Effect of Intercropping Sorghum and lowland Pulses on the Sorghum based cropping system in the Moisture Deficit Areas of Belessa, Central Gondar Ethiopia

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Abstract

Intercropping is extremely important in areas where environmental risks are common. During the main cropping season of 2017 and 2018, an intercrop experiment involving sorghum and lowland pulses was conducted in East and West Belessa, Central Gondar zone, Ethiopia. It sought to identify the most appropriate and compatible crop for a sorghum-based intercrop system in order to maximize system productivity, as well as to determine the optimal sorghum, mung bean, and haricot bean intercropping row ratio for the system's economic return. The intercropping experiment was designed in additional series, with sorghum being the main crop and legumes as additional crops. It was set up in a randomized complete block design with three replications. The treatments included a pure stand of sorghum, mung bean, and haricot bean, as well as three planting patterns (1:1, 1:2, and 2:1 ratios) in which sorghum intercropped with each of the two legumes, for a total of nine treatments. Melkam, Rassa, and Nasser were the improved sorghum, mung bean, and haricot bean varieties used in the experiment. The findings revealed that almost all agronomic parameters of sorghum were not significantly affected by intercropping patterns, whereas grain yield and number of pods per plant of both pulses were significantly affected by various intercropping patterns. The maximum land equivalent ratio (1.7, 1.48, and 1.39) was achieved with treatments 1:2 sorghum-haricot bean, 1:1 sorghum-haricot bean, and 1:1 sorghum-mung bean, respectively. The 1:1 sorghum-mung system produced the highest sorghum equivalent yield (3872.8 kg/ha). In terms of monetary gain, treatment 1:1 sorghum-mung bean yielded the highest net benefit (23816ETB ha-1) with a 3.01 marginal rate of return. Thus, due to its high productivity, profitability, and simplicity. 1:1 sorghum-mung bean intercropping patterns were recommended for the study area, as were similar agro-ecology and cropping systems.

Key words= *Belessa, Haricot bean, Intercropping, land equivalent ratio, mung bean and sorghum*

Introduction

Sorghum (Sorghum bicolor L) is the world's fifth most important cereal, after wheat, rice, maize, and barley (Naim et al. 2012). It is used as both a staple food and livestock feed. Sorghum's ability to adapt to adverse environmental conditions has made it a popular crop around the world. Sorghum is a major cereal used in intercropping. It grows in a variety of agro-ecologies, particularly in moisture-stressed areas where other crops struggle to survive and food insecurity is common (FAO and ICRISAT, 1996). The Amhara region produces approximately 209,845.3 tons of sorghum on 97,794 hectares of land (CSA, 2016/17). In East and West Belessa woreda, sorghum is the third most important cereal crop (after tef and chickpea), accounting for approximately 12.2%, or 2073 hectares, of total cultivated area, with the majority grown as a single crop under poor management. The average yield in the area is 1.8 tonnes per hectare (BWADO, 2012).

Mung bean (Vigna radiate L. Wilczek), also known as green gram, is one of the most important pulse crops grown in tropical and subtropical regions worldwide (Khan et al., 2012). Mung bean seeds are primarily used for culinary purposes. Mung bean is a relatively new crop in Ethiopia, and it can be found throughout the country. Farmers in some moisture-stressed areas of North Eastern Amhara have been growing mung beans to supplement their protein needs while also making the best use of scarce rainfall (Asfaw Asrat et al., 2012). It grows in a few areas of West and Central Gondar, and its consumption is not widely spread, but it is currently becoming a cash crop and earning higher income for farmers due to its high market price. According to Onuh et al. (2011), intercropping mung bean with other crops provides benefits such as increased soil fertility through nitrogen fixation, shading of the soil surface, and erosion resistance. Haricot bean (Phaseolus vulgaris L.), also known as common bean, originated in Tropical America (Mexico, Guatemala and Peru). In Ethiopia, it was introduced by the Portuguese in the 16th century (Lemu, 2016). Haricot bean is regarded as the primary cash crop and protein source for farmers in many low- and mid-altitude areas of Ethiopia (Negash, 2007).

The most feasible method for increasing agricultural production in small or marginal farming units is to increase productivity per unit area and time (Chatteriee and Maiti, 1984). This can be accomplished by developing and implementing a sustainable crop production system, particularly under rain-fed conditions.

Intercropping is one of the most common practices used in sustainable agricultural systems, and it plays an important role in increasing productivity and yield stability in order to improve resource utilization and crop growing environmental performance (Alizadeh et al., 2010). It is a cropping system that involves planting two or more crops in the same field. Willey and Osiru (1972) discovered that intercropping increased crop yields by up to 55% when compared to growing crops separately. Benefits of intercropping include better resource utilization, improved soil fertility by legume components of the system, soil preservation by covering bare land between rows, reduction of biotic and abiotic risks through increased diversity, and weed infestation suppression (Ehrmann & Ritz, 2014). Mostly intercropping is more productive than mono cropping (Carruthers et al. 2000).

Intercropping has been a long-standing practice in Ethiopia. The study areas are familiar with intercropping sorghum with various cereals without an appropriate row ratio. It is also distinguished by a short growing season due to the short duration of annual rainfall, which causes terminal moisture deficiency in crop growth. As a result, incorporating early maturing pulse crops into the intercrop system and adapting them to the target area's production system is critical. Thus, the study was done with the following objectives:

- To identify the most appropriate and compatible crop for sorghum-based intercrop system that achieving the maximum system productivity
- To determine the appropriate sorghum, mung bean and haricot bean intercropping row ratio that provide better economic return of the system.

Material and Methods

Description of the study areas

The field experiment was conducted in 2017 and 2018 main cropping season at Central Gondar zone East and West Belessa, the description indicated (Table 1).

Table 1. Site descriptions of the study areas

Location	Altitude (meter)	Total RF (mm)	Temperature (^{O}C)		Latitude	Longitude	Soil type
			Min	Max			
West Belessa	1100-1680	700-823	13	28	13.133 N	37.900 E	Vertisol
East Belessa	900	970.88	13	36.2	1312’35 N	38825E	Vertisol

RF = rain fall, Min=minimum, Max=maximum,

Experimental treatments and design

There were nine treatments which include T1) sole sorghum, T2) sole mung bean, T3)=sole haricot bean; and three planting arrangements of sorghum intercropped with each of the two legumes; namely T4) 1:1 sorghum-mung bean, T5) 1:1sorghum-haricotbean, T6) 1:2 sorghum-mung bean, T7) 1:2sorghum-haricot bean, T8) 2:1 sorghum- mung bean and T9) 2:1 sorghum -haricot bean row ratio. The treatments were laid out in randomized complete block design with three replications. Improved varieties Melkam, Rassa and Nasser were used for sorghum, mung bean and haricot bean, respectively. The intercropping system was designed in additive series sorghum was considered as the main crop without affecting its population while the legumes additional crops.

Seed rate of 10, 40 and 100 kg/ha were used for sorghum; mung bean and haricot bean were, respectively. Each crop seed was sown by drilling. Thinning was conducted 15 days after sowing for all crops in order to keep the appropriate plant density in such away inter and intra row spacing of 75 by 15 cm, 30 by 5 cm and 40 by 10 cm for sorghum, mung bean and haricot bean, respectively. The gross size of a single plot was 3 m length and 4.5 m width (13.5 m^2) for all treatments. In the case of sole sorghum and the intercrops, a net plot size of 3m x 3m was harvested. For the sole planting of mung bean, the net plot size was 3.9 m x 3 m, while the net plot size for the sole haricot bean was 3.6 m x 3 m. A spacing of 1.5m between replication and 1m between plots was kept. The intercropped mung bean and haricot bean were planted two weeks after the planting of sorghum. 100kg/ha of NPS were applied for sole planting of sorghum, mung bean and haricot bean and 50kg/ha of urea was applied for sorghum at tillering stage. The amount of fertilizers (NPS and urea) and seed rate applied to intercropped treatment were the same as sole crops but to in proportion with their population (number of rows per plot).

Data collected

All agronomic data of sorghum: days to maturity, plant height (cm), head length (cm), grain yield (kg/plot), thousand seed weight (gm.) and dry biomass (kg/plot) were recorded. Days to maturity, pod length (cm), number of pods per plant, number of seed per pod, grain yield (kg/plot), dry biomass (kg /plot), Harvest index (ratio of grain yield and biological yield in per cent) and hundred seed weight (gm.) were also a recorded data of pulses.

Evaluation of the intercropping system

The following measures are used to evaluate the advantages or performance of the systems.

Sorghum equivalent yield: To combine the total productivity of the cropping system into a common term or unit for comparison with the sole crop, equivalent yield of sorghum was adopted by transforming the grain yield of intercropped pulses as seed equivalent yields. Legume yields were converted to sorghum equivalent yield using the following formula:

$$SEY = Ys + \{(Yp \times Pp) / Ps\}$$

Where, SEY = sorghum equivalent yield, Ys= yield of sorghum on the intercrop system; Yp= yield of pulses on the intercrop system; Pp = selling price of pulses; Ps= selling price of sorghum (Thayamini et al., 2010). It was computed from combined data over year and location.

Land Equivalent Ratio (LER): To calculate biological efficiency, Willey (1979) visualized that the productivities can be expressed in any units that provides a common base on which to combine and compare quite different crops. This was defined as the land equivalent ratio (LER). It indicates the relative land area required by sole crop to produce yields as realized in intercropping system. Intercrop advantage was calculated by the determination of land equivalent ratio.

$$LER = (Yab/Yaa) + (Yba/Ybb)$$

Where, Yaa and Ybb are yields as sole crops of sorghum and pulses and Yab and Yba are yields as intercrops of sorghum and pulses. Values of LER greater than 1 are considered advantageous.

Relative yield (RY): It is the partial land equivalent ratio of one single crop in the intercropping system and the sum of relative yield of the component crops involved in the system give the total land equivalent ratio.

$$RY = Yab/Yaa$$

Where, Yaa is yields as sole crops of sorghum and Yab is yields as intercrops of sorghum

Economic analysis

The economics of a production system is often the most desired option while aiming to enhance the total productivity per unit area using intercropping and obtain crops of diverse domestic and economic needs. Local market price of sorghum, mung bean and haricot bean grain and NPS fertilizer used in the economic analysis was 9, 18, 7, and 13.5 ETB/kg, respectively. The labor was valued at the local wage of 50 ETB per man day, equivalent to 8 h, for planting, harvesting and threshing of pulses. The economic analysis was carried out as described by CIMMYT (1998) to estimate the benefit- cost ratio. After all the treatment were arranged in increasing order of total variable cost. A dominance analysis was done and the non-dominated treatments were further subjected to marginal rate analysis.

Statistical analysis

All collected data were subjected to Analysis of variance (ANOVA) after testing homogeneity of error variance, using SAS Software Version 9.0 following standard procedures (Gomez and Gomez, 1984) and the treatment mean were compared using least significant difference (LSD) test at 5% probability level. The analysis of variance was done separately for each crop used in the intercropping.

Results and Discussion

Effect of intercropping on sorghum yield and yield components

The combined analysis of variance showed intercropping of sorghum with pulses (haricot bean and mung bean) at different row ratio were not significantly ($P>0.05$) affect days to maturity, plant height, head length, grain yield and dry biomass of Sorghum except thousand seed weight ($p<0.01$) (Ttable 2). This result in line with Dudhade et al. (2009) who reported that non-significant variation of grain yield of pigeon pea intercropped with green gram over their sole pigeon pea. In contrary to the current finding, Alemayehu Assefa et al., (2016); Tilahun Tadesse et al. (2012) reported an increase in grain yield of intercropped maize with legumes compared to sole cropped maize. However, numerically highest grain yield of sorghum was recorded from sole planting of sorghum. Similarly, Raghuwanshi et al., (1993) reported that maximum grain yield of sorghum was obtained from sole crop of sorghum as compared to intercropping with soybean. However, in case of intercropped treatment, 1:1 sorghum-mung bean intercropping pattern showed the highest grain yield (2907kgha-1) and lowest (2576 kgha-1) was scored from 1:2 sorghum-mung bean intercropping pattern.

Days to maturity of sorghum ranged from 117.4 to 118.4 days. This in conformity with Lulie et al., 2016 who reported that a non-significant effect of sorghum-bean intercropping on sorghum days to maturity. Though there was insignificant variation in dry biomass of sorghum, sole planting of sorghum scored the maximum (12183kgha-1) followed by 2:1 sorghum-haricot bean intercropping pattern (11145kgha-1) and treatment 1:2 sorghum-haricot bean pattern scored the least (10143 kgha-1). Numerically the highest harvest index of sorghum (29.4%) and the lowest (27 %) were achieved in 1:1sorghum- haricot bean arrangement and sole sorghum, respectively (Table 2.). It agreed with the finding of Singh and Stoskopt (1971) stated that harvest index positively correlated with grain yield but negatively correlated with vegetative growth. Effect of different intercropping patterns were highly significant (P<0/01). on sorghum 1000-seed weight. It agrees with Bandyopadhyay and De (1986) stated that intercropping sorghum with groundnut or cowpea showed that 1000-seed weight of sorghum was influenced significantly by intercropping treatments. 1:2 sorghum-haricot bean intercropping pattern was scored highest thousand seed weight with a mean of 23.2 gram and the least (20.2) from 1:2 sorghum-mung bean arrangement than all the intercropping patterns (Table 2.).

Table 1. Yield and yield contributing characters of sorghum under varying planting patterns of sorghum–pulses intercropping at East and West Belessa.

TRT	DMA	PH (cm)	HL (cm)	GYLD (kgha^{-1})	DB (kgha^{-1})	HI %	TSW
Sole S	118.4	147.3	24.8	2913.7	12183	27.0	21.8b
1S:1MB	118.2	144.9	23.6	2907.0	11113	28.5	21.3bc
1S:1HB	117.6	146.4	23.4	2816.4	10708	29.4	21.8b
1S:2MB	117.4	147.7	22.8	2576.0	10692	26.0	20.2c
1S:2HB	118.1	151.6	23.6	2611.0	10143	27.6	23.2a
2S:1MB	117.6	146.9	24.2	2661.0	10506	28.8	20.5bc
2S:1HB	118.1	144.1	24.0	2722.6	11145	29.0	21.4bc
CV	1.8	7.8	9.8	22.5	38	23.6	9.5
LSD	1.4^{ns}	7.5^{ns}	1.5^{ns}	407.8^{ns}	2758.2^{ns}	4.4^{ns}	1.4**

Data were combined over years (2017 and 2018) and location (east and west belessa) DMA=days to maturity, PH= plant height, HL=head length, GYLD=grain yield kg/ha DB=dray biomass, HI=harvesting index, TSW= thousand seed weight, ns=non-significance, CV= coefficient of variance and LSD= least significant difference. Moreover, Sole S= sole sorghum, 1S:1MB = 1:1 sorghum-mung bean, 1S:1HB= 1:1 sorghum-haricot bean, 1S:2MB = 1:2 sorghum-mung bean, 1S:2HB= 1:2 sorghum-haricot bean, 2S:1MB = 2:1 sorghum-mung bean, 2S:1HB = 2:1 sorghum-haricot bean (where, HB= haricot bean, MB= mung bean and S= sorghum).

Effects of intercropping on yield and yield components of pulses

The analysis of variance showed that grain yield of both pulses (mung bean and haricot bean) was significantly affected by different intercropping patterns (Table 3.). The maximum grain yield was achieved in sole cropping of mung bean (1250kgha^{-1}) and haricot bean (1340kgha^{-1}) treatment. But in the intercropped mung bean and haricot bean treatment 1:2 sorghum-mung bean and 1:2 sorghum-haricot bean intercropping arrangement showed the highest grain yield (568.3kgha^{-1}) and (1156.9 kgha^{-1}) followed by 1:1 sorghum-mung bean (457.7 kgha^{-1}) and 1:1 sorghum-haricot bean (752 kgha^{-1})intercropping patterns, respectively.

In the present study yield of pulses were significantly reduced, this could be attributed to different plant population per hectare in the intercropped pulses at all intercropping patterns. This result was in agreement with, Alemayehu Assefa *et al*., (2016) reported grain yield for the intercropped legumes were generally lowest relative their sole crop due to plant population. It also agreed with Jeyakumaran and Seran (2007); Andrews (1972) reported that the effect of intercropping on the yield of a particular crop is influenced by the effect of lowering the population of that crop.

Effect of different patterns of intercropping system was not significant on pulses number of grains per pod (Table 3.). However, sole planting of mung bean was scored the highest number of grains per pod than other treatments with a mean of 12. It agrees with Khan *et al*. (2012) revealed that number of grains per pod of mung bean was reduced considerably in intercropping system as compared to sole crop. The analysis of variance showed that the effect of intercropping patterns on mung bean and haricot bean number of pods plant^{-1} was significant at 5% level (Table 3.). The highest pods plant^{-1} (13.6 and 10.9) was scored in sole cropping of mung bean and haricot bean, respectively. A similar result was reported by Khan *et al*. (2004) who observed that number of pods plant^{-1} of mung bean were higher in monoculture as compared to their corresponding intercropped. But in case of intercropped treatments of mung bean 2:1 sorghum-mung bean arrangement showed the highest pod per plant (10.8) followed by 1:2 sorghum-mung bean pattern (10.3). On the other hand, the highest pod per plant of intercropped haricot bean was scored in 2:1 sorghum-haricot bean arrangement (9.5) which is statistically identical with 1:1 sorghum-haricot bean (9.4) and 1:2 sorghum-haricot bean (9.0) intercropping arrangement.

The results of variance analysis showed that the effect of cropping patterns on the weight of 100- seed was not significant at 5% level (Table 3.). It lines with, Banik *et al*., (2006) stated that different ratios of intercropping did not have a significant effect on chickpea hundred seed weight. The variance analysis showed that a non-significant ($p>0.05$) variation among the treatment in plant height and pod length for both intercropped pulses (Table 3.). For mung bean intercropped treatment plant height was ranged from 64.1(2:1 sorghum-mung bean) to 57.6 cm (sole mung bean) and for haricot bean from 72.9 (1:2sorghum- haricot bean) to 67.3cm (2:1sorghum-haricot bean). Similarly, for both intercropped pulses pod length showed a highly uniform performance among the treatment.

The analysis of variance showed that there was a highly significant ($P<0.01$) variation among the treatment for both intercropped pulses (Table 3.). Sole planting of mung bean gained the maximum (3000kgha^{-1}) dry biomass and the least was scored from 2:1 sorghum-mung bean (700 kgha^{-1}) intercropping pattern. It could be primarily due to plant population difference among the treatment. From haricot bean intercropped 1:2 sorghum-haricot bean arrangement scored the highest (2200 kgha^{-1}) dry biomass and 2:1 sorghum-haricot bean scored the least (900 kgha^{-1}). Harvest index of pulses was significantly ($P<0.01$) affected by different intercropping pattern (Table 3). Days to maturity of both mung bean and haricot bean was not significantly ($P>0.05$) influenced by different intercropping patterns (Table 3.).

Table 3. Performance of sorghum pulses intercropping on yield and yield parameters of mung bean and haricot bean under different planting arrangements.

RT	DMA	PH	SPP	PPP	PL	HSW	GYLD $kgha^{-1}$	DB $kgha^{-1}$
Sole MB	77.3	57.6	12.9	13.6a	10.5	5	1250a	3000
Sole MH	72.9	72	6.7	10.9	9.6	18	1340a	2000a
1S:1MB	76	58.4	12.5	10b	10	5	457.7c	1000c
1S:1HB	72.9	67.3	6.9	9.4	9.4	18	752c	1200b
1S:2MB	76	59.9	12.4	10.3b	10.1	18.8	568.3b	1900b
1S:2HB	72.6	72.9	6.6	9	9.2	19	1156.9b	2200a
2S:1MB	76	61.4	12.2	10.8b	10	5.2	226.3d	700d
2S:1HB	73.6	71.5	6.9	9.5	9.5	18.8	413.7d	900c
CV for MB	1.2	13.8	6.8	20.7	8	10.3	18	27.5
CV for HB	1.3	17	7.1	17.4	10.8	0.7	29.7	22.7
LSD for MB	ns	ns	ns	1.6**	ns	ns	75.8**	**
LSD for HB	ns	ns	ns	ns	ns	ns	181.7**	0.24**

Data were combined over years (2017 and 2018) and location (East and West Belessa)
DMA=Days to maturity, PH= plant height, SPP=seed per pod, PPP=pod per plant, PL= pod length HSW= hundred seed weight, GYLD=grain yield kg/ha, DB=dray biomass, ns=non-significance, CV= coefficient of variance, LSD= least significant difference. Moreover, MB= mung bean and HB= haricot bean, Sole MB= sole mung bean, Sole HB= sole haricot bean, 1S:1MB = 1:1 sorghum-mung bean, 1S:1MH = 1:1 sorghum-haricot bean, 1S:2MB = 1:2 sorghum-mung bean, 1S:2HB = 1:2 sorghum-haricot bean, 2S:1MB= 2:1sorghum-mungbean, 2S:1HB= 2:1 sorghum-haricot bean row ratio.

Total intercropping productivity and performance

Total land productivity is a basic consideration in evaluating intercropping system. For this purpose, relative yields of sorghum and pulses, sorghum equivalent yield, land equivalent ratio and economic profitability could be the better indicators of the different row management of crops.

Relative yield of sorghum at different intercropping patterns were not significantly different from one. It was ranged from 0.99-0.88(Table 4.). This could be due to statistically non-significant grain yield difference of sorghum among the treatment. Relative yield of pulses (mung bean and haricot bean) showed a highly significant variation ($p<0.01$) among the treatment. This might be due to the presence of statistically significant grain yield variation among the treatment (Table 3.). It was in line with Tohura *et al*. (2014) who assured that, relative yield of mung bean in intercropping situation were lower than that of sole mung bean. It was ranged 0.18 (2:1sorghum-mungbean) to 0.8 (1:2 Sorghum-haricot bean).

Total LER were significantly (P<0.01) influenced by intercropping arrangements (Table 4). It is the sum of relative yield of two component crop in the culture. All intercropping pattern gave land equivalent ratio greater than a unit, which mean that growing sorghum with pulses (haricot bean and mung bean) in combination at different row arrangements revealed advantage than pure stand. Maximum LER was obtained from 1:2 sorghum-haricot bean system (1.7) followed by 1.48 and 1.39 from 1:1sorghum-haricot bean and 1:1sorghum-mungbean intercropping patterns, respectively. It means that, by intercropping sorghum with pulses (haricot bean or mung bean) the land use efficiency was increased by 70%, 48%and 39%respectively. in other word, these planting system could produce 2611, 2816 and 2907 kg of sorghum and 1156.9 kg haricot bean, 752 kg of haricot bean and 457 kg of mung bean from one hectares of land instead of growing them separately in 1.7, 1.48 and 1.39 hectares of land to obtain the same total yield, respectively.

Equivalent yield is another way to evaluating total productivity of intercropping system in terms of sorghum equivalent yield. The variance analysis showed a significant (P<0.01) variation among the intercropping patterns in sorghum equivalent yield. The highest SEY was recorded from 1:1 sorghum-mung bean intercropping patterns (3872.8 kgha-1) and 2:1 sorghum-haricot bean arrangement (3065.3) scored the least; it could be due to higher market price of mung bean than haricot bean. This result assured that using1:1 sorghum-mung bean intercropping patterns could produce 3872.8 kg of sorghum from one hectare of land instead of planting it in pure stand to gain 2913.7kg sorghum from the same hectare of land. 1:1 sorghum-mung bean intercropping pattern gained the maximum (33%) yield advantage than the other cropping patterns. The present result also showed that all intercropping arrangement scored a yield advantage over sole sorghum plantation. This result was in conformity with Alemayehu Assefa *et al*., (2016) who reported that intercrop system was significantly productive relative to sole crop system.

Table 4. Evaluation of the performance intercropping system at different planting arrangement

Treatment	Sorghum grain yield kg/ha	Sorghum RY	Pulses grain yield kg/ha	Pulses RY	SEY	LER	Yield Adv.%
Sole S	2913.7	1	-------	------	2913.7	1	-----
Sole MB	------	-----	1250	1	------	1	-----
Sole HB	------	-----	1340	1	------	1	-----
1S:1MB	2907	0.99	457.7	0.38cd	3872.8	1.39	33
1S:1HB	2816.4	0.96	752	0.5b	3401.3	1.48	17
1S:2MB	2576	0.88	568.3	0.42c	3660.9	1.28	26
1S:2HB	2611	0.89	1156.9	0.8a	3510.8	1.7	20
2S:1MB	2661	0.91	226.3	0.18e	3147.9	1.1	8
2S:1HB	2722.6	0.95	413.7	0.32d	3065.3	1.28	5

** Data were combined over years (2017 and 2018) and over location (East and West Belessa). Numbers followed by different letters on the same column indicated significant difference at the 5% probability level using SAS Least square mean test. Note: RY relative yield, SEY =sorghum equivalent yield, LER = land equivalent ratio,.Sole MB= sole mung bean, Sole HB= sole haricot bean, 1S:1MB = 1:1 sorghum-mung bean, 1S:1MH = 1:1 sorghum-haricot bean, 1S:2MB = 1:2 sorghum-mung bean, 1S:2HB = 1:2 sorghum-haricot bean, 2S:1MB= 2:1sorghum-mungbean, 2S:1HB= 2:1 sorghum-haricot bean row ratio.*

Economical profitability

Total gross benefit was the highest in 1:1 sorghum-mung bean system (ETB. 30961.00/ha) followed by 1:2 sorghum-mung bean system (ETB.30072.00/ha) from (Table 4). The least total gross benefit was scored from sole sorghum ((ETB. 23601/ha) followed by 2:1 sorghum-haricot bean system (ETB. 24659.00/ha). All mung bean intercropped treatment were scored the higher gross benefit than haricot bean intercropped, this is due to its high market price. The highest total cost of cultivation (ETB. 14551.00) was found in 1:2 sorghum-haricot bean followed by 1:2 sorghum-mung bean system (ETB. 14321.00), due to its labor intensive and complex planting system, where the lowest was in 2:1 sorghum-haricot bean system (ETB. 4637/ha). The highest net benefit was recorded from 1:1sorghum-mungbean system (ETB. 23816.00/ha) followed by 2:1 sorghum-mung bean system (ETB. 20549.00/ha) the lowest net return was ETB. 13887.00/ha, obtained from 1:2 sorghum-haricot bean planting (Table 4.). This result was in line with Carruters *et al*., (2000) who stated that intercropping gave higher economic return than monoculture in case of intercropping corn with soybean, lupin and forages. The highest MRR was obtained from 1:1

sorghum-mung bean system (3.01); it means that for every additional 1 ETB there will be a positive return of 3.01 ETB (Table 4.).

Table 5. Economic analysis of sorghum–pulses intercropping under varied pulses row

Treatment	Adjusted Grain yield		Gross Benefit ETB/ha Sorghum	Pulses	Total	Total Variable Cost ETB/ha	Net Benefit ETB/ha	Dominance analysis	MRR
Sole S	2622		23601		23601	0	23601		
1S:1MB	2616	412	23547	7415	30961	7145	23816		3.01
1S:1HB	2535	677	22813	4738	27550	7176	20374	D	
1S:2MB	2318	511	20866	9206	30072	14321	15751	D	
1S:2HB	2350	1041	21149	7288	28438	14551	13887	D	
2S:1MB	2395	204	21554	3666	25220	4671	20549	D	
2S:1HB	2450	372	22053	2606	24659	4637	20022	D	

Price of mung bean seeds = 18 birr/kg, price of haricot bean 7 birr/kg, NPS Fertilizer 13.5 birr/kg and ETB= Ethiopian birr. 1S:1MB = 1:1 sorghum-mung bean, 1S:1MH = 1:1 sorghum-haricot bean, 1S:2MB = 1:2 sorghum-mung bean, 1S:2HB = 1:2 sorghum-haricot bean, 2S:1MB= 2:1sorghum-mungbean, 2S:1HB= 2:1 sorghum-haricot bean row ratio and MRR= marginal rate of return

Conclusion and Recommendation

Land Equivalent Ratio was greater than one for all the intercrop treatments, indicating that it is advantageous to grow sorghum and pulses in association than in pure stands. Economic analysis revealed that the effective monetary advantage was obtained from 1:1 sorghum mung bean intercropping system. From the result of this study, farmers in the study area are recommended to use 1:1 sorghum-mung bean intercropping system. 1:1 sorghum-haricot bean intercropping system is secondly recommended for the production of sorghum haricot bean in the moisture deficit area of Central Gondar at East and West Belessa and similar agro-ecology.

Reference

Alemayehu Assefa, Tamado Tana, Yigzaw Dessalegn, Kindie Tesfaye., & Wortmann, C. S. (2016). Maize-common bean/lupine intercrop productivity and profitability in maize-based cropping system of Northwestern Ethiopia. *Ethiopian Journal of Science and Technology*, *9*(2), 69-85.

Alizadeh-Shabdiz, F., & Morgan, E. J. (2010). U.S. Patent No. 7,856,234. Washington, DC: U.S. Patent and Trademark Office.

Andrews, J. T., & Miller, G. H. (1972). The Quarternary History of Northern Cumberland Peninsula, East Baffin Island, NWT Part X: Radiocarbon Date List. Arctic and Alpine Research, 4(3), 261-277.

Asfaw Asrat, Fekadu Gurum, Fitsum Alemayehu & Yiheyis Rezene. (2012). Analysis of multi-environment grain yield trials in mung bean vigna radiate (L.) Wilczek based on GGE bipot in Southern Ethiopia.

Bandyopadhyay, S. K., & De, R. (1986). Plant growth and seed yield of sorghum when intercropped with legumes. The Journal of Agricultural Science, 107(3), 621-627.

Banik, P., Midya, A., Sarkar, B. K., & Ghose, S. S. (2006). Wheat and chickpea intercroppingsystems in an additive series experiment: advantages and weed smothering. *European Journal of Agronomy*, *24*(4), 325-332.

BWADO (Belessa woreda agricultural development office) 2012. Annual crops final yield report.

Carruters, K., Prithiviraj, B.,Fe,Q., Clouterier, D.,Martin, R.C. and Smith,D.L.,2000.Intercropping corn with soybean, lupin and forages. European jouranal of agronomy, 103-115.

CIMMYT (international Maize and Wheat Improvement Center). (1988). From Agronomic from agronomic data to farmer recommendation: an economic training manual (No. 27).

Dudhade, D. D., Deshmukh, G. P., Harer, P. N., & Patil, J. V. (2009). Studies on intercropping of pulse crops with pigeon pea under rain fed condition. Legume Research, 32(3), 215-217.

Ehrmann, J., & Ritz, K. (2014). Plant: soil interactions in temperate multi-cropping production systems. *Plant and Soil*, *376*(1-2), 1-29.

Ethiopian Central Statistical Agency. (2016/17). Ethiopian Demographic and Health Survey.

Gomez, K. A., Gomez, K. A., & Gomez, A. A. (1984). Statistical procedures for agricultural research.

Jeyakumaran, J., & Seran, T. H. (2007). Studies on intercropping capsicum (Capsicum annum L.) with bushitao (Vigna unguiculata L.). *Proceedings of the 6th Annual Research Session*, *Oct*, 18-19.

Khan, M. A., Naveed, K., Ali, K., Bashir, A., & Samin, J. (2012). Impact of mungbean-maize intercropping on growth and yield of mungbean. *Pakistan Journal of Weed Science Research*, *18*(2).

Khan, M. B., & Khaliq, A. (2004). Study of mungbean intercropping in cotton planted with different techniques. *J. Res. Sci*, *15*(1), 23-31.

Lemu, Ephrem Terefe. (2016) "Review of Haricot Bean Value chain in Ethiopia." *International Journal of African and Asian Studies* 24: 65-72.

Lulie, B., Worku,W. and Beyene,S.,2016. Determination of Haricot bean planting density and spatial arrangement for staggered intercropping with Maize at Wondo Genet, Southern Ethiopia, Acad. Res.J.Agric.Sci.Res, 4(6), 297-320.

Negash Rahmeto. (2007). Determinants of adoption of improved haricot bean production package in Alaba special woreda, southern Ethiopia (Doctoral dissertation, Haramaya University).

Onuh, M. O., Ohazurike, N. C., & Ijezie, A. (2011). Effects of mungbean/melon/maize intercrop on the growth and yield of mungbean (Vigna radiata (L.) Wilczek) cultivated in Owerri Rainforest Area. World J. Agric. Sci, 7(2), 161-165.

Putnam, R. D., & Bayne, N. (1984). Hanging together: The seven-power summits. Harvard University Press.

Raghuwanshi, R. K. S., Umat, R., Gupta, A. K., & Gurjar, N. S. (1993). Performance of sorghum (sorghum-bicolor) plus soybean (glycine-max) intercropping system under varying fertility regimes in malwa region. Indian Journal of Agronomy, 38(1), 107-111.

Singh, D. P., & Singh, B. B. (2011). Breeding for tolerance to abiotic stresses in mungbean. *Journal of food legumes, 24*(2), 83-90.

Singh, I. D., & Stoskopf, N. C. (1971). Harvest Index in Cereals 1. Agronomy Journal, 63(2), 224-226.

Teame, G., Gebregergs, G., Gebremedhin, Z., & Gramy, D. (2019). Determining Critical Weeding Period in Mungbean (Vigna radiata (L.) Wilczek) Under Rain Fed Condition in Western Tigray, Ethiopia. Journal of Agriculture and Ecology Research International, 1-6.

Tilahun Tadesse, Minale Liben and Alemayehu Assefa. (2012). Role of maize (Zea mays L.)-fababean (Vicia faba L.) intercropping planting pattern on productivity and nitrogen use efficiency of maize in Northwestern Ethiopia highlands. International Research Journal of Agricultural Science and Soil Science 2(3): 102-112.

Willey, R. W., & Osiru, D. S. O. (1972). Studies on mixtures of maize and beans (Phaseolus vulgaris) with particular reference to plant population. The Journal of Agricultural Science, 79(3), 517-529.

Willey, S. H., & Bartlett, J. G. (1979). Cultures for Clostridium difficile in stools containing a cytotoxin neutralized by Clostridium sordellii antitoxin. Journal of clinical microbiology, 10(6), 880-884.