Effects of Maize and Mung Bean Intercropping on Performance of the Component Crops and System Productivity

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Abstract

Interaction effect of variety by cropping system is expected to be arising from morphological features of component crops thus Selection of compatible varieties of component crops can increase productivity of intercropping systems. Hence, a field experiment was carried out at two locations to identify the best compatible varieties of maize and mung bean that can increase the performance of the component crops and the productivity of the intercropping system. Factorial combinations of intercropping of three varieties of maize (Melkassa-1, Melkassa-2, Melkassa-6Q) and three varieties of mung bean (N-26/Rassa, NVL1, Shewa Robbit) with their respective sole crops were laid out as a randomized complete block design with three replications. The result showed that location and variety had a significant effect on growth parameters and yield components of maize and mung bean intercrops. The higher grain yield (4.1t ha^{-1}) was recorded from Melkassa Agricultural Research Center site. Regarding varieties, the highest maize grain yield (4.8t ha^{-1}) was obtained from variety Melkassa-2 intercropped with mung bean variety-26. The higher grain yield of intercropped mung bean was (530 kg ha^{-1}) recorded from Melkassa Agricultural Recearch Center. Among the different intercropping combinations, intercropping maize variety Melkassa-2 with mung bean variety N-26 had the highest Land Equivalent Ratio (1.57), maize equivalent yield (6390kg ha^{-1}) and monetary value (63900 ETBha^{-1}). Intercropping resulted in the highest Land Equivalent Ratio (LER) (1.30), maize equivalent yield (5270 kg ha^{-1}) and Gross Monetary Value (56300 ETB ha^{-1}). Thus, maize variety Melkassa-2 with mung bean variety N-26 can be used as compatible varieties of component crops to maximize the productivity of the intercropping system in drylands of central and eastern Ethiopia.

Keywords: Intercropping, economic yield, land equivalent ratio, maize, mungbean,

Introduction

Cereal-legume intercropping is the most commonly used practice by smallholder farmers in developing countries because of its environmental as well as economic advantages (Willey, 1979). For developing a feasible and economically viable intercropping system, planting pattern of the compatible crops are an important agronomic approach for enhancing system productivity. Intercropping cereals with legumes provides an opportunity to harness the benefits of legumes sustaining the cereal based cropping system without adverse effect on yield. However, the advantage of intercropping is obtained when correspondent species have differences in crop architecture, maturity time, and nutrient use to optimize the use of natural resources and environmental factors when cropped together (Nurbakhsh *et al.*, 2013).

In Ethiopia, maize (*Zea mays* L.) ranks first among cereals in grain yield (4.2 t ha^{-1}) and in total grain production, while it is second to *teff* in total area coverage with 2.27 million ha in 2019/2020 cropping season (CSA, 2020). The major reasons for popularity of maize include: its highest yields per unit area, positive response to use of inputs, ease of production and food preparation, compatibility with many cropping systems, adaptability to major agro-ecologies. It is food security crop in the country where recurrent drought is a common phenomenon (Tesfa *et al.,* 2001).

Mung bean [*Vigna radiata* (L.) Wilczek] is an eco-friendly food grain leguminous crop of dry land areas with rich source of proteins, vitamins, and minerals (Keatinge *et al.*, 2011). It is of recent introduction to Ethiopian pulse crops production but its importance especially as an export crop is increasing. It is mostly grown by smallholder farmers under drier marginal environmental condition as food and cash crop due to its short growth duration and high market value. According to CSA (2020) report, the estimated area under mung bean in Ethiopia during the main cropping season of 2019/2020 cropping season was 49,123.52 ha with productivity of 1136 kg ha^{-1}. Mung bean is a quick crop, requiring 75–90 days to mature. It is a useful crop in drier areas and has a good potential for crop rotation, relay cropping and intercropping with cereals (Singh, 2014).

In maize based intercropping system, selection of an appropriate intercrop having desirable plant type and growth pattern assumes greater importance. Crops maturing well before the peak growth period of maize are ideal. Other studies on intercropping has indicated how niche difference in crop species can leading to increased biological efficiency and yield advantage (Mucheru-muna *et. a l.* 2010). Maize and mung bean intercropping can reduce the risk of crop failure that could result from terminal moisture deficit, as mung bean matures early relative to maize. However, the yield in intercropping system depends on selection of compatible genotypes with suitable characters for establishment of minimum competition and maximum complementarity (Mutungamiri *et al.,* 2001).

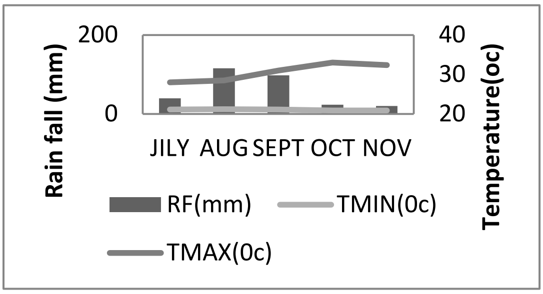
In Ethiopia, improved maize and different legume varieties have been recommended for sole cropping system and compatibility study of legume and maize varieties is not well-addressed (Tesfa *et al.,* 2012). Interaction effects of variety by cropping system are expected to be arising from morphological features such as leaf arrangement, canopy shape and growth habit. For sustainable intensification of maize and mung bean in maize-based cropping system of central and eastern Ethiopia, growth and morphological characters governing compatibility of varieties of the component crops under intercrop conditions need to be understood. Hence, this study was undertaken to identify the best compatible varieties of maize and mung bean that can increase the productivity of intercropping system.

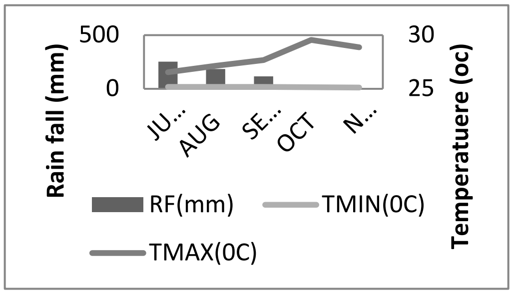
Materials and Methods

Description of the Experimental Site

The experiment was conducted at two locations, *i.e.* Melkassa in central Ethiopia and Fedis in Eastern Ethiopia in 2017 cropping season (July to November). Melkassa is located at 8^{o}24' N latitude, 39^{o}12' E longitude and an altitude of 1550 meters above sea level. The long-term mean annual rainfall is 791.69 mm with erratic distribution having peaks in July and August. The long-term (1977–2005) mean monthly maximum and minimum temperature was 28 and 14 ^{o}C, respectively (MARC, 2005). The soil of the experimental site is clayey loam. The total seasonal rainfall and mean temperature of growing season were 813.6 mm and 21.4 ^{o}C, respectively (Figure 1).

Fedis is located at of 9˚07'51.6"N latitude, 42˚04'24.3"E longitude, and an altitude of 1702 meters above sea level. The rainfall has a bimodal distribution pattern with small rains falling from March and May and the main rains falling from June to October, but with erratic distribution. The total seasonal rainfall and mean temperature of the growing season were 657.7 mm and 20.4 ^{o}C, respectively (Figure 1).





Melkassa Fedis

Figure 1. Monthly total rainfall (mm) and average maximum and minimum air temperatures (°C) of crop growing seasons during 2017 at Melkassa and Fedis

Soil sampling and analysis

Prior to planting, soil samples were collected from 0-30 cm depth from five spots across the experimental fields, in a *zig-zag* pattern, composited, and analyzed for selected soil physico-chemical properties. The composited soil sample was air-dried, ground and sieved to pass through a 2 mm sieve. Soil sample was analyzed at Melkassa Agricultural Research Center soil laboratory. Total nitrogen was determined following Kjeldahl procedure as described by Cottenie (1980); the soil pH was determined by using a digital pH meter (Page, 1982). Organic carbon was determined following wet digestion method as described by Walkley and Black, (1934); and the available phosphorous was measured using Olson II methods (Olsen *et al.*, 1954); cation exchange capacity (CEC) was determined by ammonium acetate method (Cottenie, 1980) and soil texture was determined by Bouyoucons hydrometer method (Bouyoucos,1962). The results of the soil analysis revealed that the soils of the experimental fields were clay loam in texture both at Melkassa and Fedis. The soils had moderate organic carbon (1.77%) and low total N (0.08%) at Melkassa and low organic carbon (1.4%) and low total N (0.11%) at Fedis. Available P was medium (6.84 ppm) at Melkassa and low (5.45 ppm) at Fedis (Table 1).

Table 1. Selected physicochemical properties of the experimental soils at MARC and Fedis (Boko site) in 2017 cropping season before planting

Soil parameter	MARC	Fedis
pH	7.73	8.05
Organic carbon (%)	1.77	1.4
Total N (%)	0.08	0.11
Available P (mg/kg)	6.84	5.45
Exchange K (c mol (+)/kg	2.85	0.92
CEC (cmol/kg)	36	35.2
Clay (%)	36	36
Silt (%)	32	35
Sand (%)	32	29
Soil texture	Clay-loam	Clay-loam

Description of the Experimental Materials

The maize varieties used for the experiment were obtained from Melkassa Agricultural Research Center (MARC). The varieties were selected due to their morphological differences (plant height, leaf area, number and size of leaves), maturity group, yielding potential and ecological preferences. Similarly, three varieties of mung bean were obtained from Melkassa Agricultural Research Center/MARC. Detailed description of the varieties used for the study is given on table 2.

Table 2. Maize and mung bean varieties used for the experiment

Maize Variety	Years of Release	Days to maturity	Plant ht (cm)	Yield(t/ha)		Altit (m)	Rf (mm)	Released institute
				On-station	On-farm			
Melkassa-I	2001	85	150-170	3.8-4.5	2.5-3.5	600-1700	450-570	MARC
Melkassa-2	2004	130	170-190	4.5-5.5	4-4.5	600-1700	-	MARC
Melkassa-6Q	2008	120	-	3-4	-	-	500-800	MARC

Source: MOAR 2008

Mung bean Variety	Years of Release	Days to maturity	Yield(t/ha)		Altitude (m)	Rainfall (mm)	Released institute
			On-station	On-farm			
(N-26)-Rasa	2011	65-80	0.8-1.5	0.5-1.0	900 – 1670	350-550	MARC
NVL-1	2014	60-70	0.75-1.5	-	450-1670	350-750	MARC
Shewa-robit	-	-	-		-	-	Local

Source: (MOARD, 2008; MOA, 2011)

Treatments and Expermental Design

Treatments consisted of factorial combinations of three varieties of maize (Melkassa-1, Melkassa-2 and Melkassa 6Q) and thee varieties of mung bean (N-26, NVL-1 and Shewa-Robit) and their respective sole crops. The treatments were laid out in a randomized complete block design with three replications. The gross plot size was 3.75 m x 3.5 m (13.125 m^2) accommodating five rows of maize. The space between plots and blocks were 0.5 m and 1m, respectively. The net plot size was 1.5 m x 3.5 m (5.25 m^2) accommodating three rows of sole and intercropped maize. For the sole mung bean, the gross plot size was 3 m 1 m (3 m^2) accommodating ten rows and the net plot size was 2.1 m x 1.4 m (2.94 m^2) accommodating eight rows of mung bean. The total experimental area was 28*34 m (952 m^2).

Experimental procedure

The experimental field was ploughed and harrowed by a tractor to get a fine seedbed and leveled manually before the field layout was made. Both maize and mung bean varieties at two locations were planted simultaneously on July 9. Spacing for sole and intercropped maize was 75× 25 cm and for sole mung bean was 30×10 cm. For intercropped mung bean 50cm x 10cm, 25cm x 10cm and 105cm x 10cm for 1mz:1mn, 1mz:2mn and 2mz:1mn row arrangements, respectively. Two seeds per hill of both maize and mung bean were planted and thinned to one plant per hill one week after emergence. At planting, full dose of Di-ammonium phosphate (18% N, 46% P_2O_5) at the rate of 100 kg ha^{-1} was applied uniformly into all plots including sole maize. Half of nitrogen in the form of urea (46% N) at the rate of 50 kg ha^{-1} was applied into sole maize and maize/mung bean intercropped plots at the time of planting and the remaining half N was applied at knee height growth stage of maize. Nitrogen at the rate of 18kg/ha of Urea was applied to sole mung bean as starter since it cannot start N fixing immediately after planting. Hand hoeing and weeding were done as required. Both maize and mung bean were harvested from the net plot after they attained their normal harvest maturity.

Crop data collected

Phenological parameters

Maize component

Plant and ear heights were measured from the ground to the base of the tassel and from the ground to the base of the first cob, respectively. Leaf area was estimated by using the formula length x maximum width x 0.75 from leaves of five sample plants in each plot just after tasseling (Mokhtarpour *et al*, 2010). Then leaf area index was calculated as the ratio of leaf area to ground area occupied by the respective plants.

Mung bean component

Leaf area of five randomly selected plants from each plot was measured by using leaf area meter (model LI-3000A) at flowering for both locations. Leaf area index was calculated by dividing the leaf area to the ground area occupied by the plants. Plant height and number of primary branches per plant were recorded at physiological maturity from five randomly selected plants.

Plant growth parameters

Maize component: plant and ear heights were measured from randomly selected five plants. Measurement was taken from ground to base of tassel and from ground to base of the first cob for plant and ear height, respectively. Leaf area was estimated by using the formula" length x width x 0.76" from leaves of five sample plants in each plot just after tasseling (Mokhtarpour *et al.* 2010). Leaf area index was calculated as the ratio of leaf area to the ground area occupied by the respective plants.

Mung bean component: leaf area of five randomly selected plants from each plot was measured by using leaf area meter (model LI-3000A) at flowering. The leaf area index was calculated by dividing the leaf area by the ground area occupied by the plants. Plant height and number of primary branches per plant were recorded during physiological maturity from five randomly selected plants.

Yield components and yield

Maize component

Cob diameter and number of kernels per cob were determined from five randomly selected cobs from each plot. Grain yield was taken from the three middle rows after shelling the sun-dried ears. Thousand kernels weight was measured from bulk of the threshed grains and the weight was adjusted to 12.5% moisture content. The grain was weighed using sensitive balance and the moisture content was determined by electronic moisture tester and the weight was adjusted to 12.5% moisture content. Aboveground biomass was also weighed after harvesting and sun drying to constant weight. Harvest index of maize was calculated as a ratio of the grain yield to the total biomass yield.

Mung bean component

Number of pods per plant was recorded from five randomly selected plants of each plot at harvest. Number of seeds per pod was recorded from 20 randomly selected pods of the five selected sampled plants. Grain yield and hundred grain weight were determined after grains were sun dried, weighed and adjusted to 10% moisture content. Aboveground biomass was also taken at physiological maturity stage from 10 plants randomly taken from each plot after sun drying to a constant weight. The dry biomass per plant was then multiplied by the total number of plants per net plot and was converted into kg ha^{-1}. This value was used to calculate the harvest index as well. Harvest index was calculated as a ratio of grain yield to the total biomass yield.

Evaluation of system productivity

Intercrop productivity was determined by land equivalent ratio (LER) (Willey, 1979), maize equivalent yield (MEY) (Anggarda *et al.*, 2015); and Gross monetary value (GMV). Land equivalent ratio is the amount of land required in sole cropping to obtain the same yield as in the intercrop. It was determined as:

$LER= (Y_{MB}/Y_{M}) + (YBM/Y_{B})$

Where Y_{MB} is intercrop maize grain yield (kg ha^{-1}), Y_M is average sole crop grain yield of maize varieties (kg ha^{-1}), Y_{BM} is intercrop mung bean grain yield (kg ha^{-1}) and Y_B is average sole crop grain yield (kg ha^{-1}) of the mung bean varieties.

Maize equivalent yield is the sum of maize yield in the intercrop system and the converted mung bean yield and was compared with sole crop maize yield. Maize was the main crop; therefore, yield of the mung bean in the intercrop system was converted to maize yield by multiplying the mung bean yield with mung bean/maize price ratio. It was calculated using the following formula:

$$EY_M = Y_{MB} + (Y_{BM} \times P_B/P_{M)}$$

Where EY_M is maize equivalent yield, YML = intercrop maize grain yield (kg ha^{-1}); Y_{BM} = intercrop mung bean grain yield (kg ha^{-1}); P_M = price of maize grain kg $^{-1}$; P_B = price of mung bean grain kg^{-1}.

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Gross monetary value (GMV) is used to calculate the economic advantage of intercropping as compared to sol cropping. Gross monetary value was calculated as the product of yield of the component crops multiplied by their respective unit price. The total values obtained from the component crops were used to indicate the Gross Monetary Value. To estimate the GMV of component crops, maize grain yield was valued at an average open market price of 10.00 ETB kg^{-1}, and mung bean at 30.0 ETB kg^{-1} at the time of crop harvest.

Data analysis

The data were subjected to analysis of variance (ANOVA) using SAS version 9 software program (SAS, 2002). Homogeneity of variances was tested using the F-test as described by Gomez and Gomez (1984) and since the F-test showed homogeneity of the error variances of the parameters of the two locations, combined analysis of variance was used. Means were compared using Least Significant Difference (LSD) test at 5% level of significance where significant differences existed among the factors.

Results and Discussion

Maize Component

Phenology and growth parameters

The main effects of location and variety combinations did not show a significant effect on days to tasseling and silking however days to maturity highly significantly ($p<0.01$) affected by the main effects of location and varietal combination of component crops. The interaction of main effects showed non-significant effect on days to tasseling, silking and maturity of maize. Significantly longer days to maturity (115.7) was recorded from Melkassa (Table 4). The possible reasons for longer days to maturity at MARC might be related to extended vegetative growth as a result of relatively adequate moisture availability.

Regarding varieties, the longest days to maturity (128) was recorded for maize variety Melkassa-2 intercropped with mung bean variety Shewa-Robit while the shortest days to maturity (84) was for maize variety Melkassa-2 intercropped with mung bean var. NVL-1. This might be due to the genetic difference of the crop on days to maturity (Table.1). Opposing this result, Wondimu *et al.*, (2016) stated that days to maturity of maize were not significantly influenced by intercropped soybean varieties.

On the other hand, cropping system had no significant effect on days to maturity of maize varieties which could be due to maize is more aggressive competent than mung bean for growth resources. In agreement with this result, Molla and Getachew (2018) did not found a significant effect of cropping system on maturity of maize when intercropped with fenugreek, field pea and haricot bean. Abraha (2013) also reported no significant effect of cropping system on days to maturity of maize in maize/cowpea intercropping

Table 3. Days to maturity (DM), plant height (PH), ear height (EH) and leaf area index (LAI) of maize intercropped with mung bean as influenced by the main effects of location, varieties and cropping systems.

Treatments	Days to Maturity(DM)	PH (cm)	EH (cm)	LAI
Location				
Melkassa	115.7^{a}	176.0^{a}	112.8^{a}	3.4^{a}
Fedis	104.9^{b}	150.9^{b}	93.3^{b}	2.9^{b}
Significance	**	**	**	**
LSD (0.05)	2.9	13.1	10.3	0.2
Intercrops				
Melkassa-1 x N-26	85^{c}	135.1^{b}	86.5^{c}	2.8^{bc}
Melkassa-1 x NVL-1	84^{c}	137.0^{b}	89.3b^{c}	2.7^{c}
Melkassa-1 x Shewa Robbit	85.2^{c}	135.0^{b}	86.5^{c}	2.7^{c}
Melkassa-2 x N-26	127.7^{a}	189.3^{a}	112.0^{a}	3.6^{a}
Melkassa-2 x NVL-1	127.6^{a}	182.6^{a}	106.4^{abc}	3.4^{a}
Melkassa-2 x Shewa Robbit	128^{a}	185.7^{a}	110.0^{ab}	3.5^{a}
Melkassa 6Q x N-26	118.7^{b}	164.9^{a}	110.5^{ab}	3.3^{a}
Melkassa 6Q x NVL-1	117.8^{b}	171.3^{a}	112.1^{a}	3.2^{ab}
Melkassa 6Q x Shewa Robbit	118.8^{b}	170.1^{a}	114.4^{a}	3.2^{abc}
Varieties				
Melkassa-1	85^{c}	124.8^{b}	86.6^{c}	2.9^{bc}
Melkassa-2	129.1^{a}	182.8^{a}	107.4^{abc}	3.6^{a}
Melkassa-Q	119.7^{b}	165.3^{a}	108.3^{ab}	3.3^{a}
Significance	**	**	*	**
LSD (0.05)	6.1	27.8	21.7	0.5
CV (%)		14.5	18	12.3
Cropping system				
Sole	115.2a	152.8	93.7	3.5^{a}
Intercropped	110.3	163.4	103.1	3.2^{b}
Significance	NS	NS	NS	*
LSD (0.05)	NS	NS	NS	0.2
CV (%)	18	17.9	17.9	13.9
Interaction (L x IC)	NS	NS	NS	NS

Means within the same column followed by the same letter or by no letters of each factor do not differ Ns, *, and ** = Non-significant, significant at 5% and significant at 1% probability

Combined analysis of data over locations revealed that main effects of location and varieties of intercropped mung bean had significant ($p<0.01$) effect on plant and ear height of maize varieties However, their interaction showed non-significant effect. The tallest plant (176 cm) and ear height (112.8 cm) were recorded at Melkassa than at Fedis (Table 3). Reasons for plant and ear height differences might be due to agro ecological variation

Among the varieties, the tallest plant and ear heights, 189.3 and 112 cm, respectively, were recorded for the maize variety Melkassa-2 intercropped with mung bean variety N-26, which were in statistical parity with same variety intercropped with the other mung bean varieties. However, 40.2% and 29.5% reductions in plant and ear height, respectively, were recorded for maize variety Melkassa-1 intercropped with mung bean variety Shewa Robbit (Table 3). The possible reason for reduction in plant and ear height in melkassa-1varieties might be due to genetic variation and less competitiveness of this variety than companion crop. Consistent with this result, Wubshet *et al*. (2020) reported significant effect varietal on plant height in sorghum when intercropped cowpea. In contrast to this result, Teshome *et al.* (2016), obtained that, plant height of intercropped maize was not significantly affected by the main effect of soybean varieties in maize/soybean intercropping due to compatibility of variety of companion crop to exploit common growth resources.

Moreover, cropping system had no significant effect on Plant and ear height of maize. In line with this result, Wolde (2015) also found a non-significant effect of cropping system on plant and ear height of maize in maize/haricot bean intercropping. In contrast to this result, Belsti *et al.* (2016) reported significantly taller height of maize from intercropped maize in maize/haricot bean intercropping.

Leaf area index (LAI) was significantly ($p<0.01$) affected by the main effects of location and varieties. However, their interaction showed no significant effect (Table 3) With this regard, 16.6% increments in LAI was recorded from MARC. The probable reasons might be related to favorable climatic and soil conditions. Among thee combinations of the varieties, the maximum LAI (3.62) was recorded for maize variety Melkassa-2 intercropped with mung bean variety N-26 and it was statistically at par with same variety and Melkassa 6Q intercropped with the three varieties of mung bean while the lowest LAI (2.73) was recorded for maize variety Melkassa-1 intercropped with mung bean varieties NVL-1 and Shewa Robbit. The possible reason for higher LAI for maize variety Melkassa-2 might be related to highest number of leaves produced per plant and extended maturity of this variety benefits to continue its vegetative growth after companion crop harvested. In agreement with this result, Wubshet *et al*. (2020) found significant effect of varieties of intercropped cowpea on leaf area index of sorghum.

The analysis of variance showed that cropping system significantly ($p<0.05$) affected LAI of maize where significantly higher LAI (3.5) was recorded due to sole cropping. The higher LAI under sole cropping might be due to absence of inter-specific competition for growth resources. This result is in agreement with the finding of Alom *et al.* (2010) who stated that, LAI of maize decreased due to intercropping, but there was no remarkable difference between the sole and intercrop maize in maize/ground nut intercropping.

Yield components and yield

The main effects of location ($p<0.05$) and variety ($p<0.01$) showed significant effect on the number of ears per plant (Table 4). Number of ears per plant increased by 10.28% at MARC over Fedis due to favorable climatic condition resulted exceeded growth performances (Table 4). Among the varieties, the highest number of ears per plant (1.2) was recorded from maize variety Melkassa-2 intercropped with mung bean variety N-26 and it was statistically at par with same variety intercropped with the other mung bean varieties while the lowest number of ears per plant (1.0) was recorded from variety Melkassa-1 intercropped with mung bean variety NVL1. The reason for such difference in the number of ears per plant might be due genetic variability and all varieties have no equal competitiveness for growth resources with companion crop of which a variety with short maturity period (Melkassa-1) suffered the most with competition since no temporal complementary effect between companion crops. Supporting this result, Teshome *et al. (*2016) stated that effect of soybean varieties was significant on number of ears per plant. Jibril *et al.* (2015) also found significant effect of variety of intercropped common bean on cob number per plant of maize.

Table 4. Number of ears per plant, cob diameter and grains per cob of maize intercropped with mung bean as influenced by the main effects of location, varieties and cropping systems.

Treatments	No. of ears per plant	Cob diameter (cm)	Number of grains per cob
Location			
Melkassa	1.2[a]	4.3[a]	474.5[a]
Fedis	1.1[b]	3.8[b]	422.3[b]
Significance	*	**	**
LSD (0.05)	1.07[b]	3.8[b]	422.3[b]
Intercrops			
Melkassa-1 x N-26	1.07[cde]	3.5[b]	373.7[c]
Melkassa-1 x NVL-1	1.0[e]	3.5[b]	359.1[c]
Melkassa-1 x Shewa Robbit	1.0[de]	3.4[b]	369.9[c]
Melkassa-2 x N-26	1.2[a]	4.5[a]	516.0[a]
Melkassa-2x NVL-1	1.1[abc]	4.4[a]	502.4[ab]
Melkassa-2 x Shewa Robbit	1.2[ab]	4.4[a]	512.0[ab]
Melkassa-6Q x N-26	1.1[abcd]	4.3[a]	473.1[ab]
Melkassa-6Q x NVL-1	1.1[bcde]	4.1[a]	461.9[b]
Melkassa-6Q xNVL-1	1.1[cde]	4.2[a]	467.5[ab]
Varieties			
Melkassa-1	1.04[cd]	3.5[b]	378.5[ab]
Melkassa-2	1.2[a]	4.5[a]	5.5.6[a]
Melkassa-6Q	1.1[abc]	4.3[a]	469.4[ab]
Significance	**	**	**
LSD (0.05)	0.09	0.53	52.39
CV (%)	7.0	11.2	10.0
Cropping system			
Sole	1.14	4.37	472.7
Intercrop	1.09	4.04	448.4
LSD (0.05)	NS	NS	NS
CV (%)	1.09	4.04	4.48
Interaction (L x IC)	NS	NS	NS

Means within the same column followed by the same letter or by no letters of each factor do not differ Ns, *, and ** = Non-significant, significant at 5% and significant at 1% probability

There was no significant difference between sole and intercropped maize on number of ears per plant which might indicate that this parameter is more affected by varietal characteristics than management practices. In conformity with this result, Molla and Getachew (2018) did not find significant difference between sole and intercropped maize on cob number per plant in maize, fenugreek, field pea and haricot bean intercropping. Similarly, Demissie *et al.* (2018) also did not find significant difference on number of cob per plant between sole and intercropped maize in maize/common bean intercropping.

Cob diameter and number of grains per cob were significantly ($p<0.01$) affected by location and variety while the interaction of location and variety combination had no significant effect on cob diameter and grains per cob (Table 4). Fedis recorded 11.6 % and 11.0% reductions in cob diameter and grains per cob, respectively. This might be related to depressed growth performance mainly LAI, resulted lower rate of assimilate translocation to seed setting.

Among the varieties, 32.4% and 43.7% increments in cob diameter and grains per cob, respectively were recorded for maize variety Melkassa-2 intercropped with mung bean variety

N-26 and it was statistically at par with same variety intercropped with the other mung bean varieties while significantly lower cob diameter and number of grains per cob were recorded for maize variety Melkassa-1 intercropped with all the three mug bean varieties (Table 4). The reason for lower cob diameter and number of grains per cob for variety Melkassa-1 might be related to absence of temporal complementary which resulted in severe competition for growth resources. In agreement with this result, Teshome *et al.* (2016) reported that number of kernels per cob of the associated maize was highly significantly affected by the intercropped soybean bean varieties.

Cropping system had no significant effect on cob diameter and number of grains per cob (Table 4). In agreement with this result, Jibril *et al.* (2015) did not find significant effect of cropping system on number of kernels per cob. In contrast to this result, Tohura *et al.* (2014) obtained significantly higher number of grains per cob (376.70) from sole than intercropping (335.5) in maize/mung bean intercropping. Teshome *et al.* (2016) also found significantly higher number of ears per plant (2.33) due to sole cropping than intercropping (2.1) in maize/soybean intercropping.

Table 5. Thousand kernels weight, Grain yield, Biomass yield and Harvest index of maize intercropped with mung bean as influenced by the main effects of location, varieties and cropping systems.

Treatments	1000 kernels weight (g)	Grain yield (t ha^{-1})	Biomass yield (t ha^{-1})	Harvest index (%)
Location				
Melkassa	227.4^{a}	4.1^{a}	13.6^{a}	29.9
Fedis	211.8^{b}	3.5^{b}	11.3^{b}	30.6
Significance	*	**	**	NS
LSD (0.05)	12.87	0.22	0.63	NS
Intercropps				
Melkassa-1x N-26	214.6	3.0^{c}	9.6^{c}	31.6
Melkassa-1 x NVL	204	2.8^{c}	9.5^{c}	30
Melkassa-1 x Shewa Robbit	209.6	2.9^{c}	9.8^{c}	29.7
Melkassa-2 x N-26	228.4	4.8^{a}	15.2^{a}	31.4
Melkassa-2 x NVL1	221.5	4.6^{a}	15.0^{a}	31
Melkassa-2 x Shewa Robbit	226.6	4.7^{a}	15.2^{a}	31
Melkassa-6Q x N-26	226.6	3.8^{b}	13.9^{b}	28.9
Melkassa-6Q x NVL1	221	3.5^{b}	12.1^{b}	29.4
Melkassa-6Q x Shewa Robbit	223.9	3.9^{b}	12.7^{b}	29
Varieties				
Melkassa-1	214.2	3.0^{c}	10.2^{bc}	30.2
Melkassa-2	229.2	4.8^{a}	15.3^{a}	31.3
Melkassa-6Q	225.8	3.8^{b}	12.9^{b}	28.9
Significance	NS	**	**	NS
LSD (0.05)	NS	0.46	1.34	NS
CV (%)	10.6	10.5	9.2	8.6
Interaction (L x IC)	NS	NS	NS	NS
Cropping system				
Sole	233.5^{a}	4.2	13.8^{a}	29.9
Intercrop	220.9^{b}	3.8	12.5^{b}	30.2
Significance	*	NS	*	NS
LSD (0.05)	11.4	NS	1.32	NS
CV (%)	9.4	21.1	19	8.5

Means within the same column followed by the same letter or by no letters of each factor do not differ Ns, *, and ** = Non-significant, significant at 5% and significant at 1% probability

Thousand kernels weight was significantly ($p<0.05$) affected by one of main effects location, while neither varieties nor their interaction had significant effect (Table 5). Thousand kernels weight increased by 7.8% at MARC due to better growth performance mainly leaf area resulted maximum photosynthetic assimilate translocation to grain filling, resulted vigorous seed size. Similarly, Wondimu *et al.* (2016) stated that, soybean varieties non-significantly affected thousand kernel weights of maize in maize/soybean intercropping.

Cropping system had significant ($p<0.05$) effect on thousand kernels weight of maize (Table 5).
Where 5.4% reduction in thousands kernel weight recorded due to intercropping. Probable reasons for lighter kernels weight might be due to the fact, depressed growth performance mainly LAI, resulted low rate of assimilate translocation to grain

filling that leads to formation of shriveled and small sized kernels. In line with this result, Tohura *et al.* (2014) obtained the highest thousand kernels weight of maize (230.7 g) from sole over intercropping (225 g) in maize/mung bean intercropping. Similarly, Odigbo *et al.* (2013) obtained significantly highest thousand kernels weight of maize from sole (206.4g) than intercropped with cowpea (181.2g). Demissie *et al.* (2018) also obtained highest thousand grains weight (365 g) from sole cropped over intercropped maize (350g) in maize/common bean intercropping.

The grain yield and aboveground biomass yields of maize were significantly ($p<0.01$) affected by location and variety (Table 5). With this regard, grain and biomass yield was increased by 17.4% and 20.4%, respectively at MARC as result of exceeded growth and yield attributes. With respect to the effect of the varieties, 11.6% and 36.8% reduction in grain and biomass yield, respectively were recorded for maize variety Melkassa-1 intercropped with mung bean variety NVL and the values were in statistical parity with the values obtained with same maize variety intercropped with the other mung bean varieties. The possible reasons for reduction in grain and biomass yield might be the comulative effect of the least yield and yield related papameters mainly grians per cob, thousand kernels weight and cob diameter was recorded from this variety. In contrast, significantly lowest grain and biomass yields were recorded for the maize variety Melkassa-1 as result of poor competitive effect for common growth resources with companion crop. In line with this result, Teshome *et al*. (2016) obtained significant effect of varieties of intercropped soybean on aboveground biomass yield of maize. Similarly result that obtained by Wubshet *et. al*. (2020) stated that dry biomass of sorghum was highly significant among sorghum varieties in sorghum/cowpea intercropping. Opposing this, Zerihun (2011) reported no significant difference on dry biomass of the intercropped maize due to the associated soybean varieties.

Cropping system had also significant ($p<0.05$) effect on biomass yield of maize, but not on the grain yield (Table 5). With this regard, 9.4% reduction in biomass yield was recorded due to intercropping (Table 5). Probable reasons might be the cumulative effect of relatively depressed growth and yield attributes as result of sever inter and intra species competition between companion crops. In agreement with this result, Belsti *et al.* (2016) found 9.3% biomass yield reduction due to intercropping in maize/haricot bean intercropping. In contrast to this result, Tohura *et al.* (2014) stated that grain yield of maize reduced in intercropped situation (3966kg/ha) compared to sole maize(4488kg/ha) in maize/mung bean intercropping.

of variance showed that neither the main effect of location and variety nor their interaction had significant effect on harvest index of maize. Moreover, cropping system also had no significant effect on harvest index. This result was in agreement with the result of Tohura *et al.* (2014) who found non-significant effect of cropping system on harvest index of maize in maize/mung bean intercropping. Tamiru (2014); and Belsti *et al.* (2016) also found non-significant effect of cropping system on harvest index of maize under maize-haricot bean intercropping system.

Mung bean Component

Phenology and growth parameters

Days to maturity was significantly ($p<0.05$) affected by the main effects of location and variety while interaction had no significant effect (Table 7). Mung bean planted at Melkass took significantly extended maturity period (75.5 days) over Fedis (66.9 days). Probable reasons for extended days to maturity might be related to agroecological variation mainly soil and moisture.

Mung bean variety Shewa Robit intercropped with maize variety Melkassa-1 took extended maturity period (73.8) while the shortest days to maturity (69 days) was recorded for mung bean variety NVL-1 intercropped with maize variety Melkassa-2 (Table 7). Probable reasons might be relared to since Shewarobbit is local variety already adopted agroecology thus it became aggressive competator over other mung bean varieties. In line with this result, Tamiru (2013) found significant difference among the varieties of soybean on days to maturity in maize/soybean intercropping.

Cropping system showed significant ($p<0.01$) effect on days to maturity of mung bean. Sole cropped mung bean took extended days of maturity (75.2) was attributed to the absence of interspecific competition for water and nutrients thereby extending its vegetative growth leading to delayed maturity. In line with this result, Anisha *et al.*, (2015) reported significantly extended days to maturity of sole cropped cowpea in maize/cowpea intercropping.

Location had significant ($p<0.05$) effect on mean plant height, however, variety and interaction of location and variety were non-significant on mean plant height of mung bean. Significantly taller plants (48.0 cm) which 8.5% increase in plant was recorded at Melkassa than at Fedis (Table 6) which might be related to adequate rainfall during the growing season at the former site.

Cropping system had significant ($p<0.01$) effect on plant height of mung bean. Sole cropped mung bean increased by 11.7% over intercropping (Table 6) which could be due to sever shading effect and growth resources competition by the associated maize in intercropping. In conformity with this result, Arshad *et al*. (2020) recorded the highest plant height of mung bean from sole cropping (56.7 cm) than in intercropping (45.2 cm) with maize. Onuh *et al*. (2011) also recorded the tallest mean plant height (47 cm) from sole cropped mung bean than in intercropping (41 cm) in maize/mung bean/melon intercropping.

Table 6. Days to maturity, Plant height, Leaf area index and primary branches per plant of mung bean as influenced by the main effects of location, varieties and cropping systems.

Treatments	Days to Maturity	Plant height (cm	Leaf area Index	Primary branches per plant
Location				
Melkassa	75.4[a]	48.0[a]	2.8	4.8[a]
Fedis	66.9[b]	44.2[b]	2.6	4.2[b]
Significance	**	*	NS	**
LSD (0.05)	2.2	4,1	NS	0.41
Intercrops				
N-26 x Melkassa-1	72.5[ab]	46.7	2.8	6.5[a]
N-26 x Melkassa-2	73.7[a]	49.1	2.6	5.6[ab]
N-26 x Melkassa-6Q	73.7[a]	45.2	2.6	5.3[bc]
NVL1 x Melkassa-1	70[ab]	45.1	2.7	4.1[de]
NVL1 x Melkassa-2	69[b]	42.7	2.5	3.7[def]
NVL1 x Melkassa-6Q	69.3[ab]	43.7	2.5	3.5[ef]
Shewa Robbit x Melkassa-1	69.7[ab]	47.6	2.8	4.5[cd]
Shewa Robbit x Melkassa-2	69.3[ab]	44.7	2.6	4.1[de]
Shewa Robbit x Melkassa-6Q	73.8[a]	50	2.6	3.8[def]
Varieties				
N-26/Rassa	74.4[a]	46.6	2.9	6.7[a]
NVL	70.3[a]	45.0	2.8	4.5cd
Shewarobbit	71.1[ab]	47.3	2.9	5.1[ab]
Significance	*	NS	NS	**
LSD (0.05)	3.6	NS	NS	0.87
CV (%)	5.5	15.5	12.8	16.6
Interaction (L x IC)	NS	NS	NS	NS
Cropping system				
Sole	75.2[a]	51.4[a]	3.6[a]	8.1[a]
Intercrop	70.9[b]	46.0[b]	2.7[b]	4.3[b]
Significance	**	**	**	**
LSD (0.05)	2.3	3.47	0.16	0.66
CV (5%)	5.9	13.5	10	23

Means within the same column followed by the same letter or by no letters of each factor do not differ Ns, *, and ** = Non-significant, significant at 5% and significant at 1% probability

The main and interaction effects of location and varieties showed non-significant effects on leaf area index (LAI) of mung bean. However, cropping system had significant effect ($p<0.01$) on LAI of mung bean. Leaf area index increased by 33.3% due to sole cropping (Table 6). The probable reasons might be related to increased number and size of individual leaves production as result of adequate moisture and space. In line with this result, Belsti *et al.* (2016); and Alemayehu *et al.* (2018) obtained significantly higher LAI of sole haricot bean than intercropped haricot bean in maize/haricot bean intercropping.

The number of branches per plant was significantly ($p<0.01$) affected by the main effects of location and varieties. However, their interaction effect was not significant. Whereas 14.3% increase in branches per plant was recorded from MARC (Table 6) possibly due to relatively better soil moisture that resulted in better growth performance of the crop at Melkassa.

Among the mung bean varieties, the highest number of primary branches per plant (6.5) was recorded for variety N-26 intercropped with maize variety Melkassa-1 and it was statistically at par with same variety intercropped with maize variety Melkassa-2 while the lowest number of branches (3.5) was recorded for variety NVL-1 intercropped with maize variety Melkassa 6Q (Table 6). The probable reason for production of less number of branches per plant by the mung bean in association with maize variety Melkassa 6Q might be related to high competitive effect of intercropped maize variety Melkassa -6Q for common growth resources In line with this result, Masa *et al.* (2017) found significant differences between varieties of common bean on number of primary branches per plant in maize/common bean intercropping.

The number of primary branches per plant was significantly ($p<0.05$) affected by cropping system where 46.9% reduction in number of branches per plant was recorded due to intercropping (Table 6). The reason for reduction on number of branches under intercropping might be related to presence of adverse shading effect and sever inter and intra species competition for growth resources. In conformity with this result, Onuh *et al.* (2011 also obtained higher number of branches (7.5) in sole cropped mung bean than in intercropping (5.4) in maize/melon/mung bean inter-cropping.

Yield component and yield

The analysis of variance showed that number of pods per plant was significantly ($p<0.05$) affected by one of main effects variety. However, interaction of location and variety was non-significant (Table 7). The highest number of pods per plant (10.5) was recorded from variety N-26 intercropped with maize variety Melkassa-1 and it was statistically at par with mung bean variety Shewa Robbit intercropped with maize variety Melkassa-1 and Melkassa-2 while the lowest number of pods per plant (8.1) was obtained when mung bean variety NVL-1 was intercropped with maize variety Melkassa 6Q. The possible reason for few number of pods per plant on variety NVL might be relatively depressed growth performance when intercrop with all maize varieties as result of poor competitive effect with companion crop.

Similarly, Setegn *et al.* (2006) indicated that number of pods per plant was reduced by 65% and 55% when climbing bean was intercropped with maize varieties. Wondimu *et al.* (2016) also reported significant reduction in the number of pods per plant of the intercropped soybean varieties in maize/soybean intercropping.

Cropping system also significantly (p<0.01) affected number of pods per plant. With this regard intercropped mung bean recorded 38.9% reduction on number of pods per plant.(Table 7). The probable reasons for reduction in pod number might be related to adverse shading effect by taller plants and presence of inter and intra species competition for common growth resources. In agreement with this result, Azim *et al*. (2012) found significantly higher number of pods from sole mung bean (17.32) than intercropped mung bean (9.07) in maize/mung bean intercropping. Onuh *et al.* (2015); and Tuhura *et al.* (2014) also obtained significantly highest number of pods per plant of 6.5 and 15.67, respectively, in sole cropped mung bean than in maize/mung bean intercropping.

Table 7. Number of pod per plant, number of seed per pod and hundred seed weight of mung bean intercropped with maize as influenced by the main effects of location, varieties and cropping systems

Treatments	No. of pods per plant	No. of seeds per pod	100 grains weight (g)
Location			
Melkassa	9.4	7.8	6.1[a]
Fedis	8.8	7.2	5.8[b]
Significance	NS	NS	*
LSD (0.05)	NS	NS	0.35
Intercrops			
N-26 x Melkassa-1	10.5[a]	8.6[ab]	6.6[a]
N-26 x Melkassa-2	9.3[ab]	7.9[abc]	5.9[ab]
N-26 x Melkassa-6Q	9.0[ab]	7.7[bc]	5.8[b]
NVL1 x Melkassa-1	9.5[ab]	6.8[cd]	6.3[ab]
NVL1 x Melkassa-2	9.0[ab]	5.8[d]	5.8[b]
NVL1x Melkassa-6Q	8.1[b]	5.3[d]	5.6[b]
Shewa Robbit x Melkassa-1	9.7[ab]	8.4[ab]	6.1[ab]
Shewa Robbit x Melkassa-2	8.9[ab]	7.8[bc]	5.8[b]
Shewa Robbit x Melkassa-6Q	8.3[b]	9.4[a]	5.7[b]
Varieties			
N-26/Rassa	11.5[a]	9.0[a]	6.7[a]
NVL	9.8[ab]	6.9[cd]	6.4[ab]
Shewarobbit	10.4[a]	8.5[ab]	6.3[a]
Significance	*	**	*
LSD (0.05)	1.72	1.53	0.74
CV (5 %)	16.1	17.3	10.7
Cropping system			
Sole	14.9[a]	10.6[a]	8.0[a]
Intercrop	9.1[b]	7.5[b]	5.9[b]
Significance	**	**	**
LSD (0.05)	0.9	0.83	0.42
CV (5%)	15.7	18.5	11.9
Interaction (L x IC)	NS	NS	NS

Means within the same column followed by the same letter or by no letters of each factor do not differ Ns, *, and ** = Non-significant, significant at 5% and significant at 1% probability

Number of seeds per pod was significantly (($p<0.01$) affected by one of main effects variety, however location and their interaction was non-significant (Table 7). The highest number of seeds per pod (9.4) was recorded for mung bean variety Shewa Robbit intercropped with maize variety Melkassa-6Q and it is statistically at par with variety N-26 intercropped with maize varieties while the lowest number of seeds per pod (5.3) was recorded for mung bean variety NVL-1 intercropped with maize variety Melkassa 6Q (Table 7). Probable reasons for reduction in seed per pod of variety NVL might be related to poor competitiveness over companion maize varieties. In line with this result Adigbo *et al.* (2013) stated that thousand seed weight of cowpea significantly affected by variety in maize/cowpea intercropping.

Number of seeds per pod was significantly (($p<0.01$) affected by one of main effects variety, however location and their interaction was non-significant (Table 7). The highest number of seeds per pod (9.4) was recorded for mung bean variety Shewa Robbit intercropped with maize variety Melkassa-6Q and it is statistically at par with variety N-26 intercropped with maize varieties while the lowest number of seeds per pod (5.3) was recorded for mung bean variety NVL-1 intercropped with maize variety Melkassa 6Q (Table 7). Probable reasons for reduction in seed per pod of variety NVL might be related to poor competitiveness over companion maize varieties. In line with this result Adigbo *et al.* (2013) stated that thousand seed weight of cowpea significantly affected by variety in maize/cowpea intercropping.

Cropping system significantly ($p<0.01$) affected the number of seeds per pod where 29.3% reduction in seed per pod was recorded due to intercropping The reason for the reduction of seed per pod of mung bean might be attributed to shading of tall growing maize plants in which the receipt lower amount of incoming solar radiation adverse affected the rate of net photosynthesis and thereby poor translocation of photosynthates from source to sink leading to formation of few number of seeds per pod in intercropping. In agreement with this result, Tuhura *et al.* (2014) obtained higher number of seeds per pod (8.95) of mung bean due to sole cropping than intercropping (7.5) in maize/mung bean intercropping. Similarly, Azim *et al.* (2012) also found significantly higher number of seeds per pod of mung bean in sole (4.23) than in intercropping (3.51) in maize/mung bean intercropping.

Hundred grains weight of mung bean was significantly ($p<0.05$) affected by location and variety, but not by their interaction. With this regard, hundred grains weight was increased by 5.3% at MARC over Fedis (Table 7). Reasons for lighter hundred seed weight might be related to depressed growth performance mainly leaf area as result of moisture scarcity throughout growth stages which resulted in low rate of photosynthetic assimilate translocation to grain filling and produced small seed size.

Among the varieties, mung bean variety N-6 intercropped with maize variety Melkassa-1 produced the heaviest hundred grains weight (6.6 g) while significantly lightest hundred seed weight (5.6 g) was for mung bean variety NVL-1 intercropped with maize variety Melkassa 6Q (Table 7). The heaviest hundred seed weight for variety N-6 might be because of inherent characteristics of the variety and due to mung bean variety N-26 benefited more from less competitiveness of maize variety Melkassa-1. Consistent with this result, Jibril *et al.* (2015) also reported a significant difference in hundred seed weight of common bean in maize-bean intercropping due to varietal difference. Likewise, Solomon (2015) also obtained significant differences in 100 seed weight among the soybean varieties in maize/soybean intercropping.

Cropping system also significantly ($p<0.01$) affected hundred grains weight of mung bean where 10.3% reduction in hundred grains weight was recorded due to intercropping (Table 7). This might be related to adverse shading effect and interspecies competition resulted depressed growth and low rate of assimilate translocation to grain filling and formation of shriveled and small sized seeds. In line with this result, Arshad *et al.* (2020), obtained the highest thousand grain weight of mung bean in sole cropping (43.5 g) than in intercropping with maize (36.8 g). Onuh *et al.* (2015); and Azim *et al.*, (2012) also obtained significantly higher thousand seed weight of 50 g and 39.3 g, respectively, of mung bean in sole cropping than in intercropping with maize.

The grain yield of mung bean was significantly ($p<0.05$) affected by main effects of location and varieties (Table 8). However, their interaction had no significant effect. Grain yield at MARC recorded 18.8% increments over Fedis due to favorable climatic condition (Table 8). With regard to variety, the highest grain yield (660.4 kg ha^{-1}) was obtained from mung bean variety Shewa Robbit intercropped with maize variety Melkassa-1 and it was statistically at par with mung bean variety N-26 intercropped with maize variety Melkassa-1 (638.3 kg ha^{-1}) while the lowest seed yield (360.4 kg ha^{-1}) was recorded for mung bean varieties NVL-1 and Shewa Robbit intercropped with maize variety Melkassa 6Q (Table 8). The possible reason for higher grain yield in mung bean varieties intercropped with maize variety Melkassa-1 might be related to less competitiveness of maize variety Melkassa-1 as evidenced from its low performance. In conformity with this result, Demissie *et al.* (2018) found significant differences among seed yields of common bean varieties in maize/common bean intercropping. Likewise, Wondimu *et al.* (2016) also proved that grain yield per hectare of soybean was significantly affected by soybean varieties and nitrogen rates in maize/soybean intercropping.

With regard to variety, the highest grain yield (660.4 kg ha^{-1}) was obtained from mung bean variety Shewa Robit intercropped with maize variety Melkassa-1 while the lowest seed yield (360.4 kg ha^{-1}) was recorded for mung bean varieties NVL-1 and Shewa Robit intercropped with maize variety Melkassa 6Q (Table 10). This might be attributed to the inherent varietal characteristics in intercropping system and lifecycle of maize variety melkassa-1and companion crop mung bean was almost similar as result competition was sever throughout growing season with this regard maize variety melkassa-1 was less competitive than companion crop. This result was confirmed by Demissie *et al.*, (2018) who found significantly differences among seed yields of common bean varieties in maize/common bean intercropping. Wondimu *et al.*, (2016) also proved that grain yield per hectare of soybean was significantly affected by the main effect of soybean varieties and nitrogen rates in maize/soybean intercropping.

Cropping system had also significant ($p<0.01$) effect on grain yield of mung bean. Grain yield reduction by 60% was recorded due to intercropping. Probable reasons might be due to adverse shading effect by taller maize plants which depressed growth and yield attributes. In line with this result, Saleem *et al.* (2015) stated that, intercropping reduced the mung bean yield by 28% compared to sole cropping of mung bean in maize/mung bean intercropping. Similarly, Arshad *et al. (*2020); Onuh *et al.* (2015); and Tuhura *et al.* (2014) obtained significantly highest grain yield of sole mung bean in maize/mung bean intercropping.

Table 8. Grain yield, biomass yield and Harvest index of mung bean intercropped with maize as influenced by the main effects of location, varieties and cropping systems.

Treatments	Grain yield (kg ha^{-1})	Biomass yield (kg ha^{-1})	Harvest index (%)
Location			
Melkassa	530.9^{a}	1776.3^{a}	29.8
Fedis S	446.8^{b}	1525.1^{b}	29
Significance	**	**	NS
LSD (0.05)	45.6	144.2	NS
Intercrops			
N-26 x Melkassa-1	638.3^{a}	2141.8^{a}	29.9^{abc}
N-26 x Melkassa-2	534.4b	1793.3b	29.9^{abc}
N-26 x Melkassa-6Q	510.9b	1736.6b	29.3^{abc}
NVL1 x Melkassa-1	438.8^{bc}	1522.2^{bc}	28.5^{bc}
NVL1 x Melkassa-2	374.7c	1269.4c	29.3^{abc}
NVL1 x Melkassa-6Q	356.3c	1282.0c	27.8c
Shewa Robbit x Melkassa-1	660.4^{a}	2110.6^{a}	31.0^{a}
Shewa Robbit x Melkassa-2	530.9^{b}	1748.4^{b}	30.6^{ab}
Shewa Robbit x Melkassa-6Q	355.4^{c}	1251.9^{c}	28.4^{bc}
Varieties			
N-26/Rassa	748.4^{a}	1297.4^{a}	30.1^{ab}
NVL	578.5^{ab}	1953.4^{ab}	29.0^{abc}
Shewarobbit	738.4^{bc}	2350.0^{a}	31.2^{a}
Significance	**	**	*
LSD (0.05)	96.6	305.8	2.73
CV (%)	16.9	15.8	7.9
Cropping system			
Sole	1230^{a}	3900^{a}	31.5^{a}
Intercrop	490^{b}	1650^{b}	29.6^{b}
Significance	**	**	**
LSD (0.05)	0.74	2.11	1.19
CV (5%)	20.1	17.6	7.3
Interaction (L x IC)	NS	NS	NS

Means within the same column followed by the same letter or by no letters of each factor do not differ Ns, *, and ** = Non-significant, significant at 5% and significant at 1% probability

The aboveground dry biomass of mung bean component showed a highly significant ($p<0.01$) difference between the locations and among the varieties while the interaction effect was not significant. Significantly higher aboveground biomass (1776.3 kg ha^{-1}) was recorded at Melkassa (Table 8) than at Fedis. This might be due to the cumulative effect of higher growth and yield attributes recorded at Melkassa.

Among the varieties, the highest aboveground dry biomass (2141.9 kg ha^{-1}) was obtained for variety N-26 intercropped with maize variety Melkassa-1 while the lowest aboveground dry biomass (1251.8 kg ha^{-1}) was recorded for mung bean varieties Shewa Robbit intercropped with maize variety Melkassa 6Q (Table 8). The higher aboveground dry biomass of the mung bean varieties in association with maize variety Melkassa-1 could be attributed to less competitiveness from the associated maize variety Melkassa-1 as observed from its poor growth and yield performance. In agreement with this result, Teshome *et al.* (2016) reported significant differences on aboveground biomass of soybean among the varieties in maize/soybean intercropping. Similarly, Zerihun (2011) reported variation on biological yield of soybean among varieties in maize/soybean intercropping.

Cropping system had highly significant ($p<0.05$) effect on the aboveground dry biomass of the mung bean. Significantly higher biomass yield (3900 kg ha^{-1}) was recorded from sole cropped mung bean than the intercropped mung bean (1650 kg ha^{-1}) (Table 8). In conformity with this result, Lyngdoh *et al.* (2020) stated a steep decline in biological yield of intercropped mung bean (0.6 t ha^{-1}) as compared to sole crop (1.5 t ha^{-1}) in maize/mung bean intercropping. Similarly, Azim *et al.* (2012) reported that maize-mung bean intercropping decreased mung bean biological yield by 21% as compared to mung bean mono cropping.

Harvest index of mung bean was significantly ($p<0.05$) affected by varieties while location and interaction of location by variety had no significant effect (Table 8). The highest harvest index (31.0%) was recorded for mung bean variety Shewa Robbit intercropped with maize variety Melkassa-1 while the lowest harvest index (27.8%) was recorded for mung bean variety NVL-1 intercropped with maize variety Melkassa 6Q (Table 8). The possible reason for highest harvest index for mung bean variety Shewa Robbit intercropped with maize variety Melkassa-1 might be related to less competitiveness of the maize variety which resulted in higher grain yield of mung bean. In line with this result, Teshome *et al.* (2015); and Zerihun (2011) reported highly significant difference among soybean varieties for harvest index in intercropping with maize.

Cropping system showed significant ($p<0.05$) difference on harvest index of mung bean. Higher harvest index (31.5%) was recorded for sole cropped mung bean than that of the intercropped mung bean (29.6%) (Table 8). The lower grain yield of mung bean in intercropping due to the shading of tall growing maize plants can be attributed to lower harvest index of the intercropped mung bean. In consistent with this result, Saleem *et al.* (2015) obtained higher harvest index (33.65%) for sole mung bean than the intercropped mung bean (30.52%) from maize-mung bean intercropping. Likewise, Berhane *et al.* (2015) reported higher harvest index (41.3%) for sole cow pea than the intercropped cow pea (28.4%) in sorghum/cow pea intercropping.

Productivity of the Intercropping System

Total land productivity is a basic consideration in evaluating intercropping system where land holdings are very meager. For this purpose, Land equivalent ratio, maize equivalent yields and gross monetary return per hectare could be the better indicators of land productivity of inter cropping system.

Main effects of location and variety had significant effect on LER. Land productivity increased by 17.5 % at MARC due to relatively adequate moisture and soil fertility. With regarded to variety, the highest LER (1.57) was recorded from intercropping of maize variety Melkassa2 and mung bean variety N-26, and it was statistically at par with intercropping of maize variety Melkassa-2 and mung bean variety Shewarobbit, while the lowest LER (1.02) was from intercropping of maize variety Melkassa-1 and mung bean variety NVL-1 (Table 9). The probable reason for low land use efficiency might be related to highly competitive effect of mung bean variety NVL-1 over maize variety Melkassa-1 resulted in low grain yield of maize. In line with this result Yaa *et al.* (2017) ontained significant effect of sorghum varieties on LER in sorghum/common bean intercropping.

Table 9. Land equivalent ratio (LER), Maize Equivalent Yield (MEY) and Gross Monetary Return (GMR) as affected by location, varieties and cropping systems

Treatments	LER	MEY (kg ha^{-1})	GMR (ETB ha^{-1})
Location			
Melkassa	1.41^{a}	5690.0^{a}	56900^{a}
Fedis	1.2^{b}	4850^{b}	48500^{b}
Significance	**	**	**
LSD (0.05)	0.15	3687	5720
Varieties			
Melkassa-1xN-26	1.26^{c}	5020^{c}	50200^{c}
Melkassa-1xNVL	1.02^{e}	4120^{d}	41200^{d}
Melkassa-1xShewa Robbit	1.23^{cd}	4880^{c}	48800^{c}
Melkassa-2 xN-26	1.57^{a}	6390^{a}	63900^{a}
Melkassa-2 x NVL	1.4^{b}	5740^{b}	57400^{b}
Melkassa-2x Shewa Robbit	1.55^{a}	6290^{ab}	62900^{ab}
Melkassa-6Q x N-26	1.32^{bc}	5330^{bc}	53300^{bc}
Melkassa-6Q x NVL	1.13^{d}	4580^{cd}	45800^{cd}
Melkassa-6Q x Shewa Robbit	1.17^{cd}	4780^{c}	47800^{c}
Significance	**	**	**
LSD (0.05)	0.14	580	5880.5
CV (%)	9.4	11.5	10.2
Sole	1.0^{b}	4200^{b}	41600^{b}
Intercrop	1.3^{a}	5270^{a}	56300^{a}
Significance	*	*	*
LSD (0.05)	0.26	820.6	8200
CV (%)	7.9	12	11
Interaction (L x IC)	NS	NS	NS

Means within the same column followed by the same letter or by no letters of each factor do not differ Ns, *, and ** = Non-significant, significant at 5% and significant at 1% probability

Cropping system also significantly influenced LER, whereas higher LER (1.30) was recorded due to intercropping. Which means the intercrop system was 30% more productive compared to sole crop production. The possible reason for higher productivity of the intercropping system might be due to efficient utilization of growth resources by component crops and the intercropping advantage of nitrogen fixation and increased light use efficiency (Reddy, 2000). In line with this result, Tuhura *et al.* (2014) stated that intercropping maize with mung bean increased land use efficiency by 43%. Saleem *et al.* (2015) stated that, Maize/mung bean intercropping was more productive and efficient system in utilizing land compared to sole cropping.

ANOVA over locations indicated that there was significant effect of location and variety on maize equivalent yield. Fedis recorded 14.8% reduction in maize equivalent yield than MARC. The probable reasons might be related to sever resources competition for shortened growth resources. With regarded to variety, the highest maize equivalent yield (6390 kg ha^{-1}) was recorded from intercropping of maize variety Melkassa-2 and mung bean variety N-26 and it was statistically at par with intercropping of maize variety Melkassa-2 and mung bean variety Shewarobbit while the lowest maize equivalent yield (4120 kg ha^{-1}) was from intercropping of maize variety Melkassa-1 and mung bean variety NVL (Table 9). The probable reasons for reduction in maize equivalent yield might be related to aggressive competitive effect of mung bean variety NVL resulted lower yield of maize.

The intercrop system was significantly more productive than sole crop system with yield advantage of 20.3% when expressed as maize equivalent yield (Figure 2). The highest maize equivalent yield for the intercrop could be due to an additional yield of the mung bean and the relative increase in maize grain yield in the intercrop treatments compared to sole crop. Consistent with this result, Alemayehu *et al.* (2016) found higher maize equivalent yield (6.75 t ha^{-1}) of the intercropping system relative to sole-cropped maize in maize/common bean/lupin intercropping.

Main effects of location and variety had significant effect on gross monetary values. MARC recorded 17.3 % increment on gross income than Fedis. Significantly the highest gross monetary return (63900 ETB ha^{-1}) was recorded from intercropping of maize variety Melkassa-2 and mung bean variety N-26 and it was statistically at par with intercropping of maize variety Melkassa-2 with mung bean variety Shewarobbit, while the lowest gross monetary return (41500 ETB ha^{-1}) was from intercropping of maize variety Melkassa-1 and mung bean variety NVL. Moreover, significantly higher gross monetary return (56300 ETB ha-1) was recorded from intercropping due to due to additional benefits from mung bean without hampering the grain yield of maize. In line with this result, Tohura et al. (2014) obtained higher monetary returns from intercropping than sole maize, in maize/mung bean intercropping. Kinde et al. (2015) also recorded higher monetary return from intercropping than sole cropping in sorghum/cowpea and sorghum/soybean intercropping.

Conclusion

Choosing of the right crop combination is very important in intercropping systems due to the fact that plant competition could be minimized not only by spatial arrangement, but also by combining those crops best able to exploit soil nutrients. The results of the study showed that maize variety Melkassa-2 in intercropping with mung bean produced significantly highest growth, yield components and yield. Similarly, mung bean variety N-26 in intercropping with maize produced significantly highest yield components and yield. Among the different intercropping combinations, intercropping maize variety Melkassa-2 with mung bean variety N-26 produced the highest Land Equivalent Ratio, maize equivalent yield and gross monetary return. Thus, maize variety Melkassa-2 with mung bean variety N-26 can be used for intercropping to maximize the productivity of the intercropping system in the study areas. Hence, maize and mung bean breeding programs need to consider selection criteria in developing varieties of maize and mung bean that can be used across range of cropping systems. Moreover, this experiment has to be conducted at least for one more season to account for seasonal variability.

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