2 intercropped simultaneously with bean were the dominant crops in intercropping (Fig. 5a).

The highest positive value (0.6) was recorded when bean varieties were intercropped after 20 days of BH546 variety was planted while the next highest value was recorded when the beans were planted 20 days after BH661 was planted. At same time of bean planting with maize varieties, BH661 was significantly more aggressive over beans than BH546 and hence less yield reduction was recorded compared to the later one. But, significantly higher AI value for BH546 was recorded when beans were intercropped 20 days followed by 15 days

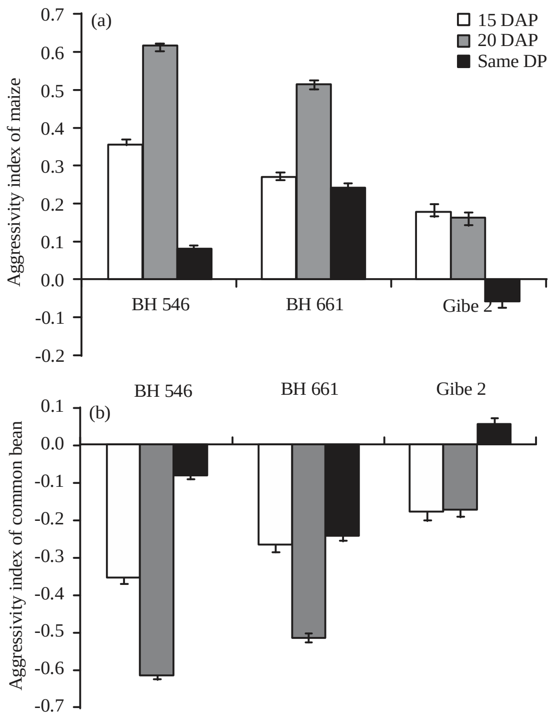

Fig. 5(a-b): Aggressivity index of (a) Maize and (b) Common bean component in intercropping systems as affected by maize varieties and time of planting

after maize planting, indicating that less yield reduction of the main crop could be occurred (Fig. 5a).

Regarding to Gibe 2 variety with different temporal arrangement of beans, the negative value of AI was recorded when the maize variety was intercropped simultaneously with bean varieties, which significantly dominated by the companion crop. When bean varieties, however were intercropped in this variety after 15 and 20 days of Gibe 2 variety, the AI values were positive though higher value was recorded when bean was planted 20 days after maize planting.

In case of AI for climbing beans, all negative values of aggressivity index of beans except for bean when intercropped simultaneously with Gibe 2 variety of maize, showed that climbing bean in maize intercropping were dominated and hence less competent than maize varieties. The least competitiveness of bean in intercropping was observed when it was planted 20 days of BH546 and followed by BH661 variety of maize planting, indicating that the main crops significantly dominate the companion ones. Significantly lower negative value of AI_{bean} for BH661 was recorded when beans were intercropped 20 days after maize planting compared to BH546, indicating that bean is more competent in BH661 than the other hybrid variety. However, the positive value of AI_{bean} was recorded when the maize variety was intercropped simultaneously with bean, which significantly dominated the main crop, Gibe 2 variety.

Partial and marginal analysis: The highest net benefit (38808 ETB ha^{-1}) and more marginal rate of return (MRR) could be obtained when climbing bean was intercropped simultaneously with BH661 variety of maize (Table 3). Even though intercropping of bean at the same time with BH546 variety gave the next highest net benefit, considerably more than 19% yield of the main crop was reduced due to competition effect of bean (but gained comparable more yield of bean) compared to its sole crop. This indicates that farmers are not willing to use this practice since they mainly focus on yield of the main crop than the companion ones (Table 4). However, intercropping of bean 15 days after planting of BH546 variety could earn 33883 ETB ha^{-1} of net benefit without significant reduction of main yield and hence farmers could also prefer to use this practice in areas where there is scarcity of BH661 to use for intercropping. In spite of its higher net benefit of Gibe 2 variety intercropped simultaneously with bean due to significant bean yield performance (1628 kg ha^{-1}), significantly more than 31% yield reduction of this variety was observed due to its less competitiveness that definitely influence its preference by the end users and hence not advisable to practice.

Regarding to comparing intercropping versus sole cropping in terms of net and marginal benefits (Table 5, 6), intercropping systems generally gave the highest net benefit (28691 ETB ha^{-1}) and MRR (561%) compared to sole crops of maize and climbing beans. However, sole cropping of maize gave better 11002 ETB ha^{-1} net benefits and MRR than that of sole climbing beans. Even though intercropping of climbing bean in BH546 regardless of time of bean planting could give better, consideration of temporal bean arrangement to intercrop in this variety is very critical. However, use of BH661 for intercropping of bean could comparably give high net benefit and the highest MRR regardless of time of bean planting. Sole planting of BH546 could give the maximum net benefit compared to other sole maize varieties though all are inferior to their respective intercropping systems and similar results were also reported[15]. Sole planting of Tibe could significantly give better net benefit than Dandessu.

DISCUSSION

Significant yield variations of maize due to varieties by bean planting revealed that varietal differences in terms of

Table 3: Partial budget analysis of maize- climbing bean intercropping as influenced by varieties and time of bean planting

Treatments maize variety	Time of bean planting	Adjusted yield ($kg\ ha^{-1}$)		Gross field benefit ($ETB\ ha^{-1}$)			Cost that vary ($ETB\ ha^{-1}$)				Net benefit ($ETB\ ha^{-1}$)
		Maize	Bean	Maize (4)	Bean (8)	Total	Maize seed	Labor for weeding	Labor for maize and bean threshing	Total	
				($ETB\ kg^{-1}$)							
BH661	15	6948	980	27792	7840	35632	1600	960	793	3353	32279
	20	7895	875	31580	7000	38580	1600	960	877	3437	35143
	Same	8192	1267	32768	10136	42904	1600	640	946	3186	39718
BH546	15	7450	976	29800	7808	37608	1600	960	843	3403	34205
	20	6792	643	27168	5144	32312	1600	960	744	3304	29008
	Same	6973	1317	27892	10536	38428	1600	640	829	3069	35359
Gibe 2	15	6144	1151	24576	9208	33784	1200	960	730	2890	30894
	20	5896	1140	23584	9120	32704	1200	960	704	2864	29840
	Same	5956	1465	23824	11720	35544	1200	640	742	2582	32962

maturity period and morphological characters like plant height, leaf arrangements and width as well as nature of crop canopy, time of bean planting in the main crop significantly influence compatibility of the component crops and hence affect yield performance of the main crop[16]. These variations in morphological characters and growth habit of both companion crops ensure variation in common resource competition. However, maximum (31%) yield decrease of maize was recorded when common bean was planted simultaneously with Gibe 2 and followed by BH546 (19%) which also coincides with other research findings[17]. The same authors also indicated that when climbing bean was planted at the same time with short plant height maize varieties, like Gibe2 open pollinated varieties, climbing bean was superior to the maize and caused significant yield reduction. In contrast, long maturing and higher plant height of hybrid maize varieties, like BH661, significantly dominated the companion crops. Even though competition among mixtures is governed by species and/or varieties and spatial arrangements, temporal adjustment for the companion in the main crops is the major concern to increase yield of second crop without reducing the yield of the main crop[10].

Land equivalent ratio for BH661 (LER = 1.53) and BH546 (1.45) in simultaneous planting with climbing bean (LER = 1.53) imply that 53 and 45% greater area would be required under sole maize to produce the same yield as that of combined yield under intercropping system. Similar result was reported that intercropping maize-common bean gave higher yield advantage and land use efficiency as compared to sole maize[17,18]. However, selection of suitable maize varieties that capable of competing with climbing bean is very crucial to get higher land productivity. For instance, significant yield reduction by more than 31% of Gibe 2 variety was recorded when intercropped with climbing bean compared to its sole crops, which is or may not be preferred by the farmers though land productivity is greater than one[18].

Positive value of agressivity index for maize also indicates that hybrid maize was the dominant species in all mixtures and planting patterns, except Gibe2 variety when planted simultaneously with climbing bean. For instance, the maximum positive value (0.6) was recorded when bean varieties were intercropped after 20 days of BH546 was planted while the next highest value was recorded when the beans were planted 20 days after BH661 was planted. However, at same time of bean planting with maize varieties, BH661 was significantly more aggressive over beans than BH546 and hence less yield reduction was recorded compared to the later one. Yilmaz *et al.*[15] also reported that the highest positive value of agressivity index indicate that the main crop

Table 4: Marginal budget analysis of maize-climbing bean intercropping as influenced by varieties and time of bean planting

Treatments	Bean planting time	Cost that vary	Marginal cost	Net benefit	Marginal net benefit	Marginal rate of return (%)
Variety						
Gibe 2	Same	2582	-	32962	-	-
Gibe 2	20	2864	282	29840	D	D
Gibe 2	15	2890	26	30894	1054	4054
BH546	Same	3069	179	35359	4465	2494
BH661	Same	3186	117	39718	4359	3726
BH546	20	3304	118	29008	D	D
BH661	15	3353	49	32279	D	D
BH546	15	3403	50	34205	D	D
BH661	20	3437	34	35143	D	D

Table 5: Marginal analysis of intercropping versus sole cropping of maize and climbing bean varieties

Cropping system	Crop/variety	Cost that vary	Marginal cost	Net benefit	Marginal net benefit	Marginal rate of return (%)
Sole beans	Tibe	5134	-	14506	-	-
Sole beans	Dandessu	5454	320	12194	D	
Sole maize	Gibe 2	7811	2357	23041	10847	460
Sole maize	BH546	8271	460	24973	1932	420
Sole maize	BH661	8272	1	25041	D	D
Inter	Gibe 2+bean	8517	245	25495	522	213
Inter	BH661+bean	9071	554	29969	4474	808
Inter	BH546+bean	9588	517	30608	639	124
Means of sole versus intercropping systems						
Sole bean		5294	-	13350	-	-
Sole maize		8118	2824	24352	11002	390
Intercropping		8892	774	28691	4339	561

Table 6: Partial budget analysis for sole versus intercropping systems

	Under different cropping system							
	Intercropping system (Maize+bean)			Sole maize			Sole bean	
Description	BH661	BH546	Gibe 2	BH661	BH546	Gibe 2	Tibe	Dandessu
AMY (kg ha^{-1})	7678	7846	5999	8324	8311	7713	-	-
ACBY (kg ha^{-1})	1041	1039	1252	-	-	-	2455	2206
GFB-Mz (4 ETB kg^{-1})	30712	31384	23996	33296	33244	30852	-	-
GFB-CB (8 ETB kg^{-1})	8328	8312	10016	-	-	-	19640	17648
Total gross benefit (ETB ha^{-1})	39040	39696	34012	33296	33244	30852	19640	17648
Cost of maize seed (ETB ha^{-1})	1600	1600	1200	1600	1600	1200	-	-
Cost of bean seed (ETB ha^{-1})	450	450	450	-	-	-	850	850
Cost of UREA (ETB ha^{-1})	1400	1400	1400	1400	1400	1400	-	-
Cost of DAP (ETB ha^{-1})	1600	1600	1600	1600	1600	1600	1600	1600
Cost of bean and maize planting (ETB ha^{-1})	1689	1689	1689	1000	1000	1000	1300	1300
Cost of labor for fertilizing (ETB ha^{-1})	640	640	640	640	640	640	320	320
Cost of labor for weeding (ETB ha^{-1})	855	855	855	1200	1200	1200	900	900
Cost for maize and bean threshing (ETB ha^{-1})	837	904	683	832	831	771	164	484
Total cost that vary (ETB ha^{-1})	9071	9588	8517	8272	8271	7811	5134	5454
Net benefit (ETB ha^{-1})	29969	30608	25495	25024	24973	23041	14506	12194

1USD: 21ETB, AMY: Adjusted maize yield (actual yield was adjusted down by 10%), ACBY: Adjusted common bean yield (adjusted down by 10%), GFB-Mz: Gross field benefit of maize, GFB-CB: Gross field benefit of common bean, ETB: Ethiopian birr (1USD: 20 ETB)

is significantly superior and hence less yield reduction than the second crop in intercropping systems. The same authors also reported that AI_{beans} were negative, except for bean when intercropped simultaneously with Gibe 2 variety of maize, showed that climbing bean in maize intercropping were dominated.

The present study in line with other finding also revealed intercropping of maize-climbing bean using appropriate varieties and optimum temporal arrangement is more profitable than sole planting on either of the two crops[17,19]. For instances, uses of BH661 intercropped with climbing bean simultaneously could give the highest net benefit and marginal rate of return. This could be due to suitable morphological character of BH661 variety which helps in competing with second crop.

CONCLUSION

The highest net benefit (38808 ETB ha^{-1}) and more marginal rate of return (MRR) could be obtained when climbing bean was intercropped simultaneously with BH661 variety of maize and hence recommendable to be used by the end users. However, intercropping of bean 15 days after planting of BH546 variety could earn 33883 ETB ha^{-1} of net benefit without significant reduction of main yield and hence advisable to be used by the farmers in areas where there is scarcity of BH661. In spite of its higher net benefit of Gibe 2 variety intercropped simultaneously with bean due to significant bean yield performance, farmers may not prefer to use it since the bean significantly dominate the main crop and reduce the yield. However, in areas where there are scarcity of hybrid maize varieties, intercropping of climbing bean after 20 or more days of maize (open pollinated varieties) planting could also be used as another options though the net benefit that could be gained is significantly less than use of hybrid varieties.

ACKNOWLEDGMENT

The authors greatly acknowledge Oromia Agricultural Research Institute for financial support. The authors also sincerely acknowledge Bako Agricultural Research Center for all technical and managerial supports provided during the experimental period. Great thanks also go to the research staffs who were directly or indirectly involved for the execution of the experiment.

REFERENCES

1. Banziger, M. and A.O. Diallo, 2004. Progress in Developing Drought and N Stress Tolerant Maize Culti Vars for Eastern and Southern Africa. In: Integrated Approaches to Higher Maize Productivity in the New Millennium, Friesen, D.K. and A.F.E. Palmer (Eds.). CIMMYT, Nairobi, Kenya, ISBN: 9789706481207, pp: 189-194.
2. FAO., 2010. FAOSTAT database. Food and Agricultural Research Organization, December 4, 2011. http://faostat.fao.org/default.aspx
3. Berhane, G., Z. Paulos, K. Tafere and S. Tamru, 2011. Foodgrain consumption and calorie intake patterns in Ethiopia. IFPRI, Addis Ababa, pp: 18. https://www.ifpri.org/publication/foodgrain-consumption-and-calorie-intake-patterns-ethiopia.
4. Abate, T., B. Shiferaw, A. Menkir, D. Wegary and Y. Kebede *et al*., 2015. Factors that transformed maize productivity in Ethiopia. Food Secur., 7: 965-981.
5. CSA., 2014. Agricultural sample survey. Volume I, Report on area and production for major crops (Private peasant holdings, main season). Central Statistical Authority (CSA), Statistical Bulletin, Ethiopia, Addis Ababa.
6. CVR., 2013. Animal and plant health regulatory directorate. Volume 15, Crop Variety Registration (CVR), Ministry of Agriculture Natural Resource, Ethiopia.
7. CIMMYT., 2010. Socioeconomic Profile of Maize-legume based farming system in Ethiopia: Characterization of livelihood strategies, production conditions and markets. Maize and Wheat International Research Institute, Baseline Survey Report for the Project, Sustainable Intensification of Maize-Legume Farming Systems for Food Security in Eastern and Southern Africa (SIMLESA).
8. Scherr, S.J. and J.A. McNeely, 2008. Biodiversity conservation and agricultural sustainability: Towards a new paradigm of ecoagriculture landscapes. Philos. Trans. R. Soc. Lond. B: Biol. Sci., 363: 477-494.
9. Ghosh, P.K., 2004. Growth, yield, competition and economics of groundnut/cereal fodder intercropping systems in the semi-arid tropics of India. Field Crops Res., 88: 227-237.
10. Dhima, K.V., A.S. Lithourgidis, I.B. Vasilakoglou and C.A. Dordas, 2007. Competition indices of common vetch and cereal intercrops in two seeding ratio. Field Crops Res., 100: 249-256.
11. Banik, P., A. Midya, B.K. Sarkar and S.S. Ghose, 2006. Wheat and chickpea intercropping systems in an additive series experiment: Advantages and weed smothering. Eur. J. Agron., 24: 325-332.
12. Tsubo, M., S. Walker and E. Mukhala, 2001. Comparisons of radiation use efficiency of mono-/inter-cropping systems with different row orientations. Field Crops Res., 71: 17-29.
13. Willey, R.W., 1979. Intercropping-its importance and its research needs. I. Competition and yield advantages. Field Crop Abstracts, 32: 1-10.
14. CIMMYT., 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. CIMMYT Economics Program, Mexico, DF., ISBN-10: 9686127186, Pages: 79.
15. Yilmaz, S., M. Atak and M. Erayman, 2008. Identification of advantages of maize-legume intercropping over solitary cropping through competition indices in the East Mediterranean region. Tur. J. Agric., 32: 111-119.
16. Otieno, P.E., J.W. Muthomi, G.N. Chemining'wa and J.H. Nderitu, 2009. Effect of rhizobia inoculation, farm yard manure and nitrogen fertilizer on nodulation and yield of food grain legumes. J. Biol. Sci., 9: 326-332.

17. Abera, T., T. Tanaand and L.M. Pant, 2005. Grain yield and LER of maize-climbing bean intercropping as affected by inorganic, organic fertilisers and population density in Western Oromiya, Ethiopia. Asian J. Plant Sci., 4: 458-465.
18. 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.
19. Zerihun, A., B. Tadesse, T. Shiferaw and D. Kifle, 2014. Conservation agriculture: Maize-legume intensification for yield, profitability and soil fertility improvement in Maize Belt areas of Western Ethiopia. Int. J. Plant Soil Sci., 3: 969-985.