

## Pre-extension Demonstration and Evaluation of Maize (*Zea Mays* L.) -Haricot Bean (*Phaseolus Vulgaris* L.) Intercropping Practices in Midlands of Guji Zone, Southern Oromia, Ethiopia

Girma Amare<sup>1\*</sup>, Basha Kebede<sup>2</sup>, Dembi Korji<sup>3</sup>

Oromia Agricultural Research Institute, Bore Agricultural Research Center

**Corresponding Author:** Girma Amare [girmare2017@gmail.com](mailto:girmare2017@gmail.com)

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### ABSTRACT

Intercropping is the simultaneous cultivation of two or more crops in both space and time. The activity was conducted during the main rainy season of 2019 in the Adola Rede and Odo Shakiso districts of Guji Zone, Oromia, Ethiopia. The demonstration Objectives includes evaluating yield output and cost-benefit ratio of maize-haricot bean intercropping practices under farmers' condition and assessing farmers' and others stakeholders' preference on maize-haricot bean intercropping practices. Two Kebeles/sites per district were selected based on maize and haricot bean production potential. and 15 farmers were selected from each Kebele/site and grouped as one FRGs. Thus, a total of 4 FRGs comprising 60 farmers (45 male and 15 female) were established. Improved maize (BH-546) and haricot bean (Haramaya) varieties were demonstrated with sole cropping of respective maize and haricot bean on plots of 100 m<sup>2</sup> area per variety at 40 cm inter- and 10 cm and 75 cm inter- and 25 cm intra row spacing for haricot bean and maize respectively, with recommended seed and fertilizer rates. Farmer-to-farmer learning on maize-haricot bean intercropping practices was enhanced through training, exchange visits, technology evaluation and field day. The data was collected using observation, measurement, face-to-face interviews, and the intercropping metrics. The collected data was analyzed using descriptive statistics, and farmers' preferences were analyzed qualitatively

## **INTRODUCTION**

Due to shifting consumption patterns and population expansion, there is an enormous global demand for agricultural commodities, which is posing a challenge to food security in emerging nations (Tittonell and Giller, 2013; Dzanku et al., 2015). As a result, production levels must be raised. The first way to boost output is to increase the area used for crop production, frequently at the expense of other land uses like grazing and forest areas. This choice, however, is invalid for the majority of smallholder agricultural systems, where there is a shortage of new land. Consequently, the optimal course of action would be to increase production through intensification by developing ways for raising crop productivity per unit area of accessible land through growing by combining time and space (Licker et al., 2010; Seran and Brintha, 2010). The procedure might provide an chance for smallholder farmers to boost soil fertility, lower crop failure risk, and raise yields (Maitra et al., 2020).

Legume-cereal intercropping, particularly maize-bean intercropping, is popular in developing nations and can be the best option for resource-poor farmers seeking sustainable productivity and food security. Intercropping has been around for more than a millennium in tropical regions, especially in Africa, and smallholder farmers are continuing to adopt it (Gitari et al., 2018a; and 2019b; Nyawade et al., 2019a; and b). The capacity of intercropping systems to yield more than monoculture systems is one of the reasons farmers favor it over monoculture systems, particularly in developing countries where subsistence and resource-constrained agriculture systems predominate. When species are intercropped, yield might be larger than in a monoculture, which is referred to in this context as overyielding (Beckage and Gross, 2020). Overyielding phenomenon under intercropping systems: a plausible explanation is the reduction of interspecies competition and niche partitioning, which leads to complementarity in the use of natural resources such as land, soil nutrients, light, and water (Evers et al., 2019; Raza et al., 2019; Gitari et al., 2020).

Among grains and pulses, respectively, maize and haricot beans are Ethiopia's principal staple food crops (CSA, 2020). An essential cereal crop for the family meal is maize. It is a significant source of carbohydrates for people's diets in underdeveloped nations and is used globally as animal feed (Undie et al., 2012). Because haricot beans mature quickly and are easily interplanted, they are an essential component of smallholder farming systems' efforts to increase productivity. For long-term soil fertility development, its capacity to fix nitrogen is crucial (Buruchara et al., 2011). Labor-intensive smallholder farms can easily implement intercropping, which provides more financial stability than solitary cropping (Lithourgidis et al., 2011).

Ethiopia's crop production system is dependent on the amount and distribution of rainfall. In the Guji Zones' midland, there was a shortage of land and moisture stress, which directly affected the output of crops meant for household consumption. Historically, land has been utilized to sustain an ever-growing human population, but land is a limited resource. In order to maximize production and farm return, intensifying this fixed resource is the most effective

intercropping approach. These days, there is not enough land to produce a wide variety of crops. Certain crops are advised, however some land is not being used to its full potential. In the research regions, farmers raised cereal crops yearly without interruption and planted haricot beans and maize in the conventional manner (in one row). Still, Decreased soil fertility and low output are possible outcomes of such approaches. Consequently, it's critical to implement appropriate legume-cereal rotation and maize-haricot bean intercropping. As a result, it is crucial to demonstrate the pre-extension of maize-haricot bean intercropping in the Guji zone's middle.

## LITERATURE REVIEW

So-called participatory approaches to development, which seek to involve the beneficiaries in the development process, emerged in response to the discontent of the 1980s (Hickey and Mohan, 2005; Kothari, 2005). "A process of equitable and active involvement of all stakeholders in the formulation of development policies and strategies as well as in the analysis, planning, implementation, monitoring and evaluation of development activities" is the definition of participation in development (FAO, 2013). Key components of social movements, such as "transformation" and "empowerment," are still supported by this strategy (Hickey and Mohan, 2005); social movements and participation, however, are more of an alternative to development than a substitute for it. It is an approach. Interventions utilizing participatory approaches can be implemented at any level of development (Hickey and Mohan (2005). Increased stakeholder ownership of policies and projects; greater efficiency, understanding, and social cohesion; more cost-effective services; greater transparency and accountability; increased empowering of the poor and disadvantaged; and strengthening capacity of people to learn and act are some of the argued benefits of a participatory rather than a linear approach to development (Pretty, 1995).

Prior to being extensively distributed to farmers, demonstrations are a useful technique for assessing the efficacy of new technology. Farmers are able to witness firsthand the advantages of these technologies and decide with confidence whether or not to implement them thanks to these demonstrations (Maake and Antwi, 2022). An extension teaching technique called the demonstration method is used to demonstrate to a group of individuals how to perform completely new Mohan (2005). "More mobilization of stakeholder ownership of policies and projects; greater efficiency, understanding and social cohesion; more cost-effective services; greater transparency and accountability; increased empowering of the poor and disadvantaged; and strengthening capacity of people to learn and act" are some of the argued benefits of a participatory rather than a linear approach to development, making development projects enhanced efficiency (Pretty, 1995).practice – or, better yet, outdated practice. The farmer is shown every step of the way in the demonstration.

## **METHODOLOGY**

### **Description of Study Areas**

The districts of Odo Shakiso and Adola Rede are situated roughly 490 and 470 kilometers south of Addis Ababa, respectively. Three agro-climatic zones – Dega (high land), Weina dega (mid land), and Kola (low land) – define districts. These zones are perfect for cultivating a range of crops with different levels of coverage. The districts experience roughly 1000 mm of yearly rainfall and 26°C of average temperature. This led to the widespread usage of two cropping seasons: Arfasa (primary cropping season), which starts in March and ends in April, during which the most frequent crops are maize, haricot beans, wheat, and barley. The second cropping season, known as Gana (short cropping season), happens after the main cropping season's crops are harvested. It was as double cropping with little cereal crops such as barley, wheat, and tef. The production of forest products, mining, and mixed farming are the study area's primary sources of revenue.

### **Site Selection**

In the Guji Zone's Adola Rede and Odo Shakiso districts, pre-extension demonstrations of maize-haricot bean intercropping techniques were carried out. Two Kebeles were deliberately chosen from each area according to their potential for producing haricot beans and maize. Fifteen farmers were chosen from every kebele.

### **Hosting Farmers' Selection**

To choose farmers and group under hosting farmers, the Farmer's Research Group (FRG) method was used. There were four FRGs in total, with fifteen female and forty-five male members. Twelve (12) interested hosting farmers and one FTC were chosen from among the FRG members. The criteria utilized to choose the hosting farmers were having enough area for the trials, taking the initiative to carry out the activity in a high-quality manner, being close to the highways, and being prepared to share the technology with others.

### **Materials Used and Field Design**

During the main cropping season, 100 m<sup>2</sup> plot sizes of a haricot bean variety (Haramaya) and an adaptable and suggested maize variety (BH-546) were planted on chosen hosting farmers' land for both treatments. Sole cropping of haricot bean and maize types was used as a control. A 25 kg/ha seed rate was used for each sole and intercropping plot, while a 75 cm inter- and intra-row spacing was used to demonstrate the practice of sole cropping a particular variety of maize. In contrast, a single haricot bean was shown to be 40 cm by 10 cm apart from the plant. While the intercropping plots, which are planted with a seed rate of 50 kg/ha for the intercropping plot and 100 kg/ha for sole cropping, are sown in a single row between two rows of maize crop at a 10-cm intra-row spacing.

Occasionally Following sowing, 121 kg/ha of NPS was applied to all maize and single haricot bean plots, 50 kg/ha to intercropped haricot bean plots, and 50 kg/ha of urea was applied exclusively to maize, based on the assumption that haricot beans would benefit from nitrogen fixation. Nitrogen in the form of urea was administered to all plots at a rate of 50 kg/ha during the knee height

growth stage of maize. Because the productivity and financial benefits of simultaneous haricot bean and maize intercropping outweighed those of subsequent interseeding, this method was chosen (Alemayehu et al., 2018). The timely hand weeding was completed twice.

### Data Types and Methods of Data Collection

Measurements, in-person interviews, and direct field observation were used to gather both qualitative and quantitative data. Data collecting sheets were utilized to gather the grain and economic data. Face-to-face interviews were conducted to gather feedback utilizing a checklist.

### Intercropping Metrics

Many criteria are currently available to compare monocropping and intercropping systems. The fundamental base is always a comparison between the intercrop's direct short-term performance and that of the monoculture, regardless of the evaluation technique used. The majority of research designs depict all intercropped species as monocultures, allowing for a comparative analysis of the benefits of intercropping versus monoculture settings. The frequently used metrics and the formulas for calculating them are presented in Table 1 and have been used to assess intercropping advantage.

Table 1. Commonly Used Metrics in the Evaluation of Intercropping Advantages. Example Metrics Show Two Species Intercrops

Metrics	Description	How to Measure?	Decision Criteria	Reference
Land Equivalent Ratio (LER)	Measures the relative land area required to grow the same quantity of both crop species in the mixture if they were grown as monocultures rather than as companions.	$LER_1 = \frac{Y_{1c}}{Y_{1m}}$ , $LER_2 = \frac{Y_{2c}}{Y_{2m}}$ $LER = LER_1 + LER_2$	$LER > 1$ indicates intercropping advantage.	Mead and Willey, 1980
Land Equivalent Coefficient (LEC)	Measures the interaction between component crops in the mixture.	$LEC = LER_1 \times LER_2$	Yield advantage is obtained if the LEC value is $> 0.25$ .	Adetiloye et al., 1983

Relative Yield of Mixture (RYM)	Measures the relative yield from the intercropping system compared to that of the monocropping system.	$RYM = \frac{Y1c + Y2c}{[(Y1m + Y2m)/2]}$	RYM > 1 indicates intercropping advantage.	Wilson, 1988
System Productivity Index (SPI)	Converts the yield of a component crop in terms of another crop in the mixture utilizing monocrops yields ratio.	$SPI = \frac{Y1m}{Y2m} Y2c + Y1c$	If SPI of intercrops > SPI of monocrops. Its advantages	Odo, 1991
Crop Equivalent Yield (CEY)	Standardizes the yield of a component crop in the mixture in terms of another component crop based on the prices.	$CEY1 = Y1c + Y2c \frac{P2}{P1}$	Advantageous if CEY of intercrops > CEY of monocrops.	Francis, 1986
Relative Value Total (RVT)	Measures the relative value from the intercropping system compared to that of the most valuable of the two monocultures	$RVT = \frac{P1Y1c + P2Y2c}{P1Y1m}$ <p>If <math>P1Y1m &gt; P2Y2m</math></p>	RVT > 1 indicates intercropping advantage.	Vandermeer, 1992

Where, Y1c or Y2c = Expected yield of crop 1 or 2 as a companion; Y1m or Y2m = Expected yield of crop 1 or 2 as a monoculture; P1 and P2 are the expected market prices of crops 1 and 2

### Data Analysis Methods

Descriptive statistics were used to assess the agronomic data that was gathered. The profitability of each treatment was also determined using NFI (Net farm income), and the preferences of farmers toward the procedures that were displayed were also qualitatively examined. To compare the benefits of intercropping versus monocropping systems, intercropping metrics were calculated.

## RESULTS AND DISCUSSION

### Capacity Building on Maize-Haricot Bean Intercropping Practice

Development Agents (DAs), Subject Matter Specialists (SMSs), and a select group of Farmers Research Group members received trainings to increase their awareness of the practice of intercropping maize and haricot beans. To improve farmer-to-farmer learning about the production and management of maize-haricot bean intercropping practice, exchange visits, mini-field days, and technology evaluations were arranged. Farmers were also asked to assess the practice of solo cropping. During the planned training, exchange visit, field day, and technology evaluation, multidisciplinary teams including Cereal, Pulse, and Extension Research Team as well as other stakeholders (Offices of Agriculture and Natural Resources) actively engaged by sharing their expertise and knowledge. Table 2 lists the number of agricultural professionals from the district office of agriculture, development agents, and farmers who attended field trips, exchange visits, and training sessions. day and technological assessment of the practice demonstration of maize-haricot beans.

Table 2. Capacity Building Methods and Number of Participants for Demonstration of Maize-Haricot Bean Intercropping Practice

Capacity building methods	Participants	Number of participants		
		Male	Female	Total
A. Training	Farmers	45	15	60
	Das	7	1	8
	SMSs	8	-	8
B. Exchange Visit	Farmers	20	-	20
	Das	3	1	4
	SMSs	3	1	4
	Others	4	1	5
C. Mini field day	Farmers	24	6	30
	Das	2	-	2
	SMSs	2	-	2
	Others	2	-	2

Own Data Result, 2019

DAs = Development Agent, SMSs = Subject Matter Specialist

### Role of Farmers and Other Stakeholders in the Technology Demonstration and Evaluation

The role of the farmers, extension workers, researchers, and other stockholders during the technology demonstration were indicated in the below table (Table 3)

Table 3. Role of Farmers and Other Stakeholder's Participation in Demonstrated Technology

Actors	Roles
FRG members	Involved in land preparation, sowing, management, yield evaluation, and providing feedback.
Hosting farmers	Trail land provision, record-keeping, facilitating of members involvement, field monitoring and reporting in the case of emergency, and providing feedback.
Research teams	Provision of training for FRG members and other actors and providing input, agronomic data collection, field monitoring, social data collection, and analysis, preparing extension materials.
Extension workers	Monitoring, feedback, and information transfer facilitating and organizing community.
Other stakeholders	Input supply, technical backup, community facilitating, and information dissemination.

### Yield Performance of Maize -Haricot Bean Demonstrated

The demonstration of intercropping maize and haricot beans produced increased crop production per unit area and was found to be more advantageous than only cultivating the respective crops of haricot and maize. Compared to the corresponding lone cropped yields of 2.71 tons/ha for maize and 3.35 tons/ha for haricot beans, the mean grain yield of intercropping plots was 2.75 tons of maize and 2.32 tons of haricot beans per hectare bean. The table below (Table 4) displays the maize-haricot bean's mean yield performance.

Table 4. Mean Yield Performance of Maize and Haricot Bean (Ton/Ha)

Treatments	Mean yield of maize and haricot bean (ton/ha)		
	N	Mean	Std. Deviation
BH-546 Sole	13	2.71	3.86
Haramaya Sole	13	3.35	10.72
BH-546 Intercropped	13	2.75	3.89
Haramaya Intercropped	13	2.32	6.08

Source: Own Data Result, 2019

BH-546 = maize variety, Haramaya = haricot bean variety, ton/ha = ton/hectare

### **Intercropping Metrics Analysis**

The average land equivalent ratio of the maize-haricot bean demonstration was 1.70, with LER results ranging from 1.65 to 1.75 (Table 5). This finding was higher than that of the Lulie et al. (2016) paper, which found that the LER of Ethiopian common beans and maize varies from 1.29 to 1.69. In a similar vein, Hirpa (2013) revealed that the LER for intercropping maize and common beans was 1.43-1.54. In terms of land utilization, maize-haricot bean intercropping was superior to single cropping, as demonstrated by the Total Land Equivalent Ratio of 1.70. Stated differently, the same yield could be obtained by intercropping on less area than by monoculture of any of the component crops.

A multiplicative indicator of the interaction between the two crop species in an intercropping system is the land-equivalent coefficient (LEC). The outcome of LEC in Table 5 was 0.71. Given that the LEC result is more than 0.25, intercropping is therefore preferable to solitary cropping for each crop.

Relative yield of mixtures (RYM), or the ratio of the intercrop's total production to the mean yield of its pure crops, produced a value of 1.68 (Table 5). In terms of relative yield from the intercropping system compared to that of the monocropping system, the RYM result showed that maize-haricot bean intercropping was more advantageous than single cropping (Wilson, 1988).

The outcome of the System Productivity Index (SPI) was 4.11 (Table 5). Standardizing the yield of one component crop in relation to another crop in the mixture is what Odo (1991) advocated as an SPI. While SPI Changes the Yield SPI of intercrops > SPI of monocrops, the ratio of a component crop to another crop in the mixture using monocrops yields. Pre-extension demonstration of the maize-haricot bean is therefore beneficial.

Crop equivalent yield (CEY) is a metric based on produce market pricing that normalizes the output of component crop 2 in terms of crop 1. As a result, Table 5 displays the intercrop's CEY result of 5.78. This suggests that, depending on pricing, the pre-extension demonstration of maize-haricot bean was beneficial for the yield of one component crop in the mixture relative to another component crop (Francis, 1986).

Table 5 displays the relative value total (RVT) result, which came out at 1.99. If a grower is thinking about the money, the intercrop needs to be in contrast to the two monocultures that are the most valuable. As a result, the maize-haricot bean pre-extension demonstration was beneficial due to 1.99. as RVT yields a result of > 1 (Vandermeer, 1992).

Table 5. Summary of Intercropping Metrics Analysis

Treatments	Grain yield ton/ha	LER	LEC	RYM	SPI	CEY	RVT	P1	P2
Sole maize	2.71	-	-	2.71	2.71	-	2.71	7	-
Sole haricot bean	3.35	-	-	3.35	3.35	-	3.35		8
Maize intercropped	2.75	1.01	1.01	2.75	2.75	2.75	2.75	-	-
Haricot bean intercropped	2.32	0.70	0.70	2.32	2.32	2.32	2.32	-	-
<b>Total</b>		<b>1.70</b>	<b>0.71</b>	<b>1.68</b>	<b>4.11</b>	<b>5.78</b>	<b>1.99</b>	<b>7</b>	<b>8</b>

Source: Computed From Own Data, 2019

### Cost-Benefit Analysis of Maize-Haricot Bean Intercropping

The farmers that hosted the intercropping demonstration of maize and haricot beans provided the production costs and returns. Included were both variable and fixed production expenses. The price of clearing land, purchasing seeds, paying for fertilizer, planting, weeding, harvesting, and shipping are examples of variable expenses. The cost of the land was the fixed cost. At the research location, the fixed cost of land for a single season during the production season was 2500 ETB/ha. During the 2019 production season, the average farm-gate price for haricot beans and maize was 8 ETB/kg and 7 ETB/kg, respectively. In the research area, there was a demand for the Haricot bean (Haramaya) variety for domestic use, but not for the market. Profitable pre-extension demonstration of intercropping maize and haricot beans for farmers with a return of 28,007.67 ETB/ha as opposed to the corresponding returns of 19,069.23 ETB/ha for haricot beans and 11,453.84 ETB/ha for maize. The profitability of intercropping maize with haricot beans is displayed in Table 5.

Table 6. Profitability Analysis of Maize-Haricot Bean Intercropping Demonstration in ETB/hass

Items	Treatments		
	Sole maize	Sole haricot bean	Maize-haricot bean intercropping
Total Fixed cost	2,500	2,500	2,500
Total variable costs	5,000	5,200	7,300
Total Cost (TFC + TVC)	7,500	7,700	9,800
Average Revenue (P x Q)	18,953.84	26,769.23	37,807.67
Average Gross margin (TR-TVC)	13,953.84	21,569.23	30,507.67
<b>Net Profit (GM-TFC)</b>	<b>11,453.84</b>	<b>19,069.23</b>	<b>28,007.67</b>

Source: Own Data Result, 2019

### **Farmers' and Other Stakeholders' Feedback on Maize-Haricot Bean Intercropping Practice**

Farmers provide valuable input for future research on intercropping practice during the demonstration of maize-haricot bean intercropping. Each farmer had his or her own point of view. During technology evaluation yield, early matured varieties, double cropping, economic benefit and effective land use were the traits preferred by farmers. To evaluate intercropping practices farmers compared the maize-haricot bean intercropping yield with respective sole crop of maize and haricot bean.

Inter-cropping of maize with haricot bean is more advantageous than sole cropping of maize and haricot bean and increases more crops production per unit area. In other words, more lands will be required in the monoculture of either of the component crops to produce the same yield obtained from their intercropping. In addition, intercropping is important for farmers to recover from failure of one crop due to adverse climatic impact while they could harvest the rest crop.

### **CONCLUSIONS AND RECOMMENDATIONS**

Even though, intercropping is practiced in the study area farmers did not know crops to be intercropped, the time of sowing and intercropping system. They simply practiced in traditional way where there is less yield and return from the farm. Few farmers practice row intercropping (sowing of both crops on the same row) while, alternative row intercropping which has many advantages of reduced maize haricot bean competition for light, space and easy for management. Land scarcity and moisture stress problem is common at midland district of Guji zone. The result of demonstration of maize-haricot bean revealed that (27.46 qt/ha of maize + 23.23 qt/ha haricot bean) and generate 28,007.67 ETB/ha of return. More grain yield of maize was obtained when it intercropped with haricot bean than sole cropping. This result might be due to haricot bean added Nitrogen for soil fertility. However, the yield of haricot bean was higher when sown alone than intercropped with maize. This might be the shading effect of maize affect the haricot bean. Based on yield, economic benefit and effective land use maize-haricot bean intercropping was recommended for the small-scale farmers. Hence, intercropping of maize haricot bean is recommended to increase crop production and minimize the effect of moisture stress and scarcity of land on crop production in midland of Guji and similar agro-ecologies.

**Author Contributions:** All authors contributed to the study conception and design, material preparation, sowing, growing practice and data collection. Statistical analysis and first draft of the manuscript were performed and written by Mr. G. A, where B.K and D.K commented on previous versions of the manuscript. All authors have read and agreed to the published version of the manuscript.

## FURTHER STUDY

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