International Journal of Agriculture and Nutrition
www.agriculturejournal.net
Online ISSN: 2664-6072; Print ISSN: 2664-6064
Received: 09-10-2020; Accepted: 25-11-2020; Published: 01-12-2020
Volume 2; Issue 2; 2020; Page No. 43-48

Determination of appropriate maize haricot bean arrangement in intercropping in North Ethiopia

Yalew Teshome
Department of Ethiopian Agricultural Research Institute, Addis Ababa, Ethiopia
DOI: https://doi.org/10.33545/26646064.2020.v2.i2a.62

Abstract
Maize haricot bean intercropping is one of the commonly practiced agronomic practice in Ethiopia. Intercropping is the production of two or more crops simultaneously in both space and time. Field studies were conducted at on site in 2019 and 2020 cropping season to identify the optimum haricot bean arrange and to review the advantage of intercropping over sole cropping. The results revealed significant differences among different maize-haricot bean arrangements. The highest grain yield was obtained from two rows of haricot bean planting between maize rows which yields 5.53tone/ha and 5.88tone/ha in 2011 and 2012 main cropping seasons respectively. The highest total land equivalent ratio (1.36), land equivalent coefficient (0.46) and monetary advantage index (10964.74) was recorded for two rows of haricot bean between planted between two rows of maize. The outcomes of the two years' experiment showed 1M: 2HB combination was optimum population and economical combination relative to other combinations. Therefore, two rows of haricot bean planting between two rows of maize intercropped is recommended for the study area for their best compatibility and economic benefit as compared to other population densities considered in the following investigation.

Keywords: Arrangement, Intercropping, LEC, LER, MAI, Sole cropping

Introduction
Maize (*Zea mays* L.), one among the most important cereals throughout the world [10]. It is cultivated widely in Ethiopia [7]. Haricot bean is one of the most important and widely cultivated species of bean in grown in Ethiopia. Both maize and haricot bean plays key role in human nutrition as a food and economic value for small and large-scale farmers. Maize contains many nutrient factors and is highly nutritious [7]. Haricot bean is a good source of protein for people in Ethiopia [18]. Intercropping with both tied ridge and planting methods. Thus the maximum mean of soil pH was observed before planting at sole haricot bean with flatbed whereas the minimum soil pH were observed after planting of maize-haricot bean intercropping with closed end tied ridge and in furrow planting. When be-fore and after planting values of pH was compared by t-test it was indicated that there was reduction due to influence of maize-haricot bean intercropping.

Intercropping is considered as one of crop intensification strategies to increase agricultural productivity per unit area of land. Intercropping commonly used agricultural cropping practice and is growing more crops [21]. There many justifications for farmers to adopt intercropping [15]. One way towards better farming is to look for the most effective associated cropping of leguminous crops with non-leguminous one [6]. In intercropping, growth and yield of legumes will be less than the major crop [20]. The overall arrangement and the relative proportion of component crops are important in determining yields and production Efficiencies of cereal legume intercrop systems [25, 8].

The vigor of the crop production system of Ethiopian is governed by the size and distribution of rain. In moisture stress areas like lowland, shortage of rain has a direct effect on the amount of available food. Even though drought is a significant and a common phenomenon in this area crop stability is a challenging for farmers to overcome these challenges farmers are looking for drought tolerant crops like, tef, haricot bean, sorghum, maize and best agronomic practices like intercropping of maize with haricot [21]. In most part of the Borana lowland area, maize-haricot bean intercropping has been practiced in traditional way and small-scale farmers growing maize-haricot bean intercropping, without knowing the negative effect of the system on each other when the population of the crop increase beyond the recommended plant population per hectare.

So, the current study was objected to recommend optimum haricot bean arrangement in maize rows and best intercropping practice for moisture stress areas of Borana and to review yield advantage of inter crop over sole cropping and best combination of maize haricot bean intercropping of maize-haricot bean with tied ridge and planting methods were highly influenced available potassium in soil which is easily uptake by the crop. So that the mean of available potassium was significantly different due to interaction of maize-haricot bean intercropping with both tied ridge and planting methods. Likely available potassium in the soil was increased after planting due to maize-haricot bean intercropping.

Materials and Methods
Description of study area
The experiment was conducted at mertule mariam ATVTE college field on station for two consecutive main cropping seasons 2019 and 2020 is found 563km from Addis Ababa to south direction. Is situated at 04 ° 52' 49" and 038 ° 08' 55" latitude and longitude, respectively, at an altitude of 1656masl. The soil of study area is characterized by well-drained sandy loam (46% sand, 36% silt and 18% clay), with a pH of 7.03. It has 0.026% total nitrogen, 15.36 ppm Phosphorus and 20.4 meq of / 100 gm soil CEC. The total annual rainfall in 2011 and 2012 was 851.6 mm and 719.0 mm respectively. The average temperature for 2011 and 2012 was 19.3 °C and 20.6 °C respectively. The most commonly cultivated crops in its surrounding areas are maize (*Zea mays* L.), haricot bean (*Phaseolus vulgaris* L.), *tef* (*Eragrostis tef* L.) wheat (*Triticum aestivum* L.). Maize and haricot bean are the predominant and staple food crops in Borana.

Experimental materials and design
Adapted and recommended open pollinated maize (Melkassa 1) and (Omo-95) haricot bean variety were used for this

experiment. The experiment was planted on plot size 3.5m x 4m ($14m^2$) in randomized complete block design (RCBD) with three replications. All plots with row planted were consist of 6 rows of maize and the row number of haricot bean varies depending on the treatment while sole haricot bean plot had consisted of 11 rows off which the central rows were used for data. Recommended spacing (75 cm x 25 cm) for maize and (40 cm x 10 cm) for haricot bean was used. The field was prepared following the conventional farmer's practice. The following treatment combinations were used for current experiment:

1. Maize sole (pure stand) (1M: 0H) of maize (53333plants)
2. Haricot bean sole (pure stand) (M0: 1H) = (125000plants)
3. 1M: 2HB=one row of haricot bean between two rows of maize (alternative) (53333:88889)
4. 2M: 1HB= two rows of haricot bean between two rows of maize (53333:222222)
5. Both maize and haricot bean broadcasted (farmers practice)

Collected data for maize

Plant height (PH), Ear height (EH), Ear length (EL), Ear diameter (ED), Grain yield per plot (Yld).

Collected data for haricot bean

Grain yield per plot (Yld): Measuring the amount of grain yield obtained from a plot in kilogram

Data analysis

Analyses of variances were conducted by using SAS computer software version 9.2 [19]. Least significant difference (LSD) test at 5% probability level was used for mean separation [12].

Analysis of productivity and benefit

Among different methods used to indicate a yield advantage of intercropping Land Equivalent Ratio (LER) was used to indicate the biological efficiency and yield per nit area of land as compared to the sole-cropping system. The LER values were computed by using the formula described by [25]:

$$LER = \frac{\overline{Ymi}}{Yms} + \frac{\overline{Yhbi}}{Yhbs}$$

Where,

LER = land equivalent ratio, Ymi = yield of maize in intercrop, Yhbi = yield of haricot bean in intercrop, Yms = yield of maize sole, Yhbs = yield of haricot bean sole

LER>1.0 implies, intercropping yielded more than growing sole cropping.

LER<1.0 implies, intercropping yielded less than sole cropping

LER = 1.0 implies, there is no different yield advantage between sole and inter-cropping (17).

The land equivalent coefficient is calculated according to the formula stated by (3):

LEC = LERm*LERhb

Where,

LEC = land equivalent coefficient; LERm = land equivalent ratio of maize and LERhb = land equivalent ratio of haricot bean

Monetary advantage index (MAI)

Monetary advantage index (MAI) was calculated according to (14).

$MAI = Mm+Mhb*\frac{1}{\quad}$

Where,

MAI = monetary advantage index; Mm = Pm ×Ym; Mhb = Phb ×Yhb; Pm = Price of maize and the Pb = Price of haricot bean; the price of maize and haricot bean seed per kg in Ethiopian Birr was taken from the Yabello grain market during the cropping season. Accordingly, the prices were 6 and 10 ETB (Ethiopian Birr) kg^{-1} for maize and haricot bean respectively. The higher the MAI value, the more profitable the cropping system is [11].

Results and Discussion

Ear length: Analysis of variance showed a significance difference among treatments in ear length for both years at (p<0.05) (table 1). The highest ear length was obtained for maize sole (13.49 cm) (table 2). This implies that as the number of haricot bean arrangements increases in maize, the ear length of maize decreases as compared to maize sole, this might be due to the synergistic effect of the two crops was changed to compete for the limited availability of moisture in the area since moisture stress is the main problem in the study area [22]. Reported significant ear length for different maize genotypes.

Ear diameter: The analysis of variance of pooled data showed a significance difference among different arrangements of haricot bean in maize for pooled data p<0.01 (table 1). The highest ear diameter was recorded from maize sole (4.45 cm), while the lowest ear length was recorded from maize in rows haricot bean broadcasted arrangement (3.75 cm) (table 2). The result declares that, as the amount of haricot bean population increase per square area in maize, it has a negative effect on ear diameter [16]. Found significant ear diameter in their study of maize crosses.

Ear height: the pooled data analysis showed a significance difference among different maize-haricot bean arrangement (table 1). The highest ear height was recorded from one maize two haricot bean arrangements (52.10 cm)while the lowest ear height was observed for both maize and haricot bean broadcast (38.43 cm).

Plant height: The population densities were found significant (p<0.01) on mean ear height of maize. The tallest mean ear height (130.25 cm) of maize was observed from a sole cropping system of maize while the lowest plant height was observed for both maize and haricot bean broadcasted (105.32). This justifies, as population of crops increase per unit area in limit moisture areas, it has a direct effect on plant height of the plant. Previous work [4] reported haricot with stevia intercropping.

Thousand seed weight: no significant difference was observed among different arrangement of haricot bean in maize (p<0.01). [23, 13] found unaffected by different row arrangements.

Grain yield: Combined analysis of variance over years showed significant difference among different arrangement of haricot bean in maize (p<0.01). The highest grain yield was observed in maize sole (4.47 ton/ha) while the lowest grain yield of maize was observed for both maize and haricot bean broadcasted (2.29 ton/ha). The highest total grain yield was obtained from intercropped plots at two rows haricot bean between two rows of maize gave the total grain yield, 5.88ton / ha and 5.46ton/ha in 2012 and 2011 cropping seasons respectively [13] has reported lower grain yield records from plots where maize was intercropped with two and three rows. The mean grain yield of maize and haricot bean differs from 2011 to the 2012 cropping season, which may be due to rainfall distribution difference (fig. 2). That means there was a good harvest when rainfall was uniformly distributed from the beginning of the cropping year to the end of the cropping season. Rainfall distribution of the 2012 main cropping season was relatively better than that of the 2011 main cropping season (March-July) (fig. 2).

In this study, cropping system significantly affected maize grain yield. Consequently, maize sole cropping had significantly (p<0.05) higher grain yield than intercropped maize (table 2). The yield advantage of sole maize had 47%, and 50% over maize grain yield in 2012 and 2011 cropping season

respectively. Kebede (2014) [29] indicated that yield of sole soybean was significantly higher than the intercropped soybean. In the same line, reported sole cropping of haricot bean had 46.33% yield advantage over intercropping in maize-haricot bean intercropping. The limiting factor for crop production and productivity in study was the availability and the optimum plant population of the two mixed crops. In moisture stress areas, the population of plants per square area is the limiting factor, the current study declares that, as the population of haricot increase beyond optimum (1M: 2HB), the yield of both maize and haricot bean significantly decreased, which may be due to lack of adequate moisture, as a result the interaction of maize and haricot bean changed to competition for moisture. Significant difference among different population density of sorghum-cowpea inter cropping are also observed by [1].

Productivity and profitability of inter-cropping Land equivalent ratio (LER)

The land equivalent ratio (LER) is the relative area of a sole crop required to produce the yield achieved in intercropping. The analysis of the result showed that, partial land equivalent ratio (PLER) of maize was less than one for all arrangements in both seasons. Productivity of intercrop was evaluated by using total and PLERs as indicated in table 3. LER value is equal to one, it means that there is no yield advantage, but when LER is more than one, then there is a yield advantage. PLER for haricot bean was lower than 0.5 which indicated advantage of haricot bean for maize in inter-cropping. While, PLER for maize was more than 0.5, it indicated disadvantage for cotton in inter-cropping. The maize PLER values range from 0.53 and 0.63 among different patterns of maize and haricot bean in 2011 main cropping season and it ranged from 0.80 to 0.62 in 2012 main cropping season. The highest PLER of maize 0.80 and 0.63 was obtained from one to one row of maize and haricot bean in 2012 and 201 cropping seasons respectively (table 3). The partial land equivalent of maize increased as the population of haricot bean decreased, this may be due to computation for moisture [5]. Reported PLER values ranged from 0.86 and 0.93 among different arrangements of haricot bean in maize rows [3]. also reported partial land equivalent ratio ranged from 0.83 to 0.87 in his study of advantages of maize-haricot bean inter-cropping over sole cropping of maize.

For haricot bean, in the 2011 cropping season PLER ranged from 0.46 to 0.67. The highest PLER of haricot bean was recorded for two row haricot bean between maize rows (0.67). The result indicates that, as the population of haricot bean increased beyond optimum number, the PLER of haricot bean decreased. In 2012 cropping season the same result was obtained. PLERs for maize and haricot bean in the inter-cropped system are less than one for both cropping season [3] also obtained similar result in his study.

Table 1: Mean grain yield of maize and haricot bean during 2019 and 2020 main cropping seasons

Treatments	2019 cropping season grain yield (ton/ha)			2019 cropping season grain yield (ton/ha)		
	Maize	Haricot bean	Total	Maize	Haricot bean	Total
Maize sole	4.41	-	4.41	4.51	-	4.51
Haricot bean sole	-	3.65	3.65	-	3.43	3.43
1M: 1HB	2.32	2.05	4.37	3.62	1.71	5.33
1M: 2HB	2.79	2.44	5.23	3.38	2.1	5.48
Maize in row HB broadcasted	2.45	2.37	4.82	3.39	1.9	5.29
Both M and HB	2.41	1.75	4.16	2.8	1.58	4.38

M = maize, HB = haricot bean

Table 2: Mean of grain yield and yield related traits of maize (pooled data of two years)

Treatments	ED (cm)	EH (cm)	EL (cm)	PH (cm)	TSW (g)
Maize sole	4.55a	47.51a	13.76a	130.25a	283.05a
1M: 1HB	4.25b	47.10a	11.52b	122.39ab	291.08a
1M: 2HB	4.03c	52.10a	10.62bc	118.37ab	279.41a
M in row HB broadcasted	3.75d	46.73ab	10.79bc	119.60ab	290.74a
Both M and HB broadcasted	3.88cd	38.43b	9.64c	105.32b	281.10a
Mean	4.13	47.11	11.62	116.64	284.53
LSD	***	**	***	***	ns

Means with the same letter are not significantly different. Ns = non-significant and ** significant at p<0.05, DF=degree of freedom, EL=Ear length, EH=ear height, ED=Ear diameter, TSW=Thousand seed weight and Yield=grain yield

Fig 1: Maize-haricot bean intercropping after forty days from planting (field view, 2020)

Based on total land equivalent ratio (TLER), the result of analysis showed that, TLER for all arrangements of maize haricot bean were greater than one but the magnitudes varies from pattern to pattern. The highest TLER of haricot bean were 1.30 and 1.36 for 1M: 2HB arrangement in 2011 and 2012 main cropping seasons respectively (table 3) the result indicated that, inter-cropping of haricot bean with maize is more advantageous than sole cropping of maize and increment of food productivity per unit area [13]. Obtained higher land equivalent ratio in maize haricot bean inter-cropping. On the same line [3], reported higher land equivalent ratio for maize haricot bean inter-cropping.

Land equivalent coefficient (LEC)

In intercropping system of cropping the minimum expected land equivalent coefficient is 25% (2). According to (1) if LEC value exceeds 25%, there is yield advantage. Accordingly, in current study the magnitude of all maize-haricot bean inter-cropping patterns was above 25%, suggesting there is a yield advantages. The highest LEC was recorded from two row haricot bean between two rows of maize arrangement were 0.42 and 0.46 in 2011 and 2012 main cropping seasons respectively (table 3). (26); (9); (3); (5) were reported similarly reported LEC values greater than the critical in their study.

Table 3: Grain yield, Land equivalent ratio (LER), Land equivalent coefficient (LEC) and Monetary advantage index for sole stands and mixture of maize with haricot bean 2019 and 2020 cropping season

Treatments	Grain yield (t/ha)			LER			LEC	MAI
	Maize	Haricot bean	Total	LERm	LERh	LERt		
2011 cropping season								
Maize sole	4.41	-	4.41	-	-	-	-	-
Haricot bean sole	-	3.65	3.65	-	-	-	-	-
1M: 1HB	2.32	2.05	4.37	0.53	0.56	1.09	0.30	2775.85
1M: 2HB	2.79	2.44	5.23	0.63	0.67	1.30	0.42	9521.72
Maize in row HB	2.45	2.37	4.82	0.56	0.65	1.20	0.36	6529.36
broadcasted								
Both M and HB	2.41	1.75	4.16	0.55	0.48	1.03	0.26	808.00
2012 cropping season								
Maize sole	4.51	-	4.51	-	-	-	-	-
Haricot bean sole	-	3.43	3.43	-	-	-	-	-
1M: 1HB	3.62	1.71	5.33	0.80	0.50	1.30	0.40	8986.07
1M: 2HB	3.38	2.1	5.48	0.75	0.61	1.36	0.46	10964.74
Maize in row HB	3.39	1.9	5.29	0.75	0.55	1.31	0.42	9208.233
broadcasted								
Both M and HB	2.8	1.58	4.38	0.62	0.46	1.08	0.29	2456.234

LER = land equivalent ratio, LEC = land equivalent coefficient, MAI = monetary advantage index, LERm = land equivalent ratio of maize, LERh = land equivalent ratio of haricot bean, LERt = land equivalent ratio of total, the price of maize and haricot bean was 6 and 10 Ethiopian birr respectively for one kilogram of each commodity.

Monetary advantage index (MAI)

MAI was increased with haricot bean population densities increased, but above the optimum population of haricot bean, MAI decreased. The highest MAI was observed for 1M: 2HB (10964.74) and (9521.72), combination in the 2012 and 2011 cropping seasons respectively. The MAI of 2011 and 2012 make cross interaction, due to the increment of haricot bean yield in the 2011 cropping season, which may be due to rainfall distribution since, haricot bean got enough rainfall at flowering stage than that of the 2012 cropping season (Appendix I). Monetary advantage index of Maize in row haricot bean broad casted arrangement is relatively good following 1M: 2HB arrangement, but this type of arrangement is not recommendable for production because its difficulty in management especially mowing and weeding (table 3). Different researchers reported higher monetary advantage index for intercropping of maize haricot bean (27); (3); (4).

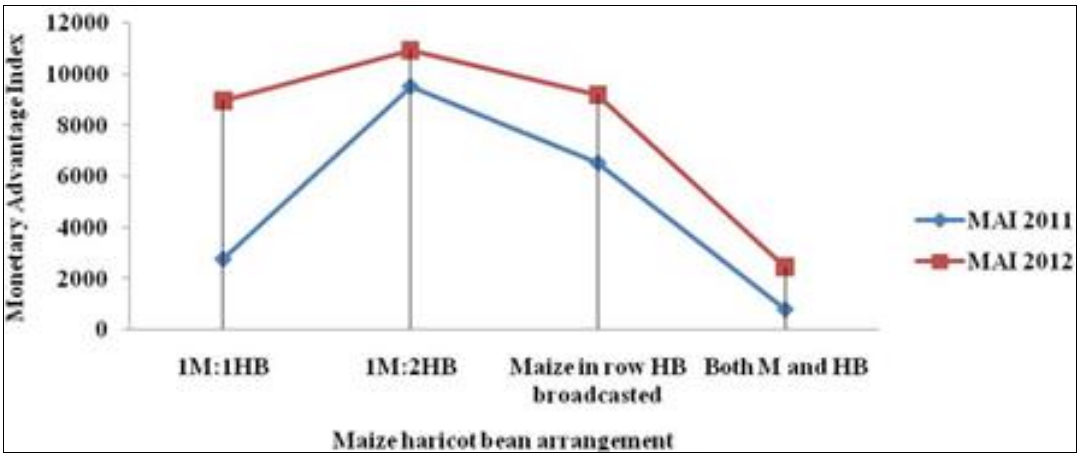
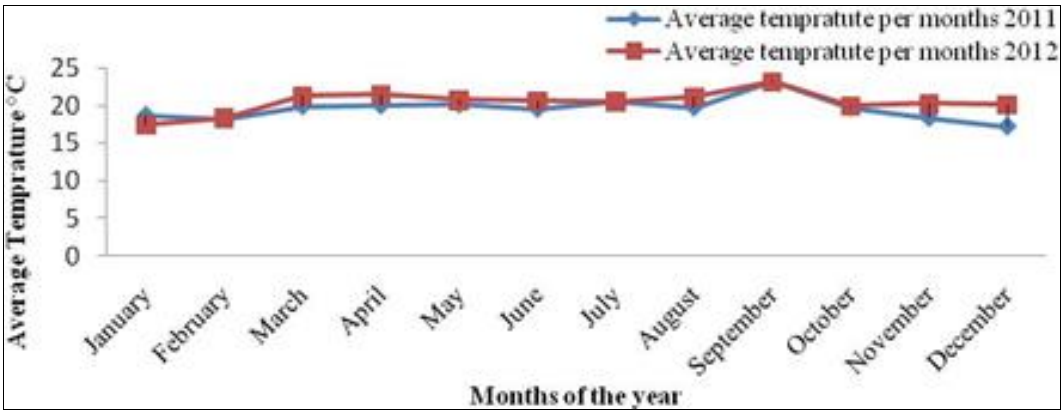
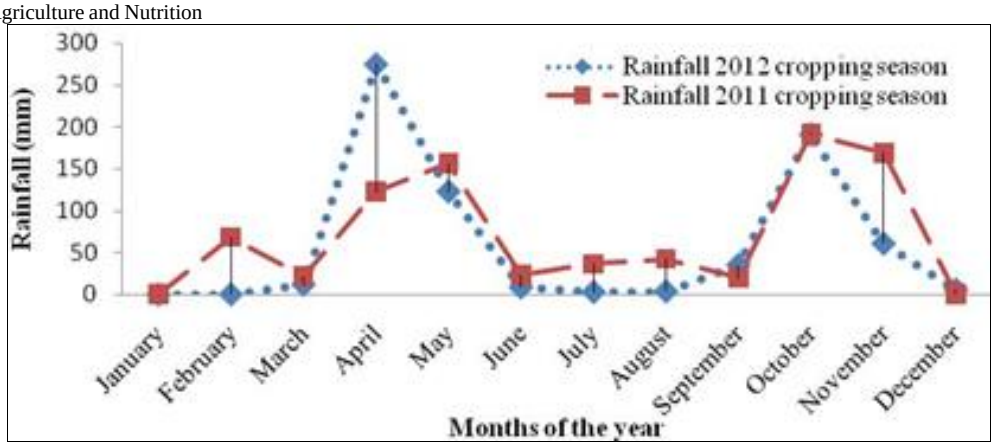


Fig 2: Relationship between 2019 and 2020 cropping season monetary advantage index, MAI = monetary advantage index2



Source: Mertule ATVTE meteorology station

Fig 3: average temperature of months in 2019and 2020 year



***Source*:** Mertulemaram ATVTE meteorology station

Fig 4: Rainfall distribution of Yabello on site in 2019and 2020 year, meteorology station is near the Experimental site ~0.5km

Conclusion

The overall maize yield was significantly affected by the row proportion of haricot bean, whereby the highest overall grain of 5.23tone/ha and 5.48tone/ha was being recorded from 1M: 2HB combination in 2019 and 2020 cropping season respectively. The land equivalent ratio (LER) is the comparative expense of a sole crop required to raise the yield achieved in intercropping. LER value is equal to one, implies no yield advantage, but when LER is more than one there is a yield advantage. Monetary advantage index values were positive for all maize haricot bean arrangements which showed a definite yield advantage in all intercropping systems compared to sole cropping. In moisture stress areas where rainfall was uncertain, 1M: 2HB combination can increase the overall productivity even can serve as an insurance when the rainfall shortage occurs at the mid of growing seasons. The Maize-haricot bean was very important for small scale farmers in the moisture stress area lowland because when the rainfall shortage was occurred there was a chance to get yield at least from the haricot bean and to minimize the risk of crop failurity happened to small scale farmers.

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