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Time of Haricot Bean Intercropping into the Maize-Based Cropping Systems under Conservation Tillage in the Rift Valley of Ethiopia

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አህፅርኦት

የተዓቅቦ የግብርና አስተራረስ ዘዴዎችን (የታሰረ ቦይ እና መሬትን ሳያርሱ የማልማት ዘዴ) መሠረት በማድረግ የበቆሎና የቦሎቄን ትክክለኛ አሰባጥሮ የመዝርያ ወቅት ለማወቅ ይቻል ዘንድ በመልካዛ ምርምር ማዕከል ሥር በሚተዳደረው የወለንጭቲ የሙከራ ጣቢያ የመስክ ሙከራ እ. ኤ. አ. በ2010 እና በ2011 ዓ. ም. የመኸር ወቅት ተካሂዷል። ሙከራው የተካሄደው ሁለት ዋና ዋና የተዓቅቦ አስተራረስ ዘዴዎችን በዋና የሙከራ መደብ በማስቀመጥ በእያንዳንዳቸዉ ዋና የሙከራ መደቦች ሰር ቀድሞ በተዘራ የበቆሎ ማሳ ላይ 3 የተለያዩ የቦሎቄ አሰባጥሮ የመዝርያ ወቅት እና በቆሎ እና ቦሎቄ ለብቻቸዉ የተዘሩ ንዑስ ሙከራዎች ሆነው ተቀምጠዋል። ሶስቱ የተለያዩ የቦሎቄ አሰባጥሮ የመዝርያ ወቅቶች የሚከተሉት ናቸዉ. 1ኛ. በቆሎ በሚዘራበት ተመሳሳይ ጊዜ ቦሎቄን አብሮ አሰባጥሮ የመዝርያ ወቅት 2ኛ በቆሎ ከተዘራ ከ15 ቀናት በኋላ ቦሎቄን አሰባጥሮ መዝራት እና 3ኛ በቆሎ ከተዘራ ከ30 ቀናት በኋላ ቦሎቄን አሰባጥሮ መዝራት ናቸው። የዚህ ምርምር ውጤት የተገመገመዉ በስብጥር የተዘሩት የሰብሎች ምርታማነት፣ የሰብሎቹ የገለባ ምርታማነት፣ አዝርዕትና ጥራጥሬ ሰብሎችን አሰባጥሮ በመዝራት ውሱን መሬትን የአጠቃቀም ብቃትን (LER) በመገምገምና በሰብል ስብጥሮች መካከል የሚታየውን ለሰብሎች ዕድገት የሚጠቅሙ የተፈጥሮ ሃብት አጠቃቀም ብቃትን አንዱ ሰብል በሌላዉ ሰብል ላይ ተሰባጥረዉ በመዝራታቸዉ ምክንያት የሚያስከትለዉን ተፅዕኖ፣ የበላይነትና ተወዳዳሪነት በመዳሰስ ነበር። የምርምር ውጤቱ እንደሚያመለክተው በዕቀባ የግብርና አስተራረስ ዘዴዎችና በተለያዩ የቦሎቄ አሰባጥሮ የመዝርያ ወቅት መካከል በማንኛውም በተቀመጡት የመገምገሚያ መስፈርቶች ላይ አንዱ በአንዱ ላይ ምንም ዓይነት ተፅዕኖ ወይም ተቃርኖ አላሳየም። ዋና የሙከራ መደቦች (የዕቀባ የግብርና አስተራረስ ዘዴዎች) በ2010 እና በ2011 ዓ. ም በተቀመጡት የመገምገሚያ መስፈርቶች ላይ ምንም ዓይነት ተፅዕኖ ማሳደር እንዳልቻሉ ዉጤቱ ያሳያል። ሆኖም በ2010 ዓ.ም. የሰብል እና የገለባ ምርት፣ የመሬት አጠቃቀም ብቃት በታቀበ የቦይ አስተራረስ ሙከራ ላይ የተሻለ ዉጤት ተመዝግቦበታል። በ2011 ዓ. ም ግን ይህ ውጤት የተገላቢጦሽ ዉጤት ተመዝግቦበታል። በዚህ ሙከራ ሰብሎችን አሰባጥሮ በመዝራት ከፍተኛ ምርት ማግኘት የሚቻለው በቆሎንና ቦሎቄን በተመሣሣይ ጊዜ አብሮ በመዝራት እንደሆነ ዉጤቱ ያሣያል። በ2010 እና 2011 ዓ. ም. በቆሎንና ቦሎቄን በተመሣሣይ ጊዜ በመዝራት አጠቃላይ ከፍተኛ የመሬት አጠቃቀም ብቃትን (LERt) ማሳደግ ተችሏል። በስብጥር የተዘሩት በቆሎና ቦሎቄ በተፈጥሮ ሃብት አጠቃቀም አንዱ በአንዱ ላይ ከፍተኛ ተፅዕኖ ማሳደራቸውን ውጤቱ ያመለክታል። በዚህም መሠረት በቆሎ በስብጥር የዕድገት ዑደት ዉስጥ ከቦሎቄ የበላይነት ማሳየቱን የተመዘገበዉ ከፍተኛ የበቆሎ የLA እና Km ውጤት ያሳያል። በሌላ በኩል ቦሎቄ ከበቆሎ ጋር ተሰባጥሮ ቢዘራ ከበቆሎ በተሻለ ተወዳዳሪ መሆኑን የተመዘገበው CR ውጤት መስክሯል። በዚህ ውጤት መሠረት በቆሎንና ቦሎቄን በተመሳሳይ ጊዜ አብሮ አሰባጥሮ በመዝራት የመሬት አጠቃቀም ብቃትን ማሳደግና በውሰን መሬት ከፍተኛ ምርትና ከአንድ ሰብል በላይ ሰብል ማምረት እንደሚያስችል ያሳየ በመሆኑ በመካከለኛው ሰምጦ ሸለቆ አካባቢዎችና የዝናብ እጥረት በሚታይባቸዉ አካባቢዎች የሚገኙ አርሶ አደሮች እንዲጠቀሙበት ቢደረግ በሰብል ምርታማነት መጨመር ጥሩ ውጤት ያስገኛል።

Abstract

Field experiments were conducted at Welenchity experimental field site, Melkassa Agricultural Research Center from June to October during the years 2010 and 2011 cropping seasons. The aim of the study was to determine optimum time of intercropping haricot bean into the maize based cropping system under conservation tillage practices, Tied-ridge and Zero-tillage. The experiment was laid out in split-plot design, with tillage practices a) Tied-ridge and b) Zero-tillage as main plot and time of intercropping haricot bean 1) Planting haricot bean simultaneously with maize, 2) Planting haricot bean 15 days after maize was planted and 3) planting haricot bean 30 days after maize was planted as sub-plots. Intercropping was assessed on the basis of the performance of the

main and component crops indices as grain yield, biomass weight, partial and total LER and competitive indices such as relative crowding coefficient (K), aggressivity (A), competitive ratio (CR) and system productivity index (SPI).There was no interaction between tillage practices and time of intercropping haricot bean in any of the indices studied. Main effects of tillage practices had no significant effects on all the indices considered during both 2010 and 2011 growing seasons, but grain yield, biomass weight, partial and total LER tended to be higher in the tied-ridge treatment during 2010 and vis-versa during 2011seasons. The results obtained showed that the greatest intercrop yields of maize and haricot bean were obtained when both crops were planted at the same time. In both years, highest total land equivalent ratio (LER_t) values were obtained when planting of maize and haricot bean was done at the same time followed by planting of haricot bean 15 days after maize was planted indicating the advantages of intercropping over the sole planting. Partial LER_m was always higher than LER_b during 2010 season and vis-versa during 2011 season. The results of competitive indices indicate that maize was the dominant crop in the mixture as measured by the positive values of A, and the high values of K_m than K_b in the mixture. On the other hand, CR values of haricot bean were higher than maize in the mixture suggesting haricot bean was more competitive than maize in the intercropping system. Moreover, the data of SPI indicated that intercropping haricot bean at the same time with maize had higher SPI during both 2010 and 2011 season. In conclusion, intercropping of haricot bean simultaneously with maize exhibited an overall advantage over the other time of intercropping and sole cropping in terms of grain yield, partial LERm, LERb and LERt and competitive ratio indices and could therefore be recommended for Central rift valley areas of Ethiopia where maize and haricot bean are major crops.

Introduction

Maize and haricot bean are important food crops for smallholder farmers in the semi-arid central rift valley areas of Ethiopia. However, due mainly to drought stresses and poor soil fertility conditions, productivity of these crops is low. Under the conditions prevailing in the semi-arid central rift valley areas of Ethiopia, management practices that optimize water conservation and efficient use of rainfall have long been an area of priority research. Although adoption rate is very low, promising results have been registered in the development of soil moisture conservation technologies.

Conservation tillage practices such as tied-ridge cultivation and zero-tillage are proven technologies for soil water conservation predominantly in the semi-arid areas Ethiopia (Tewodros, *et al*., 2005). Tied ridge cultivation (TRC) reduces rainfall run-off and soil erosion, and so can increase soil moisture availability and crop yield under a variety of semi-arid conditions. Tied ridge cultivation is the most effective technique for soil moisture conservation and thus increasing crop yield in zones with annual rainfall of less than 800 mm. Results found at Melkassa indicated that highest grain yield of maize and sorghum was obtained from plants grown in the furrows of tied ridges (Reddy and Kidane, 1993). The practice also tends to improve crop response to fertilizer application. In below normal rainfall years and on-farm sites of acute moisture stress, fertilizer use without soil moisture conservation practice (tied ridge) was found to be non-responsive.

Conservation agriculture (CA) is recommended as a practice for sustainable crop production that simultaneously preserves soil and water resources (Hobbs, et al., 2008). Given the positive effects of CA on soil and water conservation, environmental health, and economic viability, it has been regarded as an environment-friendly technology and has been applied worldwide (Lahmar, 2010). Previous studies conducted in Ethiopia and other parts of Africa showed that conservation tillage practices that involve the retention

of surface crop residues were effective in reducing evaporation losses and increasing water storage and water use efficiency (Tewodros, et al, 2005). This approach involves minimum disturbance of the soil surface by using an ox-drawn ripper tine to open the planting furrow. The practice has been recommended as a soil, water and draught-power conservation strategy and also reduces labor and time (Worku and Hussen, 2004). Several experiments were conducted to determine the effectiveness of conservation tillage over the traditional practice at different locations for different crops (tef, Maize and Sorghum) and has been reported that conservation tillage gave higher yields than the conventional tillage (Tewodros, et al., 2005).

The potential benefits of both TRC and conservation tillage practices, however, were tested only under sole crop conditions at various locations. Since tied ridge cultivation and conservation tillage practices can increase soil moisture retention, the practices may also extend the duration of crop growth in the post-rainy period (after the rains have stopped and while soil moisture is being depleted) and therefore reduce the risk of drought stress. It is believed that by using TRC and conservation tillage, it is possible to extend the growth period by at least 30 days (Tewodros *et al*., 2005). Thus, in most years the length of the growing season can be extended between 115 to 130 days.

One of the most important strategies to increase crop production in smallholder farmers in the semi-arid areas is development of improved cropping system that intensifies land use efficiency and can make effective use of growth resources (water, nutrient, light, etc.). Intercropping is one of the cropping systems practiced for higher crop production advantages per unit area. The vital features of intercropping systems are that they exhibit intensification in space and time, competition between and among the system components for light, water and nutrients and the proper management of these interactions. In light of these the system is considered among the agricultural practices associated with sustainable crop production (Tolera, 2003). Since the use of conservation tillage (Tied-ridge and zero-tillage) extends the growth period by effectively conserving soil moisture, integrating intercropping practice to these tillage practices can maximize growth resources use and increase crop production. Increased crop production (over-yielding) often observed in intercrops compared to sole crops has been attributed to enhanced resource use (Szumigalski and Van-Acker, 2008). For intercropping to be more productive it is recommended that component crops differ greatly in growth duration so that their resource requirement for growth resources occurred at different times (Hailu, 2015). It is strongly believed that if legumes are intercropped in a timely manner, competition with the companion crop (maize) for light, water and nutrients can be minimized. At present, there is a lack of information on the effectiveness of determining time of intercropping in the semi-arid areas of Ethiopia.

This study was, therefore, conducted with the aim of comparing the effects of TRC and conservation tillage practices on the performance of maize and haricot bean in intercropping, quantify the productivity and competitive indices of these common crops by determining appropriate time of intercropping haricot bean to the main crop maize using moisture conservation practices and evaluate the impact of intercropped haricot bean on the companion maize crop.

Materials and Methods

The study was conducted for two years during 2010 to 2011 crop growing season on the experimental field at Welenchity research site under rainfed conditions in a semi-arid area. The field has a typical clay loam soil that is too low in organic carbon (%) and total N (%) to fulfill the N demand of crops grown in the area and to maintain the soil N dynamic constant (Yusuf and Mesfin, 2006). and shows good response to moisture conservation practices. The experimental design was a split plot in a randomized complete block design and replicated three times. The treatments consisted of two in-situ soil moisture conservation practices, 1) Tied ridge cultivation and 2) Zero tillage assigned as main plot and three time of haricot bean intercropping into maize, a) planting haricot bean simultaneously with maize, b) intercropping haricot bean 15 days after maize is planted (DAP) c) intercropping haricot bean 30 days after maize is planted (DAP) as sub-plots. Tied-ridges were made 35 cm high constructed at every 6m length and closed at both ends of the row. Before planting, no herbicides was used, but there was about 10 to 15% dry weeds on the zero-tillage plots which were later harvested and left on the ground as mulch. After planting, growing weeds were also continually weeded and left as ground cover. Maize was planted at 80 cm space between ridges/rows and 25 cm within rows and at the time of intercropping haricot bean was planted at a recommended proportion of two rows of maize and one row of haricot bean at a plant spacing of 10 cm. Plot size was 4.50 m x 5 m = 22.50 m^2. Medium duration (120 day maturing) maize variety Melkassa II and haricot bean variety of Awash-I was used in this study. Fertilizer was as per the recommendation and so 50 KG/HA OF Urea as source of N was applied in split, half each at planting and when the maize plant reached at knee height and 100 kg/ha of DAP as source of P was applied at planting.

During the study period data collected included agronomic data such as above ground biomass of haricot bean and maize were estimated at harvest from 3 m^2 per plot and were dried at 60 ^oC for 72 hrs to determine dry matter yield. Grain yield, 1000 seed weight, plant height, cob weight $plant^{-1}$, number of cobs $plot^{-1}$, number of pods per plant, number of seeds per pod, and other yield components were also recorded, but grain yield and dry matter yield are reported here. Gross monetary value (GMV) was calculated for maize and haricot bean each, using the expression below.

GMV = Grain yield (kg ha^{-1}) × unit price (Eth. Birr kg^{-1})

The market price for maize and haricot bean at the time of crop harvest around Welenchity was estimated at Eth. Birr 6.00 kg^{-1} and Eth. Birr 7.75 kg^{-1}, respectively. The total gross monetary value (GMV_t) was then estimated by addition of the GMV_m and GMV_b.

The advantage and disadvantages of intercropping were determined using the land equivalent ratio (LER) which was used as the criterion for mixed stand advantage as both maize and haricot bean were common crop species (Willey and Osiru, 1972). In particular, LER indicates the efficiency of intercropping for using the resources of the environment compared with mono-cropping. Land Equivalent ratio a measure commonly used to

evaluate the performance of an intercropping system was computed from yields of maize and haricot bean in the intercropping system and sole crop.

For a maize/haricot bean association

The LER was calculated as: $LER_b + LER_m$

$LER_m = (Y_{mi}/Y_{sm})$; $LER_b = (Y_{bi}/Y_{sb})$

Where mi and sm are the yields of maize in intercropping and sole maize, respectively, and bi and sb the corresponding yields of haricot bean

The competitive relationships between the two crops were determined using the relative crowding coefficient (*k*) and aggressivity (*A*) values using the formulae suggested by Willey (1979) as indicated below:

Relative crowding coefficient of maize $(K_m) = \dfrac{Y_{mi} \times Z_b}{(Y_{sm} - Y_{mi}) \times Z_m}$

Relative crowding coefficient of CB $(K_b) = \dfrac{Y_{bi} \times Z_m}{(Y_{sb} - Y_{bi}) \times Z_b}$

Aggresivity of maize $(A_m) = \dfrac{Y_{mi}}{(Y_{sm} \times Z_{mi})} - \dfrac{Y_{bi}}{(Y_{sb} \times Z_b)}$

Aggressivity of CB $(A_b) = \dfrac{Y_{bi}}{(Y_{sb} \times Z_b)} - \dfrac{Y_{mi}}{(Y_{sm} \times Z_m)}$

Where Y_{sm} is the pure culture yield of maize, Y_{sb} the pure culture yield of haricot bean, Y_{mi} the mixed culture yield of maize, Y_{bi} the mixed culture yield of haricot bean, Z_m the sown proportion of maize and Z_b is the sown proportion of haricot bean.

The crowding coefficient (K) is a measure of the relative dominance of one species over the other in an intercrop (Banik, *et al*., 2006). Willey (1979) emphasized that each component crop in the intercropping system has its K value. Accordingly, a component crop with higher K value is the dominant and that with low K value is dominated. The yield advantage in the intercropping system as designated by K_t is determined by the product of the K of component crops. When the K_t is greater than one there is a yield advantage, when K_t is equal to one there is no yield advantage, and when it is less than one there is a disadvantage.

Aggressivity (A) is often used to indicate how much the relative yield increase in 'a' crop is greater than that of 'b' crop in an intercropping system (Dhima *et al*. 2007). It determines the competitive ability of a crop when grown in association with another crop.

In particular, if A is 0, both crops are equally competitive, if A_{cereal} is positive then the cereal species is dominant, and if A_{cereal} is negative then the cereal species is the dominated species.

Competitive ratio (CR) is only used as a measure of intercrop competition (inter-specific comptetion) between species in the system (Trydeman et al, 2004). The CR gives a better measure of competitive ability of the crops and is also advantageous as an index over crowding coefficient and aggressivity (Willey and Rao, 1980). The CR represents simply the ratio of individual LERs of the two component crops and takes into account the proportion of the crops in which they are initially sown. The CR is calculated according to the following formula:

$CR_m = (LER_m / LER_b) (Z_{bi} / Z_{mi})$

$CR_b = (LER_b / LER_m) (Z_{mi} / Z_{bi})$

According to Esmaeili, (2011) when CR is below 1 there is a positive benefit and the species can be grown in a mixture. If CR > one, indicates the base crop is competitor, while values < one implies the minor component crop is profusely suppressed the base crop or (Willey and Rao, 1980) if $CR_{cereal} = 0$, both crops are equally competitive, if CR_{cereal} is positive then the cereal species is dominant, if CR_{cereal} is negative then the legume is profusely suppressed the cereal species and is considered dominant species.

Another index for assessing intercrops is the system productivity index (SPI), which standardizes the yield of the primary crop (cereal) in terms of the primary crop (legume) (Odo 1991). System productivity index (SPI) was calculated as; SPI = (Ysm / Ysb x Ybi) + Ymi (Odo, 1991). Where: SPI = System productivity index, Ysm and Ysb = Mean yield of maize and haricot bean in sole cropping, Ybi and Ymi = Yield of maize and haricot bean in intercropping.

Statistical Analysis

Since there was a variation in the recorded seasonal climate data during the two growing seasons of the study period, an analysis of variance was performed for each year for a split-plot design using Statistix V8 (Analytical Software, Tallahassee, FL, USA). For significant main treatment effect and treatment interaction effects, LSD at 0.05 probability level means separation was applied.

Results and Discussion

Weather conditions

The rainfall data indicated that there is a variation in amount and distribution between the two growing seasons, 2010 and 2011. The amount of rainfall during 2010 growing season was higher and the distribution more even than 2011. During the beginning of the growing season in June and during end of the season in September 2011 rainfall was much lower than during the same season in 2010, suggesting that crops have experienced some degree of moisture stresses at seedling establishment stage and flowering and/or

grain filling stage due to low amount of rainfall during on set and cessation of the season, respectively, during 2011 than 2010 season.

The total seasonal amount of rainfall was 590.4 mm and 468.4 mm and the annual total rainfall was 982.2 mm and 611.3 mm during 2010 and 2011, respectively

Main treatment effect of Tillage Practices

The main effect of tillage practices (tied-ridge and zero tillage) was not significant (P<0.05) on any of the indices studied during 2010 and 2011 growing seasons (Table 1). In the present study soil water content over the study period was not recorded, however, the result suggested that the performance of both tied-ridge and zero tillage in soil moisture conservation is comparable. This finding is in accordance to the results of similar studies reported by Tewodros *et al.*, 2005 who reported that the effects of tied-ridge and zero tillage practices were not significantly different in soil moisture conservation, grain and dry matter yield.

Table 1: Response of Grain Yield (kg/ha), Biomass weight (kg/ha), LERm, LERb and LERt, GMVb and GMVm in maize and haricot bean to tillage methods in 2010 and 2011 at Welenchity

Parameters	2010				2011			
Maize	Tied-ridge	Zero-tillage	CV (%)	LSD (P<0.05)	Tied-ridge	Zero-tillage	CV (%)	LSD (P<0.05)
Grain yield (kg/ha)	3303.6	2821.3	24.9	NS	4220.8	4361.2	14.8	NS
Biomass wt (kg/ha)	8224.0	5923.6	26.13	NS	8711.6	9134.4	25.8	NS
LERm	1.10	1.19	9.43	NS	0.95	0.89	23.1	NS
Haricot bean								
Grain yield (kg/ha)	2121.5	1745.8	18.5	NS	815.2	947.6	12.7	NS
Biomass weight (kg/ha)	4570.3	4018.0	15.9	NS	3098.3	3109.0	7.8	NS
LERb	0.64	0.81	17.5	NS	1.24	1.04	18.3	NS
LERt	1.5	1.7	25.3	NS	2.4	2.2	19.9	NS
GMVb	17475	13982	25.2	NS	7410.1	6646.7	15.3	NS
GMVm	19822	17928	17.1	NS	26167	25325	12.6	NS

The results however, indicated that grain yield (kg ha^{-1}), biomass weight (kg ha^{-1}), and partial and total LER of maize and haricot bean tended to be higher in the tied-ridge than zero-tillage during 2010 growing season and vice versa during 2011 season. The tendency to produce higher grain and dry matter yield during higher rainfall season in 2010 in the tied-ridge treatment may be related to the relatively higher soil water stored and increase infiltration as opposed to zero-tillage where excess water was lost as run off. The results of Tewodros, *et al.,* 2005 suggested that zero-tillage did not increase grain, dry matter yield and water use efficiency when the precipitation is realistically sufficient or increased in the semi-arid areas. During 2011 season, the relatively higher grain and dry matter yield in zero-tillage practice as compared to tied-ridge practice may be associated with the amount of rainfall during which below average rainy season, evapo-transpiration rate might have been reduced due to the accumulated mulches which were added over a series of weed harvests, and resulted to more soil moisture conservation resulting into increased biomass production with subsequent improved assimilate translocation, partitioning and consequential increase in grain yield.

Main treatment effect of time of intercropping haricot bean to maize

The main treatment effect of time of intercropping haricot bean to the maize crop was not significant (P<0.05) on the grain yield of maize during 2010, but significantly influenced during 2011 season (Table 2). The result revealed that in 2010 season, intercropping haricot bean simultaneously with maize tended to reduce maize grain yield as opposed to delayed planting. The result implies that during high rainfall season, planting haricot bean simultaneously with maize, favored the fast growing and early maturing haricot bean a competitive advantage over maize of effectively making use of resources (soil nutrient and water) for increased growth and grain yield. This corroborates with the findings of Ghosh, *et al*., 2006. In 2011 crop season, significantly highest maize grain yield was produced when haricot bean was planted simultaneously with maize as against delayed intercropping probably due to the effect of soil moisture stress during stand establishment at the beginning of the season which has severely reduced grain yield of haricot bean. The soil moisture deficit that occurred during seedling stage had reduced the competitive ability of haricot bean as it is very susceptible to drought stress. On the other hand, main treatment effect of time of intercropping was significant on the grain yield of haricot bean during both 2010 and 2011 crop season. With delayed time of intercropping haricot bean to the maize crop, there was a significant decline in the grain yield of haricot bean during both 2010 and 2011 crop season and maize during 2011 growing season. The results of highest grain yield of both maize and haricot bean when time of intercropping haricot bean is done at the same time with maize is in accordance with other reports on cereal crops with forage legumes (Mpairwe, *et al*. 2002), food legumes (Amujoyegbe and Elemo, 2013).

Table 2: Grain yield (kg/ha) of maize and haricot bean and GMV (birr) in response to Haricot bean time of planting under maize/Haricot bean intercropping in 2010 and 2011 at Welenchity

Time of intercropping	Grain yield (kg/ha)					
	2010			2011		
	Maize	Haricot bean	Total GY (kg ha^{-1})	Maize	Haricot. bean	Total GY (kg ha^{-1})
Maize + Haricot bean Simultaneously	2781.5	2260.8^{A}	5042.3	5088.6	1138.9^{A}	6227.5
Planting Haricot bean 15 DAP maize	3333.5	1700.8^{A}	5034.3	3981.3	1083.3^{A}	5064.6
Planting Haricot bean 30 DAP maize	3396.2	964.7^{B}	4360.9	3368.8	361.1^{B}	3729.9
Sole maize	2738.7	-	2738.7	4725.4	-	4725.4
Haricot bean	-	2808.3^{C}	2808.3	-	942.3^{C}	942.3
Mean	3062.5	1933.7		4291	906.9	
CV (%)	24.9	18.5		12.6	15.3	
LSD (P,0.05)	NS	584.2*		681.7*	463.8*	

The decline in the grain yield of haricot bean during 2010 season may be potentially influenced by many variables such as competition with the second crop maize for greater utilization of water, light and soil nutrient over the delayed introduction of haricot bean plants to the maize system. In cowpea/millet intercropping the millet canopy was

reported to interfere with light interception and thus yields of intercropped cowpea were reduced (Reddy and Visser, 1997). The yield response of haricot bean to delayed introduction to the maize stand was in line with the results obtained by Amujoyeg be and Elemo, (2013) in maize/cowpea intercropping. Generally, irrespective of planting time treatment, grain yield of haricot bean during 2010 season was much higher than 2011. The higher grain yield of haricot bean during 2010 than 2011 season may suggest that relatively better rainfall have created favorable conditions for the growth of haricot bean. The decline in grain yield of both maize and haricot bean in the system with delayed time of intercropping haricot bean to the maize stand during 2011 may be associated to early cessation of rainfall which might have impaired complete grain filling.

In contrast to the grain yield, time of intercropping haricot bean to maize crop has no significant effect on the biomass weight of maize during 2011 (Table 3). But biomass weight of maize in 2010 and that of haricot bean during both 2010 and 2011 crop season was significantly influenced by time of introducing haricot bean to maize crop (Table 3). Accordingly, highest biomass weight of maize during 2010 season was obtained when maize was sole planted followed by introducing haricot bean to maize 15 days after maize was planted. Biomass weight of sole maize was significantly ($P<0.05$) higher than the mixture during 2010 season, however, there was no significant difference from the intercropping system during 2011.

Table 3: Biomass yield (kg/ha) of maize and haricot bean in response to haricot bean time of planting under maize/Haricot bean intercropping in 2010 and 2011 at Welenchity

Treatment	Biomass Wt (kg/ha)					
	2010			2011		
	Maize	Haricot bean	Total	Maize	Haricot bean	Total
Maize + Haricot bean Simultaneously	10750^{A}	6357.9^{A}	17107.9	9064.0	5000.0^{A}	14064.0
Planting Haricot bean 15 DAP maize	13233^{A}	4571.9^{B}	17804.9	9064.0	3666.7^{B}	12730.7
Planting Haricot bean 30 DAP maize	10533^{A}	2516.8^{BC}	13049.8	8314.0	1888.9^{C}	10202.9
Sole maize	16133^{B}	-	16133.0	9250.0	-	9250.0
Haricot bean	-	3730.0^{C}	3730.0	-	1859.0^{C}	1859.0
Mean	12663	4294.1		8923.0	3103.6	
CV (%)	25.2	15.9		25.8	7.8	
LSD (P,0.05)	4280.2*	1296.0*		NS	1294.5*	

The high amount of rainfall received in 2010 has created favorable conditions for the development of higher biomass weight. The response of biomass weight of haricot bean in the intercropping system followed similar trends to the grain yield during both seasons. Accordingly, highest biomass weight (kg ha^{-1}) of haricot bean was produced when haricot bean was planted simultaneously with maize and significantly ($P<0.05$) decreased with delayed time of intercropping haricot bean.

In terms of both grain yield and biomass weight the combined yield of maize and haricot bean in the intercropping system were higher than sole maize or haricot bean suggesting the advantages of intercropping over sole planting (Table 2 and 3). For example, the total grain yield advantages of combined maize and haricot bean over the sole maize and

haricot bean ranged from 55% to 84% in 2010. Similar results have been reported in Sorghum-Mung bean-Soybean (Arshad and Ranamukhaarachchi, 2012) intercropping and tef-faba bean (Getachew, et al., 2006) mixed cropping, sorghum-soybean-cowpea intercropping (Lemessa, et al., 2015). The results of 2011 season however, indicated that the advantages gained by combining maize and haricot bean over sole maize was minimal ranging from 7% to 32% in the intercropping haricot bean 15 DAP maize and simultaneous planting treatments, respectively. Delayed intercropping haricot bean 30 DAP maize remarkably reduced (-21%) the combined grain yield of maize and haricot bean over sole maize probably due to occurrence of terminal drought or early cessation of rainfall. The grain yield advantages by combining maize and haricot bean over sole haricot bean ranges from 295% to 561%. The reason for wider yield gap between combined maize and haricot bean over sole haricot bean is due to the effects of soil moisture stress on haricot bean which had remarkably reduced grain yield during 2011 season relative to 2010 season.

In addition to agronomic parameters used to compare the advantages of any cropping system in small scale farming conditions, total gross monetary (TGMV) value is also used to evaluate economic advantages of intercropping system. The results of this study indicated that intercropping of haricot bean to the maize system was advantageous than sole maize and/or sole haricot bean cropping and among the time of intercropping treatments, simultaneous planting of haricot bean was more advantageous than delayed intercropping haricot bean to the maize system. (Table 4). Generally, the advantages of GMV_t accrued from time of intercropping haricot bean treatments over the sole maize and haricot bean followed similar trends to that of the total grain yield obtained from similar treatments. Similar results are reported from intercropping of sorghum with soybean and cowpea (Lemessa, *et al.,* 2015).

Table 4: GMVm, GMVb and GMVt (birr/ha) of maize and haricot bean in response to Haricot bean time of planting under maize/Haricot bean intercropping in 2010 and 2011 at Welenchity

Treatment	Gross Monetary Value (birr/ha)					
	2010			2011		
	GMVm	GMVb	GMVt	GMVm	GMVb	GMVt
Maize + Haricot bean Simultaneously	16689	17521	34210	30531	8826.4	39357.4
Planting Haricot bean 15 DAP maize	20001	13181	33182	23888	8395.8	32283.8
Planting Haricot bean 30 DAP maize	20377	10447	30824	20213	3588.7	23801.7
Sole maize	18432	-	18432	28353	-	28353
Haricot bean	-	21765	21765	-	7302.9	7302.9
Mean	18875	15729		25746	7028.4	
CV (%)	17.1	25.2		12.6	15.3	
LSD (P,0.05)	ns	4247.7		4090.0	3594.4	

GMVm= Gross monetary vlue of maize, GMVb= Gross monetary value of haricot bean and GMVt = Gross monetary value of total

The advantages of intercropping over sole planting have also been observed in the data of LER which is given in Figure 2. Time of introducing haricot bean to the maize crop had a significant ($P<0.05$) effect on the partial LER_b during 2010 and partial LER_m and LER_t

during 2011. However, the partial LER_m in the intercropping system during 2010 was always above unity (1.00) indicating the advantages of intercropping over sole cropping. Partial LER_m during 2011 season decreased with delayed time of haricot bean intercropping (Figure 2) and the highest partial LER_m was obtained by intercropping haricot bean at the same time with maize. The increase in partial LER_m during 2010 with delayed intercropping of haricot bean is associated with the increase in maize grain yield as with delayed intercropping. The results of this study is in agreement to the report of Tamiru, 2014 in haricot bean/maize relative time of inter-planting study who reported that highest partial LER_m was recorded with delayed intercropping of haricot bean to maize stand. On the other hand, the decline in partial LER_m during 2011 season was a consequence of decrease in maize grain yield with delayed time of intercropping haricot bean as well as the effect of terminal drought stress which have remarkably reduced grain yield of maize.

Partial LER_b during both 2010 and 2011 was significantly different among time of haricot bean intercropping to maize crop.

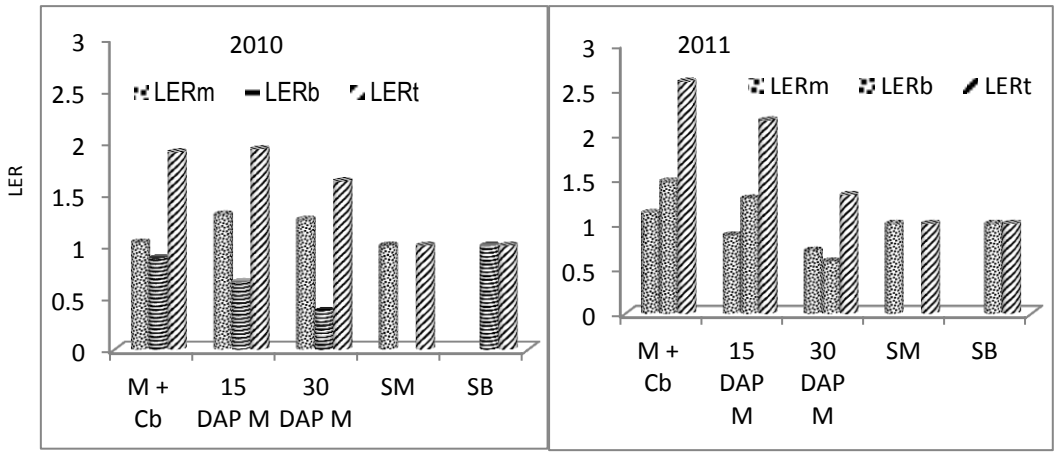

Figure 2: Partial LER of maize, haricot bean and total under different time of haricot bean intercropping and sole maize and haricot bean (M + cb = haricot bean planted simultaneously with maize, 15 DAPM= haricot bean planted 15 days after planting maize, 30 DAPm= common bean planted 30 days after planting maize, SM = Sole maize and SB = Sole haricot bean

During both seasons partial LER_b decreased with delayed time of haricot bean intercropping to the maize crop. During 2010 season partial LER_b was below 1.00 (unity) at all time of intercropping haricot bean indicating there was an advantage for maize crop in terms of the use of environmental resources (Tamiru, 2014). The probable reason for the below unity values of partial LER_b during 2010 season could be due to the increasing trend of maize grain yield with delayed intercropping of haricot bean which had a negative effects on haricot bean growth and development as opposed to the sole haricot bean grain yield. This result is in accordance with the reports of Amujoyegbe and Elemo, (2013). However, during 2011 when there was below average rainfall season, the highest partial LER_b value was obtained as with early time of intercropping haricot bean to the maize crop. During the same season LER_m was below unity with delayed time of introducing haricot bean as opposed to LER_b which had above unity of 1.47 and 1.28

when haricot bean was intercropped simultaneously with maize and 15 days after maize was planted, respectively. This is attributed due to the fact that maize yield with delayed intercropping sharply declined below sole cropped maize yield and consequently resulted in to below unity partial LER_m. During 2011 season, although grain yield of haricot bean in the system was lower relative to the 2010 season, above unity partial LER_b was a consequence of very low grain yield recorded in the sole haricot bean as a result of drought stress during grain filling stage and so the ratio of grain yield in the intercropping haricot bean to the sole haricot bean results in to above unity partial LER_b. The results of partial LER_m and LER_b indicates that it is advantageous to have the crops in mixtures, with the companion crop planted at the same time or not later than 15 days after planting the main crop maize. Total LER_t was generally above 1.00 during both 2010 and 2011 which shows the advantages of intercropping over the sole cropping. Delayed time of intercropping, however, resulted to decrease LER_t. during both 2010 and 2011 seasons. The highest LER_t value of 2.58 and 2.15 were obtained when haricot bean was intercropped at the same time with maize and 15 days after planting maize, respectively. This result suggested that it is advantageous to have the crops in mixture, since the farmer would need as much as 2.58 to 2.15 hectares of land when crops are grown in sole in order to achieve the same yield level from 1ha of land when crops are grown in mixture. In addition, it is advisable to intercrop companion crops simultaneously or not later than 15 DAP maize to maximize land use efficiency and grain production. This view supports Ijoyah and Jimba (2011) who reported an increase in LER_t of Sweet potato planted at the same time with Okra during 2009 and 2010 crop season.

The response of aggressivity (A) and competitive ratio (CR) of maize and haricot bean in the intercropping system during 2010 and 2011 is presented in Table 5. The result of A indicated that maize was the dominant crop in the mixture as measured by the positive values during both 2010 and 2011 crop season irrespective of time of intercropping haricot bean to maize. During 2010 season, with delayed in the time of intercropping haricot bean to maize crop, A of maize was on increasing trend. On the other hand, the highest positive A value of maize was recorded when haricot bean was intercropped at the same with maize. Unique feature of this index is that if the A value of one of the component crop is positive the other crop becomes negative and as the A value is greater, the higher is the difference in the competitive abilities of component crops. In this system the increasing trend of positive A values of maize during 2010 season indicated that competitive ability of maize became greater with delayed time of intercropping haricot bean.

Table 5: Aggressivity (A)and Competitive ratio (CR) of maize and haricot bean in response to Haricot bean time of planting under maize/Haricot bean intercropping in 2010 and 2011 at Welenchity

Treatment	Aggressivity (A)				Competitive ratio (CR)			
	2010		2011		2010		2011	
	A_m	A_b	A_m	A_b	CR_m	CR_b	CR_m	CR_b
Maize + Haricot bean Simultaneously	1.62	-1.62	1.50	-1.50	0.33	3.47	0.33	5.67
Planting Haricot bean 15 DAP maize	2.25	-2.25	1.07	-1.07	0.50	2.01	0.24	6.22
Planting Haricot bean 30 DAP maize	2.28	-2.28	1.15	-1.15	0.95	1.23	0.48	3.33
Sole maize	0.00	-	0.00	-	0.25	-	0.25	-
Haricot bean	-	0.00	-	0.00	-	4.00	-	4.00
Mean	1.54	-1.54	0.93	-0.93	0.51	2.68	0.32	4.81

A= Aggressivity, CR= Competitive ratio

Competitive ratio (CR) is used to assess the degree of competition between different species in the intercropping system (Trydeman *et al*., 2004). The result of CR, for haricot bean was higher than maize at all time of intercropping haricot bean to the maize system. Although the results suggest that both crops are compatible for intercropping, it was clear that haricot bean had exhibited dominance over maize in the system, suggesting that haricot bean (CR > one) was more competitive than maize (CR < one) (Table 5). As with A, with delayed in the time of haricot bean intercropping the values of CR for maize tended to increase and that of haricot bean consistently declined during both 2010 and 2011 seasons indicating that haricot bean is more competitive if planted simultaneously with maize before stand establishment. In this system, the growing condition suggests that CR appeared to be influenced more by phenology and growth characteristics of the species in the system. Maize is a slow growing and long maturing species as opposed to that of haricot bean a fast growing and early maturing species. By the time haricot bean was planted simultaneously with maize, haricot bean had faster stand establishment and matures earlier when maize was at medium vegetative stage. It is therefore, surmised that this characteristic gives a competitive advantage to haricot bean to exploit and make effective use of growth resources than the slow growing and late maturing companion crop. This result corroborates the findings of Tobita, *et al*., (1996) and Ghosh, *et al*., (2006). On the other hand, by the time haricot bean was delayed planted 15 and 30 days in to the system, maize was at full stand establishment, vegetative stages, and deeper root growth to enable it exploit efficiently solar radiation, plant nutrient and moisture resources in the soil profile (Berntsen *et al*., 2004).

Generally, maize had higher relative crowding coefficient (K_m) value than haricot bean K_b indicating that maize is more competitive than its associate haricot bean (Banik *et al*., 2000, Dhima *et al*, 2007) (Table 6). The negative K values for maize during 2010 and 2011 season and that of haricot bean during 2010 season suggest that in this mixture there was no yield advantage or disadvantage (Takim, 2012). With delayed time of haricot bean intercropping, the K_m value are above one during both 2010 and 2011 seasons, indicating yield advantages of maize over haricot bean in this intercropping system. Similar results have been reported by Banik et al., 2000, Dhima et al, 2007. The total K_t during both 2010 and 2011 is always above ones again demonstrating a yield advantage of intercropping system.

Table 6: Relative Crowding Coefficient (K) of maize haricot bean and total and System Productivity Index (SPI) in response to Haricot bean time of planting under maize/Haricot bean intercropping in 2010 and 2011 at Welenchity

Treatment	Relative crowding coefficient (K)						SPI	
	2010			2011				
	K_m	K_b	K_t	K_m	K_b	K_t	2010	2011
Maize + Haricot bean Simultaneously	-9.65	-4.23	72.78	-2.58	0.12	4.95	5377.7	10384
Planting Haricot bean 15 DAP maize	21.52	-2.62	34.97	17.25	0.13	25.55	5262.7	9121
Planting Haricot bean 30 DAP maize	15.27	0.77	4.80	3.08	0.20	0.78	4498.4	6796
Sole maize	0.00	-	0.00	0.00	-	0.00	-	-
Haricot. beam	-	0.00	0.00	-	0.00	0.00	-	-
Mean	6.78	-1.52	28.14	4.44	0.36	7.82	5046.3	8767

K= Relative crowding coefficient, SPI= System productivity index

The system productivity index (SPI) which standardized the yield of the secondary crop (haricot bean) in terms of the primary crop (maize) and also identified the combinations that utilized the growth resources most effectively and maintained a stable yield performance indicated that intercropping of haricot bean at the same time with maize produced the highest SPI than delayed intercropping during both 2010 and 2011 season. SPI consistently declined with delayed intercropping of haricot bean (Table 6). This result indicated that intercropping haricot bean at the same time with maize was the most profitable practice. Similar results are reported in sorghum and cowpea intercropping (Oseni, 2010)

From the results of this study, it may be concluded that there is a scope for farmers to increase maize and haricot bean productivity in the semi-arid central rift valley areas of Ethiopia, by integrating improved soil moisture conservation practices (Tied-ridge and zero-tillage) and intercropping system in the maize and haricot bean production system. The productivity of the system could further be improved and sustained by planting maize and haricot bean simultaneously which increased productivity of both maize and haricot bean by avoiding competition between the species during early stand establishment.

Farmers should therefore, be encouraged to practice soil moisture conservation practices together with intercropping maize and haricot bean to sustainably increase productivity of the system and optimize use of resources.

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