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Grain Yield and Profitability of Hybrid Maize-Climbing Bean Intercropping as Influenced by Varieties and Planting Time of Climbing Bean in Western Oromia, Ethiopia

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Abstract
Maize and climbing bean intercropping is one of the major maize based cropping systems in Haro Sabu District. The field study was conducted at Haro Sabu Agricultural Research Center, during 2018 with the objective of assessing the effects of varieties and relative planting date of climbing bean intercropping with maize on yield of the component crops and productivity of the system. The experiment was laid out in Randomized complete Block design (RCBD) with three replication in factorial combination of three climbing bean varieties (Dandesu, Tibe and Waragutu) and four dates of planting (simultaneous planting, 7 days after planting of hybrid maize, 14 days after planting hybrid maize and 21days after planting hybrid maize) along with respective sole crop of climbing bean varieties and hybrid maize shone variety (PHB30G19). Grain yield of climbing bean indicated significant difference under date of planting. The highest grain yield (2.36 tha^{-1}) was obtained from intercropping of variety Tibe and 14 DAPM. The highest gross monetary value (54076 ETB ha^{-1}) and (48393 ETB ha^{-1}) was obtained from 14 DAPM and climbing bean variety Tibe receptively. Based on this study intercropping of hybrid maize with Tibe variety at 14 DAPM could be recommended for the study area.
Keywords: climbing bean, gross monetary value, hybrid maize, productivity
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Introduction

Simultaneous cultivation of more than one crop species on the same piece of land and is regarded as the practical application of basic ecological principles such as diversity, competition and facilitation is called intercropping [1]. The productivity and productivity of the crops are increasing under intercropping systems [2]. Improvement of soil fertility through intercropping with nitrogen fixation by the component legume, efficient use of environmental resources [3]. According to the findings of some research findings the yield of intercropping is often higher than sole cropping [4]. This is mainly due to resources such as water, light and nutrients can be utilized more efficiently in intercropping than in sole cropping. The underlying principle of efficient resource use in intercropping is that, if crops differ in the way they utilize environmental resources when grown together, they can complement each other and make better combined use of resources than when they are grown separately.

However, the success of intercropping systems is due to an enhanced temporal and spatial complementarity of resource capture, for which both aboveground and belowground parts of crops play an important role [5]. Therefore, intercropping seems relevant management options in improving the efficiency of this system. Maximum yield of the component crops in an intercropping can be achieved by minimizing competition effects through appropriate planting pattern and timing of intercropping based on growth characteristics and requirements of the component species. Even though, such agronomic options seem easily controllable management factors, their effects on intercrop yields need to be well understood and determined experimentally.

On other hand, morpho-physiological differences and agronomic factors such as the proportion of crops in the mixture regulate competition between component crops for growth-limiting factors [6]. The degree of yield loss due to competition in an intercropping depend on the competitive ability, planting density and relative planting time of the component crop species, planting arrangement and nutrient availability in the soil [7]. Thus, enhancing productivity of maize and bean intercrops requires improving the interspecies complementarity or reducing competition effects. This might be achieved through manipulation of plant arrangements, plant densities, relative planting dates and planting compatible cultivars [8].

The other important management aspect is spatial arrangement which can improve radiation system practiced by farmers in western Ethiopia [9]. Most farmers intercropped legume crops at the same time with maize in alternate planting time without reducing the plant population of maize in order to achieve his/her major objective of food self-sufficiency.

Various investigations in Ethiopia reported that most farmers have been practicing various intercropping systems such as maize-common intercropping, because of land scarcity and the need to reduce risk of crop failure caused by erratic rain fall, drought, and pests [10]. However, this practice was not scientifically improved yet.

Thus, choice of appropriate plant population density in an intercropping using appropriate spatial arrangement; and determining of planting time of legume crops are the key management options in improving the efficiency of this production system. Hence, the objective of this study was to determine the appropriate climbing bean varieties and planting date of climbing bean for maximize profitability and the component crop yields in maize-climbing bean intercropping.

MATERIALS AND METHODS

Description of the experimental Site

The field experiment was carried out at Haro Sabu Agricultural Research Center (HSARC from June to October 2018. The Center is located in western Oromia region at 550 km away from Addis Ababa. It lies at latitude of 8º 52'51" N and longitude 35º13'18'' E and altitude of 1515 m above sea level. The center has warm humid climate with average minimum and maximum temperatures of 12.44ºC and 28.5ºC, respectively. It receives average annual rain fall of 1492 mm and its distribution pattern is uni-modal (National meteorological Agency, 2017). The soil type of the experimental site is reddish brown and sandy clay loam in texture and its pH is 5.55. The area is characterized by coffee dominant based farming system and crop-livestock mixed farming system in which maize, sorghum, finger millet, climbing bean, soybean, sesame, banana, mango, and sweet potato are the major crops grown in the area

Experimental Materials

One hybrid maize Improved Shone variety and three climbing bean varieties (Dandesu, Tibe and Waragutu) were used as experimental materials.

Treatments and Experimental Design

The treatments consisted three climbing bean varieties (e.g. Dandesu, Tibe and Waragutu) and four date of bean planting (e.g. the same date of planting climbing bean with hybrid maize, 7 days after hybrid maize planted, 14 days after hybrid maize planted and 21 days after hybrid maize planted. And there were four additional treatments (sole hybrid maize, sole Dandesu, sole Tibe and sole Waragutu) totally 16 treatments. The experiment was arranged in randomized complete block design (RCBD) with three replication in factorial arrangement (Table 1).

Table 1: List of combination

1	Dandesu intercropped with hybrid maize at the same date of maize planting
2	Tibe intercropped with hybrid maize at the same date of maize planting
3	Waragutu intercropped with hybrid maize at the same date of maize planting
4	Dandesu intercropped with hybrid maize 7 days after maize planted
5	Tibe intercropped with hybrid maize 7 days after maize planted
6	Waragutu intercropped with hybrid maize 7 days after maize planted
7	Dandesu intercropped with hybrid maize 14 days after maize planted
8	Tibe intercropped with hybrid maize 14 days after maize planted
9	Waragutu intercropped with hybrid maize 14 days after maize planted
10	Dandesu intercropped with hybrid maize 21 days after maize planted
11	Tibe intercropped with hybrid maize 21 days after maize planted
12	Waragutu intercropped with hybrid maize 21 days after maize planted
13	Sole hybrid maize
14	Sole Dandesu
15	Sole Tibe
16	Sole Waragutu

Experimental Procedures and Field managements

The field was ploughed and harrowed by a tractor to get a fine seedbed and leveled manually before the field layout was made. Both hybrid maize and climbing bean varieties were planted simultaneously on June 1, 2018, likewise climbing bean varieties were planted 7, 14 and 21 after hybrid maize planted. The distances between beans plants in the intercrops were 10 cm and thus the climbing bean plant population in the intercropped were 133,333 plants ha^{-1} whereas 250,000 plants ha^{-1} for sole crops with spacing of 40 cm between rows and 10 cm between plants. However, the plant population for both sole and intercrop of maize were 44,444 plants ha^{-1} with

75×30 cm plant spacing. The gross plot of maize was 5 rows of 3 m length at inter row spacing of 75 cm (3.75 x 3 m =11.25 m^2). The middle 3 rows of maize and beans between the rows of maize were harvested thus the net plot size was 4.05 m^2 (2.25 x 1.8 m^2) for maize and 3.75 (2.5 x 1.5 m^2) for beans. The sole maize gross and net plot size were the same as for inter cropped maize. The sole beans gross plot had 9 rows with 40 cm apart and the middle 7 rows were harvested the net plot size were 8.4 (2.8m^2 x 3 $m^{2)}$. Two seeds per hill of both maize and climbing bean were planted and thinned to one plant per hill one week after emergence. At time of planting, all plots of maize receive full NPSB (18% N, 38% P_2O_5, 7% S, and 0.1% B) at the recommended rate of 100 kg ha^{-1} NPSB and urea at knee height growth stage of the maize. All other agronomic managements were employed. Both maize and climbing bean were harvested from the net plot after they attained their normal physiological maturity, *i.e.* when 75% of plants in a plot formed black layer at the point of attachment of the kernel with the cob for maize and when 95% of pod color changed to yellow and their leaves started shading for climbing bean and the both maize and climbing bean were threshed manually.

Data Collection and Measurements

Grain yield (t ha^{-1}): Grain yield from each net plot area was weighed and was adjusted to 12.5% and 10% moisture level respectively for hybrid maize and climbing bean than converted to hectare bases.

$Adjusted\ yeield\ =\ actual\ yield\ X\ \frac{100-M}{1oo-D}$ Where M is the measured moisture content in grain and D is the designed moisture content (12.5 and 10%)

Harvest index (%): It was determined as a ratio of grain yield to above ground dry biomass at harvest per net plot area and multiplied by 100.

HI= $\frac{GY}{AY}$ x 100, where HI is harvest index, GY is grain yield and AY is above ground dry biomass yield including grain.

Economic evaluation of intercropping

Gross monetary value was used to calculate the economic advantage of intercropping as compared to sole cropping. Gross monetary value was calculated as the product of yield of the component crops multiplied by their respective unit price which was 5 ETB/kg for hybrid maize and 15 ETB/kg for climbing bean during harvesting at the study area, Haro Sabu local market.

Data Analysis

Analysis of variance was carried using SAS version 9.3 software. Mean separation was carried out using least significance difference (LSD) test at 5% probability level.

RESULTS AND DISCUSSIONS

Grain yield of Maize

Analysis of variance indicated that the main effects of date of planting and cropping system showed significant (P<0.01) affects the grain yield of hybrid maize while the effect of climbing bean varieties and the interaction was not significant. The highest hybrid maize yield (7.05 t ha^{-1}) was obtained at 21 DAPM, while the lowest (2.84 t ha^{-1}) was obtained from simultaneous planting (Table 2). This indicates increased trend of grain yield of hybrid maize with delaying time of climbing bean intercropping and as maize attains its maximum growth. None significant different was observed among the three DAPM. The lowest grain yield of hybrid maize due to climbing bean varieties at simultaneous planting might be due to miserable effects of climbing bean on hybrid maize at early growth stage. In agreement with this result, the highest maize yield was recorded when bean was intercropped 20 days after BH546 variety was planted [9]. Likewise, the delayed bean planting increased maize grain yield in maize/bean cropping systems [11]. Sole cropped maize had significantly higher grain yield (8.10 t ha^{-1}) than the intercropped system (5.86 t ha^{-1}). The grain yield reduction of the intercropped maize might be associated with inter specific competition between the intercrop components for growth resources

Harvest Index

The main effects of date of planting and variety as well as cropping system showed significant (P<0.01) effect on harvest index, but interaction effect was not significant. The highest (35.85%) and lowest (29.9%) harvest index was recorded from intercropping at 14 DAPM and simultaneous planting, respectively (Table 2).There was no significant difference among 7, 14 and 21 DAPM. The significantly highest harvest index was obtained due to intercropping with variety Tibe and the effect of other two bean varieties was similar. Significantly higher harvest index of hybrid maize (44.02%) was obtained from sole maize than the intercropped maize (33.88%) (Table 2). The lower harvest index of maize under intercropping might be due to inter specific competition for growth resources, moisture, nutrients and light. The present result agreed with this result that the higher harvest index (44.7%) of maize was recorded from sole maize than intercropped maize (41.5%) with soybean varieties [10].

Similarly, in Bambara groundnut + maize and Bambara groundnut + sorghum intercropping, reported significantly higher harvest indices from sole maize (0.599%) and sole sorghum (0.386%) than those in intercrops [12].

Table 2: Main effects of varieties and date of planting of the intercropped climbing bean and cropping system on harvest index and grain yield of the hybrid maize component

Treatment	GY(t ha^{-1})	HI (%)
Date of climbing bean planting		
Simultaneous	2.84^{b}	29.91
7 DAPM	6.63^{a}	34.18
14 DAPM	6.92^{a}	35.85
21 DAPM	7.05^{a}	35.56
LSD (0.05)	0.45	
Climbing bean varieties		
Dandesu	5.73	33.82
Tibe	5.92	36.05
Waragutu	5.94	31.77
LSD (0.05)	NS	
CV (%)	7.47	
Cropping system		
Sole	8.10^{a}	44.02
Intercropping	5.86^{b}	33.88
LSD (0.05)	1.92	
CV%	6.1	

Means within the same column followed by different letters of each factor differ significantly at 5% probability level; LSD = Least Significant Difference (P< 0.05); CV = Coefficient of Variation.

Grain yield of climbing bean varieties

Analysis of variance indicated that the grain yield of climbing bean was significantly (P<0.01) affected by variety and date of planting and significantly (P<0.05) affected by interaction and cropping system. The highest grain yield (2.36 t ha^{-1})) was obtained from 14 DAPM maize of variety Tibe and the lowest grain yield (0.83 t ha^{-1})) was obtained from simultaneous planting of variety Waragutu (Table 3). This indicates that yield of climbing common bean varieties differ on date of planting under intercropping. In agreement with this result, the seed yield of common bean component was significantly affected due to time of intercropping, varietal differences and their interaction [13]. Higher grain yield (2.14 t ha^{-1}) was obtained from sole cropped climbing bean than the intercropped climbing bean (1.48 t ha^{-1}) (Table 3). The grain yield reduction of the intercropped climbing bean might be due to competition exerted by maize. In accordance, the grain yield at climbing bean was reduced in intercropping system compared to sole cropping [14].

Table 3: The interaction effect of varieties and date of planting of the intercropped climbing bean with maize on grain yield (t ha^{-1}) of the climbing bean component

	Climbing bean Variety		
Date of climbing bean planting	Dandesu	Tibe	Waragutu
Simultaneous	0.85^{e}	1.82^{b}	0.83^{e}
7 DAPM	1.57^{c}	1.95^{b}	1.34^{d}
14 DAPM	1.92^{b}	2.36^{a}	1.56^{c}
21 DAPM	0.88^{e}	1.38^{d}	0.96^{e}
Intercropping mean	1.48^{b}		
Sole mean	2.14^{a}		
	CCBV x DP	Cropping system	
LSD (0.05)	0.15	0.19	
CV (%)	6.1	2.95	

Means within the same column followed by the different letters of each factor differ significantly at 5% probability level; LSD = Least Significant Difference; CV = Coefficient of Variation; DAPM = days after planting of maize.

Gross Monetary Value (GMV)

Gross Monetary Value was used to evaluate economic advantages. The highest gross monetary value of 54076 ETB ha^{-1} was obtained from 14 days after hybrid maize planted and the lowest gross monetary of 27021 ETB ha^{-1} was obtained from simultaneous planting (Table 4). The highest gross monetary value of (4530 ETB ha^{-1}) from planting density of 75% of common bean inter cropped with maize and the lowest gross monetary value (3674ETB ha^{-1}) was obtained from planting density of 25% common bean intercropped with maize[15].

The significantly highest gross monetary value (48393 ETB ha^{-1}) and the lowest (41419ETB ha^{-1}) were obtained from varieties Tibe and Waragutu intercropped with hybrid maize, respectively (Table 4). In this experiment intercropping gave higher gross monetary value (44117ETB ha^{-1}) than sole cropping of maize (40533 ETB ha^{-1}) and climbing bean (21400 ETB/ha). It has been reported that sole sorghum and haricot bean gave the least gross monetary value of 2784.30ETB ha^{-1} and 2047.50ETB ha^{-1} respectively in sorghum/haricot intercropping [16].

Table 4: Effect of climbing bean varieties and date of planting on Gross Monetary Value of sole and intercropped maize and climbing bean.

Treatment	Grain yield (t/ha)		Cost benefit		
Date of planting	Maize	Climbing bean	Maize (Birr/ha)	C/ bean (Birr/ha)	GMV (Birr/ha)
Simultaneous	2.84^{c}	1.28^{c}	14210.0	12811.1	27021
7 DAMP	6.63^{b}	1.61^{b}	33155.6	16188.9	49344
14 DAMP	6.92^{ab}	1.94^{a}	34620	19455.6	54076
21 DAMP	7.05^{a}	1.08^{d}	35288.9	10788.9	46078
LSD	0.38	0.19	1923.6	1904.8	2558.6
Climbing bean verities					
Dandasu	5.73	1.39^{b}	28669.2	13908.3	42578
Tibe	5.92	1.88^{a}	29600.8	18791.7	48393
waragutu	5.93	1.17^{c}	29685.8	11733.3	41419
LSD (0.05)	NS	0.16	-	-	-
CV (%)	6.79	13.32	-	-	-
Cropping system					
Intercropping	5.8^{b}	1.45^{b}	29317	14800.0	44117
Sole	8.1^{a}	2.14^{a}	40533	21400.0	-
LSD (0.05)	1.9	0.11	-	-	-
CV (%)	7.82	2.94	-	-	-

Means within the same column followed by the different letters of each factor differ significantly at 5% probability level LSD= Least significantly difference (P< 0.05); CV= Coefficient of variation; GMV= Gross Monetary Value; MV= Monetary Value, DAMP= days after maize planted.

CONCLUSION AND RECOMMENDATION

Almost the yield of climbing bean varieties was significantly affected by cropping systems. The Grain yields (2.14t ha^{-1}) were obtained from sole cropping. As the result of economic analysis, intercropping of maize with climbing bean is more advantageous than sole cropping. The height gross monetary value (54076 ETB ha^{-1}) was obtained from 14 DAMP. While the lowest gross monetary value (27021 ETB ha^{-1}) was obtained from simultaneous planting. Regarding climbing bean varieties, the highest GMV (48393 ETB ha^{-1}) was obtained from variety Tibe and the lowest gross monetary value (41419ETB ha^{-1}) from variety Waragutu.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declares that they have no conflicts of interest

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References

[1] Hauggaard-Nielsen, H., Jørnsgaard, B., Kinane, J. and Jensen, E.S., 2008. Grain legume–cereal intercropping: The practical application of diversity, competition and facilitation in arable and organic cropping systems. *Renewable Agriculture and Food Systems*, *23*(1), pp.3-12.
[2] Yildirim, E. and Guvenc, I., 2005. Intercropping based on cauliflower: more productive, profitable and highly sustainable. *European Journal of Agronomy*, *22*(1), pp.11-18.
[3] BİNGÖL, N.T., Karsli, M.A., Yilmaz, I.H. and Bolat, D., 2007. The effects of planting time and combination on the nutrient composition and digestible dry matter yield of four mixtures of vetch varieties intercropped with barley. *Turkish Journal of Veterinary and Animal Sciences*, *31*(5), pp.297-302.
[4] Dahmardeh, M., Ghanbari, A., Syasar, B. and Ramroudi, M., 2009. Effect of Intercropping Maize (Zea mays L.) VVith Cow Pea (*J'igna unguiculata* L.) on Green Forage Yield and Quality Evaluation. *Asian journal of plant sciences*, *8*(3), pp.235-239.
[5] Wu, K., Fullen, M.A., An, T., Fan, Z., Zhou, F., Xue, G. and Wu, B., 2012. Above-and below-ground interspecific interaction in intercropped maize and potato: A field study using the 'target'technique. *Field Crops Research*, *139*, pp.63-70.
[6] Morgado, L.B. and Willey, R.W., 2003. Effects of plant population and nitrogen fertilizer on yield and efficiency of maize-bean intercropping. *Pesquisa Agropecuária Brasileira*, *38*(11), pp.1257-1264.
[7] Bitew, Y., Alemayehu, G., Adgo, E. and Assefa, A., 2021. Competition, production efficiency and yield stability of finger millet and legume additive design intercropping. *Renewable Agriculture and Food Systems*, *36*(1), pp.108-119.
[8] Mutungamiri, A., Mariga, I.K. and Chivinge, O.A., 2001. Effect of maize density, bean cultivar and bean spatial arrangement on intercrop performance. *African Crop Science Journal*, *9*(3), pp.487-497.
[9] Zerihun Abebe, Chala Dabala and Tadesse Birhanu. 2017. System Productivity as Influenced by Varieties and Temporal Arrangement of Bean in Maize-climbing Bean Intercropping. *Journal of Agronomy*, 16: 1-11. Haramaya University, Ethiopia.
[10] Zerihun Abebe. 2011. System Productivity as Influenced by Integrated Organic and Inorganic Fertilizer Application in Maize (Z*ea mays* l.) Intercropped with Soybean (*glycine max* l. merrill) Varieties at Bako, Western Ethiopia.Msc. Thesis. Haramaya University, Ethiopia.
[11] Chemeda Fininsa. 1997. Effects of planting pattern, relative plating date and intra row spacing on a Haricot bean/Maize intercrop. African Crop Science Journal 5: 15-22.
[12] Karikari, S.K., Chaba, O., and Molosiwa, B.1999. Effects of Intercropping Bambara Groundnut on Pearl millet, Sorghum and Maize in Botswana. *African Crop Science Journal*, 7(2): 143-152.
[13] Deresa Shumi, Demissie Alemayehu and Tekalign Afeta. 2017. Effect of Variety and Time of Intercropping of Common Bean (*Phaseolus vulgaris* L.) With Maize (*Zea mays* L.) on Yield Components and Yields of Associated Crops and Productivity of the System at Mid-Land of Guji, Southern Ethiopia
[14] Demissie Alemayehu. 2018. Effect of Variety and Time of Intercropping of Common Bean (*PhaseolusVulgaris* L.) With Maize (*Zea mays* L.) On Yield Components and Yields of Associated Crops and Productivity of the System
[15] Biruk Tesfaye. 2007. Effect of Planting Density and Varity of Common Bean (*Phaseolus vulgaris L.)* Intercropped with Sorghum (*Sorghum bicolor L.)* on Performance of the Component Crops and Productivity of the System in South Gonder, Ethiopia. M.Sc. Thesis Haramaya University, Ethiopia.
[16] Yesuf Mohammed. 2003. Effects of planting arrangement and population densities of haricotbean on productivity of sorghum/haricot bean additive mixture. M.Sc. Thesis.