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Advantages of Maize-Haricot bean Intercropping over Sole Cropping through Competition Indices at west Badewacho woreda, Hadiya Zone, SNNPR

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A field experiment was conducted at west Badewacho Woreda, Hadiya Zone, to investigate the effect of cropping systems and planting patterns on crop yield, and to evaluate the systems for better management of resources using different competitive indices. The treatments were sole maize, sole Haricot bean, 100 maize+25 haricot bean, 100 maize+50 haricot bean, 100 maize+75 haricot bean and 100 maize+100 haricot bean, using randomized complete block design with three replications. The result revealed that grain yield of sole maize and haricot bean were significantly (P<0.05) higher than that of intercropped by 13.4% and 46.33%, respectively. On the other hand, Intercropping of maize with haricot bean increased land use efficiency and gave higher total yields compared to growing either species in sole culture. Regardless of mix proportion, maize intercropped with haricot bean at 100 % population density had better yield advantages, land use efficiency, and economics return than other intercropping system as justified by the higher "LER" 1.40, "K" (13.77) and "MAI" 1777.85. Therefore, maize intercropped with 100 % haricot bean population density is recommended for the study area for their better compatibility and economic benefit as compared to other population densities.

Key Words: Competition, Haricot bean, Intercropping, Maize and Sole cropping.

INTRODUCTION

Maize is one of the most important traditional crops in tropical farming systems. In Ethiopia, it is an important crop because of its high productivity per unit area, suitability to major agro ecologies, compatibility with many cropping systems, and ease of traditional dish preparation. Maize is also a food security crop in the country where recurrent drought is a common phenomenon (Tesfa *et al*., 2001).

In Ethiopia, maize ranks first among cereals in productivity per hectare and in total grain production, while it is second to teff in total hectare coverage. Maize is cultivated on about 2.01 million hectares accounting for 20.9 % of nearly 9.6 million hectares of all land allocated to all cereals (CSA, 2013). The crop is mainly produced for human consumption in different forms such as; bread, roasted and boiled green ears, parched mature grains for local beverage production, etc. It is an important forage crop that can be harvested and fed green as fodder or made into silage. After the ears are removed, they will be used as animal feed, construction material and firewood (Kebede *et al.*, 1992).

Ethiopia is now one of the top ten producers of total pulses in the world, the second-largest producer of faba beans after China, and the fifth or sixth largest producer of chickpeas. Within Ethiopia, pulses are the third-largest crop export behind coffee and oil seed, and represent a USD 90 million export industry (Shahidur et.al., 2010). Among legumes, haricot bean, Phaseolus vulgaris, has been cultivated as a field crop for a very long time and hence, it is the important food legume produced in Ethiopia (Ali K., 2003).

Haricot bean is a principal food crop particularly in Southern and Eastern part of Ethiopia, where it is widely intercropped with maize and sorghum, respectively, to supplement farmers income (EPPA,2004). It is considered as the main cash crop and protein source of the farmers in many low lands and mid altitude zones of Ethiopia [Rahmeto Negash, 2007). In addition to the domestic markets, Ethiopia is supplying white beans into the export canning industry in European Union (EU) and other eastern European markets. In the past two to three years, Ethiopia has also been a major supplier of red beans into northern Kenya and this market has shown most rapid growth (Ferris and Kaganzi, 2008).

Intercropping is considered as one of crop intensification strategies to increase agricultural productivity per unit area of land. It is the practice of growing two or more crops simultaneously in the same field. Intercropping provides a balanced diet, minimizes risks of crop failure due to adverse effects of pests, improves the use of limited resources, reduces soil erosion, increases yield stability and provides higher returns (Dapaah *et al*., 2003). Farmers practice different cropping systems to increase productivity and sustainability (Hauggard-Nielson H, 2001). Cropping system characteristics can fundamentally alter the a biotic and biotic features of an agro-ecosystem and could modify the life cycle of pests such as weeds (Banik, P, 2006). The use of intercropping by smallholder and peasant farmers is a common practice that dates back to ancient civilization (Dahmardeh M, 2009) in the tropics and rain-fed areas of the world (Dhima, K.V, 2007). The advantages of intercropping include soil conservation, lodging resistance, yield increment and weed control over the mono-cropping.

When two crops are planted together, intra and/or inter specific competition or facilitation between plants may occur (Zhang FS, 2003). Studies showed that mixtures of cereals and legumes produce higher grain yields than either crop grown alone (Dapaah HK, 2003). Competition among mixture is thought to be a major aspect affecting yield as compared with sole cropping of cereals (Ndakidemi PA, 2006) and a number of indices such as land equivalent ratio, relative crowding coefficient, competitive ratio, actual yield loss, monetary advantages and intercropping advantages have been used to describe competition between component crops of intercropping systems (Yilmaz S, 2007). The objectives of this study was to examine the effect of cropping systems and planting patterns on crop yield, and to evaluate the systems for better management of resources using different competitive indices.

MATERIALS AND METHODS

The experiment was conducted at Elefeta Farmers' Training Centre (FTC), in west Badawacho Woreda, Hadiya zone, during 2012 small rainy season (B*elg)*. West Badawacho Woreda is located in the Southern, Nations, Nationalities, and Peoples' Region (SNNPR), about 352km south of Addis Ababa and lies at 7^0 0.9′N and 37^0 50′E. The soil of the experimental area is classified as Nitosol with sub-soil stratified as loam to clay loam texture characteristic with pH ranging from 5.5-6. It receives mean annual rainfall of 750-1100 mm and has mean annual temperature of 21 ºC.

The experimental design was randomized complete block design (RCBD) in additive series with six treatments and three replications. Maize was the principal crop and spaced at a distances (25*80)cm^2 and the plant population was 50,000ha^{-1}. Pathways between blocks and plots were 2m and 1m, respectively. Each plot had a size of 4mx3m (12 m^2) accommodating five maize rows. Each row and plot had 12 and 60 plants, respectively. Only the central three rows of maize were used for data collection. The sole haricot bean taken as 250,000ha^{-1} and was spaced at a distance (10*40)cm^2 and also four haricot bean population densities 25, 50, 75 and 100% as a companion crop. In every alternative rows of maize with plant to plant distance 25, 20, 15 and 10cm for 25, 50, 75 and 100% for haricot bean population densities were used, respectively. Each plot had 10 rows of haricot bean off which the central six rows of haricot bean were used for data collection.

The experimental field was prepared following the conventional farmers' practices. It was oxen ploughed 4 times before sowing and the maize and the haricot bean with its different plant population densities were sown following the field layout, simultaneously in rows with the rate of two seeds per hill to assure germination and good stand after which the seedlings were thinned to a single plant per hill. Fertilization, at the time of planting all plots received Di-ammonium Phosphate (DAP) (18% N, 46% P_2O_5) at the rate of 100 kg ha^{-1} basal application. Nitrogen was applied in the form of urea (46% N) at the rate of 100 kg ha^{-1} in split form in which the first application was done at knee- height stage of maize, while the remaining half was applied just before tassling to all plots except the sole haricot bean assuming the bean would be benefited from the fixed nitrogen.

The incidence of stalk borer was controlled by the application of Cypermethrin 1% granule one time at knee height when plants were 50-75 cm tall. All intercultural operation were carried out from land preparation up to harvesting as per required and recommendation. Maize harvested at complete maturity and the haricot bean were harvested when the first pod of the plants fully matured and dried. Seeds were weighed and adjusted to constant moisture levels of 12.5% and 13 % maize and haricot bean, respectively. Observations on desired parameters of the component crops were recorded using standard procedures and the data were statistically analyzed using SAS statistical computer package program to determine the treatment effects. while the differences among treatment means were compared by Least Significance Difference (LSD) test at P = 0.05.

Evaluation of the cropping systems was carried out as in using the following indices:-

(I) Land equivalent ratio (LER) which verifies the effectiveness of intercropping for using the resources of the environment compared to sole cropping. The LER values were calculated as: LER = (LERM + LERHB), where LERM = YIM/YM and LERHB= YIHB/YHB, where YM and YHB are the yields of maize and haricot bean as sole while YIM and YIHB are the yields of maize and haricot bean as intercrops, respectively;

(II) Whereas the formula used for computing the LEC is: LER maize× LER haricot bean.

(III) Relative crowding coefficient (K) which measures the dominance of one species over the other in a mixture. K was calculated as: K = KM x KHB, where KM = YIM x ZIHB / (YM – YIM) x ZIM and KHB = YIM x ZIM / (YHB – YIM) x ZIHB where ZIM and ZIHB were proportions of maize and haricot bean in the intercrops, respectively. When the value of K is greater than 1, there is a yield advantage; when K is equal to 1, there is no yield advantage; and, when it is less than 1.00, there is a disadvantage;

(IV) Aggressivity (A) was used to determine the competitive relationship between 2 crops in a mixture. The aggressivity was calculated as: AM = (YIM/YM x ZIM) – (YIHB/YHB x ZIHB), and AHB = (YIHB/YHB x ZIHB) – (YIM/YM x ZIM).

(V) Competitive ratio (CR) gives more desirable competitive ability for the crops. The CR represents simply the ratio of individual LERs of the two component crops and takes into account the proportion of the crops on which they are initially sown. The CR index was calculated using the following formula: CRM = (LERM / LERHB) (ZIHB / ZIM) while CRHB = (LERHB / LERM) (ZIM / ZIHB).

(VI) Actual yield loss (AYL) index, which gave more accurate information about the competition than the other indices between components of intercropping system. The AYL is the proportionate yield loss or gain of intercrops compared to sole crop. The AYL was calculated as: AYL = AYLM + AYLHB, where AYLM = {(YIM/XIM) / (YM /XM)} – 1, and AYLHB = {(YIHB/XIHB) / (YHB/XHB)} -1, where X is the sown proportion of intercrop components and

(VII) Intercropping advantage (IA) was estimated as IA = AYL x Price of haricot bean or maize (the current price of haricot bean and maize is 7 and 5 Ethiopian Birr per kg, respectively. The data were statistically analyzed using SAS statistical computer package program to determine the treatment effects. The means separation was carried out by Duncan's multiple range test (LSD) at p<0.05.

(VIII) Finally, the monetary advantage index (MAI) was calculated since none of the above competition indices provides any information on the economic advantage of the intercropping system. The calculation of MAI was as follows:

MAI = (value of combined intercrops)(LER-1) / LER; the higher the MAI value, the more profitable the cropping system is (Ghosh, 2004).

RESULT AND DISCUSSION

Grain yield, Land equivalent ratio and Land equivalent coefficient:-

Sole cropped maize had significantly (P<0.05) higher grain yield than intercropped by an average of 0.756 t/ha 13.4% (Table 1). Tolera (2003) also concluded that planting haricot beans in association had no appreciable effect on the yield of maize. Similarly, Kimani *et al*. (1999) indicated that although intercropping maize with bean tended to lower maize grain yield, the effects were not significant. The highest grain yield was obtained from intercropped plots at mix- proportion of 100M: 50H.B gave the total grain yield, 6.29 ton/ha followed by plots at mix-proportion of 100M:100H.B (Table 1). The highest intercropped maize was obtained from maize intercropped with 50% Haricot bean population density while the lowest intercropped maize was recorded from maize intercropped with 100% haricot bean population densities this might be due to the competitive ability of the companion crop increased though the haricot bean population density increased.

In this study, cropping system significantly affected haricot bean grain yield. Consequently sole haricot bean had significantly (P<0.05) higher grain yield than intercropped (Table 1). The yield of sole haricot bean was greater than intercropped by 1t/ha (46.33%). This result

Table 1. Grain yield, Land equivalent ratio (LER) and Land equivalent coefficient (LEC) for sole stands and mixture of maize with Haricot bean

Planting Pattern	**Mix proportion**	**Grain yield t/ha**			**Land Equivalent ratio (LER)**			**Land Equivalent coefficient LEC**
		Maize	H.B	Total	PLERM	PLERH	TLER	**LEC**
Sole maize	**100**	5.62	-	5.62	1.00	-	1.00	-
Sole haricot bean	**100**	-	2.16	2.16	-	1.00	1.00	-
1M:4H.B	**100:25**	4.89	0.64	5.53	0.87	0.40	1.28	0.35
1M:2H.B	**100:50**	5.21	1.07	6.28	0.87	0.47	1.33	0.41
1M:3H.B	**100:75**	4.71	1.33	6.04	0.84	0.54	1.38	0.45
1M:1H.B	**100:100**	4.64	1.59	6.23	0.83	0.57	1.40	0.47
Mean		4.86	1.16	5.36	0.85	0.49	1.35	0.42

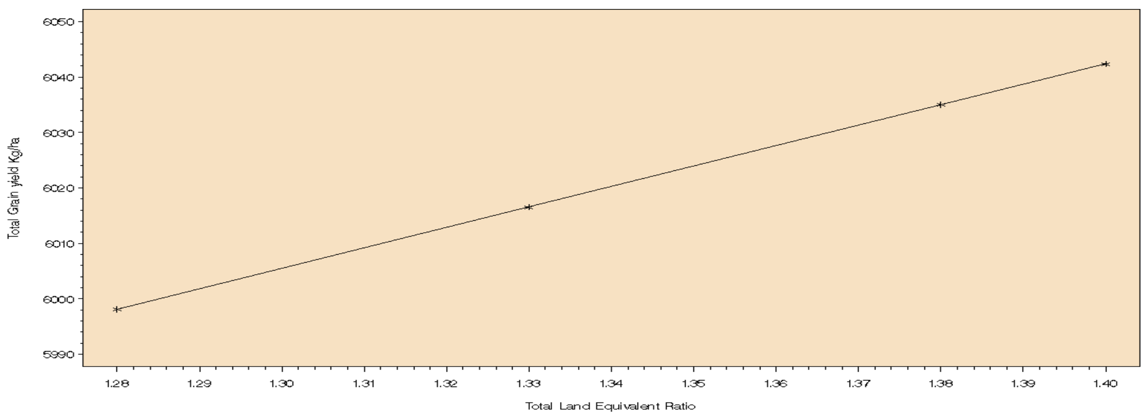

Figure 1. Relationship between total grain yield (kg ha−1) and land equivalent ratio (LER) of maize and haricot bean in intercropping. Y =5525.9 + 368.9X, r= 0.52

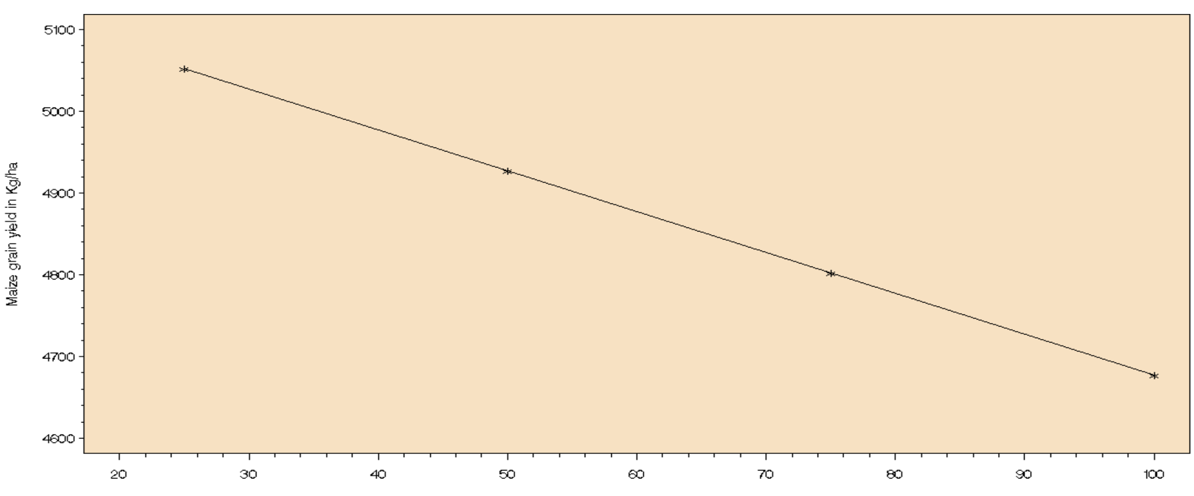

Figure 2. Relationship between maize grain yield (kg ha−1) and haricot bean population densities (%) of maize and haricot bean in intercropping. Y =5176.7- 500X, r= - 0.91

Table 2. Relative crowding coefficient (K), Aggressivity (A) and competitive ratio (CR) for mixture of maize with Haricot bean

Planting Pattern	Mix proportion	Relative crowding coefficient (K)			Aggressivity (A)		Competitive Ratio (CR)	
		Maize	H.B	Total	Maize	H.B	(CR) M	(CR) H.B
Sole maize	**100**	-	-	-	-	-	-	-
Sole haricot bean	**100**	-	-	-	-	-	-	-
1M:4H.B	**100:25**	1.24	0.1	0.13	+0.79	-0.79	0.62	1.86
1M:2H.B	**100:50**	6.90	0.49	3.43	+0.68	-0.68	1.07	1.07
1M:3H.B	**100:75**	4.99	1.22	5.88	+0.38	-0.38	1.36	0.84
1M:1H.B	**100:100**	4.91	2.78	13.77	+0.09	-0.09	1.49	0.69
Mean		4.5	1.15	5.8	0.48	-0.48	1.14	1.12

in line with Tolera (2003), reported bean yield reduction of 45% while intercropped with maize. Similarly, Solomon K. (2014) indicated that yield of sole soybean was significantly higher than the intercropped soybean. The yield reduction in the component haricot bean intercropped with maize might have been associated with the aggressive competition of maize for growth resources since maize is taller than haricot bean in physique. The highest intercropped Haricot bean grain yield was obtained from maize intercropped with 100% Haricot bean population density, this result indicated that while the population densities of haricot bean increased the Biological yield also increased. This result in line with Solomon K. (2014) reported progressive increment in seed yield of soybean recorded as planting density increased. The significance of the above results could be explained using the competition indices below.

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. If LER value is equal to one, it means that there is no yield advantage but when LER is more than one, then there is yield advantage.

In this particular study, partial LER for maize was higher than 0.50 whereas Partial land equivalent ratio of haricot bean increased from 0.4 to 0.57 by means of increasing haricot bean population density from 62,500 to 250,000 plants per ha^{-1}. Mariga *et.al*., (2001), reported that a higher land equivalent ratio for higher population densities of pigeon pea in maize/ pigeon pea intercropping.

The result on TLER of different intercropping systems indicated that, values were greater than one in all the intercropped treatments and the range of yield advantage over sole cropping of Maize was between 28 and 40 % with the highest in the case of maize intercropped with 100 % Haricot bean population density. This implies that, the association of maize and haricot bean is complementary to each other on growth resource utilization. Muoneke et al. (2007) confirmed that the values above unity in most systems indicated complementarities in resource utilization by the component crops.

Higher LER in intercropping treatments compared to mono-cropping of maize was attributed to better utilization of natural (land, CO2 and light) and added (fertilizer and water) resources. Higher LER in intercropping compared to mono-cropping of rice was also reported by Bhatti et al. (2006).

According to Adetiloye et al. (1983), for a two-crop mixture the minimum expected productivity coefficient is 25%; meaning a yield advantage is obtained if land equivalent coefficient (LEC) value exceeds 0.25. In this regard all maize : haricot bean intercrop combinations in this study had LEC values above 0.25, suggesting yield advantages. Though, all maize haricot bean mixes exhibited LEC values greater than the critical, population densities had a direct association with land equivalent coefficient that mean as haricot bean population densities increased LEC also increased so the highest value of LEC was recorded (0.47) at 100% haricot bean population density (Table 1). Egbe (2005) has similarly reported LEC values greater than the critical in intercropping sorghum with soybean at different spatial arrangements.

Competition functions

Competitive behavior of the component crops across different intercropping systems was determined in terms of relative crowding coefficient, aggressivity and competitive ratio.

Relative crowding coefficient (K) which is a measure of the relative dominance of one species over the other in a mixture (Banik et al., 2006). According to Willey (1979), in an intercropping system, each crop has its own RCC (K). The component crop with higher “K” value is the dominant and that with low “K” value is dominated. To determine if there is a yield advantage in intercropping, the product of the coefficient of both component crops is obtained and that is usually designated as "K". If the product of RCC of the two species is equal, less or greater than one it means that the intercropping system has no advantage, disadvantage and advantage, respectively. Table 2

In all the intercropping systems, the relative crowding coefficient of maize was greater than unit this implies that making intercropping had advantage. Such a result was expected since cereals are more competitive than legumes. Similar results reported by Dhima et al. (2007) in cereal-vetch intercropping. whereas the relative crowding coefficient of haricot bean increase when the number of plant population densities increased, the lowest K value of haricot bean were recorded in mix-proportion of maize with 25 and 50% population densities of haricot bean this shows that combination haricot bean at this population densities had disadvantage. Except, the intercropping system of maize with 25% of Haricot bean population density all the intercropping systems had yield advantage because the product of the component crops were greater than one (Table 2). So according to this result, making intercropping of maize with 25% Haricot bean population density had disadvantage because its K value lower than one (0.13). Across the intercropping systems, the maximum yield advantage was recorded for maize intercropped with 100% Haricot bean population density as indicated by its maximum value of "K" (13.77). Yilmaz *et al.*(2008) had reported similar findings in maize-legume intercropping systems in the East Mediterranean region.

Aggressivity (A) Aggressivity is an important competition function to determine the competitive ability of a crop when grown in association with another crop. An Aggressivity value of zero indicated that component crops are equally competitive. For another situation, both crops will have the same numerical value but the sign of the dominant species will be 'positive' and that of dominated 'negative'. The greater the numerical value, the higher is the difference in competitive abilities and the higher the differences between actual and expected yields. In this particular study, the main crop indicated dominant behavior over the intercrop as showed by their positive (+) sign against negative (-) sign for Haricot bean. Similar findings reported by previous cereal-legume mixture (Ghosh, 2004; Dhima et al., 2007).

Aggressivity values of maize ranging from +0.09 to +0.79, the highest value was obtained in mix-proportion maize with 25% haricot bean population density. According to this study, Aggressivity value of maize decrease from (+0.79) to +0.09 when the population densities of haricot bean increased. Lowest, Aggressivity value of maize obtained in mixture of maize with 100% Haricot bean population density (+0.09) as compared to the other, which indicated that maize crop was the least competitive ability while intercropped with Haricot bean at this population density.

Competitive ratio (CR) Competitive ratio (CR) is another way to know the degree with which one crop competes with the intercrop. According to this result the highest and lowest CR value of maize were obtained while maize intercropped with 100% (1.49) and 25% (0.62) Haricot bean population density, respectively. Among the different Haricot bean population densities intercropped with maize, the haricot bean proved to be better competitive when grown in 25% population density. In general, this study revealed that when the population density of Haricot bean increased the competitive ability of the companion crop decreased and the main crop one was increased.

The next index that was used was the actual yield loss(AYL) index, which gave more accurate information about the competition than the other indices between and within the component crops and the behavior of each species in the intercropping system, as it is based on yield per plant (Banik et al., 2000). The AYL is the proportionate yield loss or gain of intercrops in comparison to the respective sole crop, i.e. it takes into account the actual sown proportion of the component crops with its sole stand. The AYL can have positive or negative values indicating an advantage or disadvantage remained in intercrops when the main aim is to compare yield on a per plant basis.

In all intercropping system, actual yield loss of maize had negative values ranging from -0.17 to -0.07 indicating that, yield loss of 17% to 7% compared to sole maize yield thereby disadvantage of intercropping over sole stands. However, the actual yield loss of haricot bean had positive values (0.18) while maize intercropped with 25% Haricot bean population density and the highest TAYL value was obtained from 100M:25H.B intercropped mixture. Thus, there was 18% (AYL haricot bean= + 0.18) increase in yield of haricot bean in the maize-haricot bean intercropping (100M:25HB when compared to their sole crop yields. However, in all other planting patterns and mix proportions, the AYL of haricot bean ranged from -0.26 to -0.00 indicating a yield loss of 26% to 0.1%, compared to sole crop yield.

The IA, which is an indicator of the economic feasibility of intercropping systems, affirmed that the most advantageous mixture was the maize intercropped with 25% haricot bean population density with IA value of +0.64(table 3). The lowest IA value of -2.72 showed that 100M:100H.B lead to highest loss.

The Monetary Advantage Index (MAI) values were positive in all planting patterns and mix-proportions, which shows definite yield and economic advantages compared to the sole cropping systems tested. In particular, MAI was increased while haricot bean population densities increased. The highest MAI (1777.85) was observed with maize-haricot bean

Table 3. Actual yield loss (AYL), Intercropping advantage (IA) and Monetary Advantage Index (MAI) for mixture of maize with Haricot bean

Planting Pattern	Mix proportion	Actual Yield Loss (AYL)			Intercropping Advantage (IA)			MAI
		Maize	H.B	Total	Maize	H.B	Total	
Sole maize	**100**	-	-	-	-	-	-	-
Sole haricot bean	**100**	-	-	-	-	-	-	-
1M:4H.B	**100:25**	-0.13	0.18	0.06	-0.64	1.28	0.64	1172.69
1M:2H.B	**100:50**	-0.07	-0.00	-0.08	-0.36	-0.03	-0.39	1438.98
1M:3H.B	**100:75**	-0.16	-0.18	-0.34	-0.79	-1.23	-2.03	1535.32
1M:1H.B	**100:100**	-0.17	-0.26	-0.44	-0.86	-1.85	-2.72	1777.85
Mean		-0.13	-0.06	-0.198	-0.67	-0.46	-1.12	1481.2

intercropping at the mix proportions of 100:100, which implies the most advantageous economic mixture. These findings are also parallel to those of LER and competitive indices. Ghosh (2004) and Dhima et al. (2007) reported that if LER and K values were higher, there was also economic benefit expressed with MAI values. More net income was obtained compared to sole cropping when bush beans intercropped with sweet maize (Santalla et al., 2001).

CONCLUSIONS

The present study concludes that intercropping of maize with different population densities of haricot bean may affect grain yield, competition between the two species (maize and haricot bean), and economics of the planting patterns as compared to solitary cropping of the same species. Regardless of mix proportion, maize intercropped with haricot bean at 100 % population density had the yield advantages of intercropping and optimum exploitation of the environmental resources as opposed to other intercropping systems.

Additionally, the maximum yield advantage was recorded for maize intercropped with 100% Haricot bean population density as indicated by its maximum value of “K” (13.77) and as confirmed by the economic and land use efficiency values. Furthermore, competitive ability of maize increased while haricot bean population densities increased but that of haricot bean decreased. Generally, maize was the dominant species in all mixtures and planting patterns. In addition, the ratio of proportion also seemed to significantly affect the efficiency of intercropping. Since intercropping adds extra income and warrants insurance against a risk to the farmers, intercropping of maize component was found to be advantageous than single cropping of maize as there is a scarcity of land and a need to diversify production. Therefore, the inclusion of maize with100% a haricot bean intercropping scheme raised yield advantage of intercropping over the single crop per year as revealed by the highest total LER, Relative crowding coefficient and monetary advantage.

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