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Evaluation of Sorghum-Pulse Intercropping System in Mehoni District Northern Ethiopia

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ABSTRACT

Limited farmland size owned by smallholding farmer is one of the challenges to increase crop production and productivity at the study area in particular and in the country at large. Accordingly, famers have a long standing traditional knowledge of growing multiple crop types in different cropping patterns. Intercropping is one of the crop combination systems practiced by resource poor farmers to increase crop production per unit area of land per year and reduce the risks to food and cash sources. The study was conducted to determine Evaluation of Sorghum-Pulse Intercrops for Yield of Component Crops in Mehoni District, Northern Ethiopia. The experiment was conducted during 2010 and 2011 cropping seasons. The treatments were included four legume crops (Dekoko, mung bean, common bean and cowpea) and one variety of sorghum and also sole crops of each crop and a total of nine treatments. The experiment was conducted in randomized complete block design with three replication. Data on growth, yield and yield components of the two crops were recorded and statistically analyzed. The analysis of variance showed that the growth parameters of sorghum plant height was significant effect (<0.05). The result showed that the maximum plant height (181.7 cm) was recorded from sorghum intercrop with common bean. More over the yield components of sorghum was highly significant difference ($\leq$ 0.01) and maximum result of most sorghum yield components obtained from sorghum intercrop with legume than sole cropping. However the maximum grain yield (4276 kgha^{-1}) of sorghum was recorded from sorghum intercrop with common bean. And also the maximum land equivalent ratio (2.86) was recorded from it. It showed that more efficient systems from a land use point of view than sole crop. Generally intercropping system was more efficient than sole cropping system for the study area and especially in limited farmland size to increase crop production.

Keywords: Sorghum, Legume, Intercropping, LER and yield

INTRODUCTION

The cropping system is defined as the combination of crops grown on a given area and time (Reddy, Floyd and Willey, 1980). Intercropping can be described as, the growing two or more crops simultaneously on a single field for all or part of their growth cycle in a season (Machado, 2009). Intercropping of cereal-legumes culture is widely practiced by small farmers in tropical and sub-tropical regions of the world (Finlay, 1974). The legume-based intercropping aims to produce higher yield from a unit area by making optimal use of all available resources that could not be utilized by a single crop (Ram and Meena 2014). It is important to ensure that component crops do not compete with each other for space, solar radiation, and nutrients (Lithourgidis *et al*. 2011). In an ideal intercropping system, most of the available natural resources are efficiently utilized to enhance productivity from a unit area of land in unit time and minimize the risk of crop failure (Seran and Brintha 2010). Biological efficiency of intercropping is generally higher as compared to sole cropping as it (intercropping) explored the relatively larger amount of soil mass than that of sole cropping (Gao *et al*. 2010). This advanced agro-technique has been practiced since time immemorial and greatly contributed to achieve the goal of sustainable agriculture (Dwivedi *et al*. 2015). Intercropping of suitable component crops has several socioeconomic (Ghosh 2004), biological (Bedoussac *et al*. 2015), and ecological (Brooker *et al*. 2015) advantages over mono-cropping. Intercropping also enhances ecosystem biodiversity (Tscharntke *et al*. 2005) as the component crops provide suitable habitat for numbers of insects and soil organisms which otherwise not present in a monocrop situation (Cai *et al*. 2010). Natural enemies like spiders, parasitic wasps, etc. help to control outbreaks of crop pests by controlling their population (Veres *et al*. 2013). As the legumes are known for BNF, they should be included in arable cropping systems as intercrops or sequential crops (Dedoussac *et al*. 2015). Legumes help in improving the soil fertility *via* BNF (Biological Nitrogen Fixation) and reduce the competition for available N in soil due to the more competitive character of the cereal (Layek *et al*. 2014a) and thus contribute to the complementary and efficient use of available N (Dedoussac and Justes 2010). Therefore, it is necessary to adopt improved and sustainable technologies in order to guarantee improvements in food productivity and thereby food security (Landers, 2007; Gruhn, Goletti, and Yudelman, 2000). Such technologies include the use of integrated soil fertility management practices (ISFM) which have intercropping cereals with legumes as one of its main components (Mucheru-Muna *et al*., 2010). This practice is an attractive strategy to smallholder farmers for increasing productivity and land labor utilization per unit of area of available land though intensification of land use (Seran and Brintha, 2010). Furthermore, intercropping cereals with legumes have huge capacity to replenish soil mineral nitrogen through its ability to biologically fix atmospheric nitrogen (Giller, 2001). For the success of intercropping system several aspects need to be taken into consideration before and during the cultivation process (Seran and Brintha, 2010). Such considerations include maturity of crop, compatible crops, time of planting and plant density. The work of Kindie *et al*. (2015) showed highest sorghum yield when sorghum intercropped with soybean than cowpea. Moreover, report of Francis (1989) revealed that the potential of cereal-legume intercropping system to provide N depends on density of crops, light interception, crop species and nutrients. Generally, variation in local climate, soil type and a range of socio-economic and biological factor are the main determinants of the physical ability of crops to grow and cropping system to exist. This is to justify that cropping system varies from location to location (Seran and Brintha, 2010). Thus, the compatibleness of legumes with sorghum has not been widely investigated in Tigray region, especially in South Tigray. It is, therefore, necessary to conduct a research on sorghum-legumes intercropping to justify the following research objectives: to evaluate the effect of legume intercrops on yield and yield related traits of sorghum and to identify best fit legume crop that maximizes the productivity of the intercrop system [1-6].

MATERIALS AND METHODS

Description of the study area

The experiment was conducted at Mehoni Agricultural Research Center (Fachagama) located in Northern Ethiopia, Tigray regional state, Southern zone under Raya Valley in irrigation condition. The geographical location of the site is at 12º 41' N latitude and 39º 42' E longitudes and at an altitude of 1578 metere above sea level (m.a.s.l) and about 678 km north from Addis Ababa and 120 km south of Tigray regional capital, Mekele. The area has minimum and maximum average annual temperatures of 13.19ºC and 23.95ºC respectively. The average annual rainfall is 539 mm (MhARC, 2017). Traditional subsistent mixed farming system, where the livelihood of the rural farming communities depend both on livestock and crop farming, is the common practice in the area. Crop production is mainly dependent on rainfall, but due to shortage and uneven distribution of rainfall, there is an increasing trend of using supplementary and full irrigation practices as the area has high ground water potential. In the study zone, sorghum is the major crop followed by maize and tef under rain fed condition and vegetable crops under irrigation (Moges, 2015) [7-15].

Experimental materials

The sorghum, dekoko, mung bean, common bean and cow pea used as intercropped materials. Meko-1 sorghum verity is one of the short growing crop and important to that area. The verity was released by Melikassa Agricultural Research Center in north Shewa, Kobbo in 1997. The Varity is early drought resistant, white seed with injera making quality and relatively tall with higher biomass production. This variety fits well for dry semi-arid areas with short growing season. Urea (46% N) and NPS with 46% P_2O_5 were used as source of nitrogen and phosphorus respectively (MARC, 1997) [16].

Treatments and experimental design

The experiment consists of nine treatments (Sole Sorghum, Sole Dekoko, Sole Mung bean, Sole Common bean, Sole cowpea, Sorghum+Dekoko 1:1, Sorghum+Mung bean 1:1, Sorghum+Common bean 1:1 and Sorghum+cow pea 1:1 ratio. Consequently, the experiment was laid out in randomized complete block design (RCBD) and it was replicated three times (Table 1) [17].

Table 1: Treatments used in the experimentation.

No	Intercropping system
1	Sole Sorghum (Meko)
2	Sole Dekoko (Raya-2)
3	Sole Mung bean (N-26)
4	Sole Common bean (Awash melka)
5	Sole Cowpea (Bekur)
6	Sorghum+Dekoko one to one ratio
7	Sorghum+Mung bean one to one ratio
8	Sorghum+Common bean one to one ratio
9	Sorghum+Cowpea one to one ratio

The gross size of experimental plot was 3.75 m × 3.6 m (13.5 m^2) accommodating five rows of sorghum planted at a spacing of 75 cm between rows and 20 cm between plants. The net sampling plot size was 2.25 m × 3.2 m (7.2 m^2) in all the cases, in which the two outer most rows and one plant at both ends of the row considered as borders leaving three middle rows for sorghum with the length of 3.2 m for data collection and measurement [18].

Experimental procedure and field management

Land preparation was done at the beginning of June with tractor, harrowed and leveled before planting. The seeds were planted at row spacing of 75 cm and plant spacing of 20 cm recommended for sorghum and done by hand in the rows as uniformly as possible and covered with soil manually at rate of two seeds per hill then, after emergence it was thinned to one seedling per hill [19].

Sorghum was planted on half of July, 2017. Nitrogen fertilizer in the form of urea (46% N) was applied as per treatment 5 cm away from the sorghum. The in-situ soil moisture conservation practice (tied ridging) was made to harvest water. The full dose of P (46 kg P_2O_5 ha^{-1}) was applied uniformly in band application in the form of Triple Super Phosphate (TSP) at planting time of sorghum for all experimental units. All other necessary agronomic management practices like weeding and crop protection measures were carried out uniformly are recommended for sorghum. Supplementary irrigation was used when there was shortage of rainfall during the execution of the experiment. When rain was stop at critical time sorghum was irrigate three times in one week interval up to maturity. The supplementary irrigation was made using ground water resource through furrows [20-23].

Data collection and measurement

Soil sampling and analysis: Soil samples at a depth of 0-30 cm were taken from five random spots diagonally across the experimental field using auger before planting. The collected soil samples were composited to one sample. The bulked soil samples were air dried in shade house to reduce contamination, thoroughly mixed and ground to pass 2 mm sieve size before laboratory analysis. Then the samples were properly labeled, packed and transported to Mekele soil laboratory. After that, soil organic carbon, total N, soil pH, available P, Cation Exchangeable Capacity (CEC), Electrical Conductivity (EC) and texture were analyzed at Mekele Soil Laboratory Research Center. The soil pH was measured in the supernatant suspension of a 1: 2.5 soil to water ratio using a standard glass electrode pH meter (Rhoades, 1982). The Walkley and Black (1934) method was used to determine the organic carbon (%). Total N was determined using Kjeldhal method as described by Bremner and Mulvaney (1982). Available P (mg kg^{-1}) was determined by employing the Olsen *et al*. (1954) method using ascorbic acid as the reducing agent. The Cation Exchange Capacity (CEC) in cmol (+) kg^{-1} was measured using 1M-neutral ammonium acetate method (Jackson, 1973). Electrical Conductivity (EC) was determined in the soil to water suspension of 1:5 (Jackson, 1973). The soil particle size distribution was determined using the Bouyoucos hydrometer method (Bouyoucos, 1962). All necessary data were collected from the net plot area where the two outer most rows were considered as border effects. The data collected include.

Sorghum phenology, growth and yield components

Days to 50% flowering of sorghum: the time from date of planting to 50% of the plants in a plot reached half-bloom stage.

Days to 90% maturity of sorghum: the time from date of planting to 90% of the plants in a plot reached physiological maturity.

Leaf Area Index (LAI): Leaf Area Index (LAI) would be measured from five random plants $plot^{-1}$ in which it would be calculated as the ratio of unit leaf area per unit ground from the net plot according to Watson (1958) where unit leaf area=leaf area x $N^{\underline{o}}$ of leaves /plant. Leaf area per plant would be determined at 50% heading using the method described by Sticker *et al.* (1961) as: Leaf area=leaf length x maximum width of leaf x 0.75. Where, 0.75=correction factor for sorghum.

Panicle length: Five random plants from each net plot area would be also taken to measure panicle length (cm) when the plants reached 90% physiological maturity [24-26].

Plant height (cm): It would be measured from five randomly selected plants of each net plot at 90% physiological maturity from the ground level to the base of the panicle.

Panicle weight (gm): The grain obtained from five sampled panicles of sorghum in the net plot would be bulked and mixed together and then the weight would be taken at 12.5% adjusted moisture level.

Grain Yield (kg ha^{-1}): All plants of net plot area would be harvested to determine grain yield per plot and converted on per hectare bases. It would be determined using sensitive balance. The grain will be dried, threshed and cleaned and adjusted to 12.5% moisture level.

Thousand kernel weight (gm): 1000 kernels would be counted using electrical seed counter from the bulked seed of net plot yield when the seeds are at 12.5% adjusted moisture. After that, thousand kernel weights would be measured using electronic sensitive balance.

Dry biomass yield (kg ha^{-1}): The above ground dry biomass yield would be measured after the plants from the net plot area have been harvested and oven dried at 70 ^{0}C till constant dry weight is attained. It would be then converted to per hectare bases.

Harvest index (%): It would be computed as ratio of grain dry weight to above ground dry biomass yield expressed in percentage.

Legumes phenology, growth and yield components

Data on days to 50% flowering, 50% pod setting and 90% maturity of Common bean would be recorded from the net plot area from date of planting when 50% and 90% plants plot^{-1} reached their respective phenological stages.

Pod length: It will be measured from three randomly selected pods per plant of five plants randomly taken from the net plot area.

Plant height (cm): It would be measured from five randomly selected plants from the ground level to the apex of the main stem at 90% physiological maturity stage of the crop. It would be taken from the net plot.

The number of pods per plant: It would be determined from the five sampled plants of a net plot at physiological maturity.

The number of seeds per pod: It would be determined from 15 pods taken from the five sampled plants of the net plot area where three pods from each would be taken.

Grain yield (kg ha^{-1}): It would be determined from the net harvestable area and adjusted to 10% moisture level. It would be then converted in to hectare basis.

Thousand seeds weight (gm): 1000 seeds would be counted manually at random from each net plot when the seeds are at 10% adjusted moisture and then their weight was measured using electronic sensitive balance.

Dry biomass yield (kg ha^{-1}): This refers to dry weight of above ground biomass. It would be determined using sensitive balance. The above dry biomass was measured after the net plot plants have been harvested and oven dried at 70^{0}C till constant dry weight is attained. It would be converted to hectare basis.

Harvest index (%): It would be computed as ratio of grain yield to above ground dry biomass yield expressed in percentage.

Productivity of the intercropping system

According to Willey (1991), productivity of the intercropping system was determined by calculating the Land Equivalent Ratio (LER) and the economic analysis using Gross Monetary Value (GMV). Land Equivalent Ratio (LER) is used to evaluate the productivity of intercrops compared with mono-crops. It would be calculated according to Mead and Willey (1980):

$$\text{LER} = \frac{\text{Yab}}{\text{Yaa}} + \frac{\text{Yba}}{\text{Ybb}}$$

Where;

Yab=yield per unit area of crop a in the intercrop

Yaa=yield per unit area of crop a in sole crop

Yba=yield per unit area of crop b in the intercrop

Ybb=yield per unit area of crop b in sole crop; a=sorghum; b=Common bean

Data management and analysis

All the data will be properly managed using the EXCEL computer software. The collected agronomic data were subjected to the analysis of variance using the Gen stat computer package edition 18. Significance difference among the treatment means would be computed with LSD at 5% probability level as cited in Gomez and Gomez (1984) [27].

RESULTS AND DISCUSSION

Soil Physico-Chemical Properties of the Experimental Site

Selected physico-chemical properties were analyzed for composite soil (0-30 cm depth) from the samples collected diagonally from five spots in every replication before planting. The results indicated that texture of the soil in the experimental site was dominated by the clay fraction. On the basis of particle size distribution, the soil contained sand (30%), silt (26%) and clay (44%). According to the soil textural class determination triangle, soil of the experimental site was clay. The texture indicates the degree of weathering, nutrient, and water holding capacity of the soil. High clay content might indicate better water and nutrient holding capacity of the soil in the experimental site. The composite soil sample had 2.51% soil organic matter which is rated as low according to EthioSIS (2014) when soils having organic matter value in the range of 2-3% are considered low. The organic matter content of the soil is taken as a basic measure of fertility status; improve water-holding capacity, nutrient release and soil structure. [It is estimated indirectly from the organic carbon determination by OM%=1.72 x % OC (Walkley and Black, 1934]. The low amount of organic matter in the soil might be due to low addition of crop residues to the soil. Therefore, regular application of organic manure such as crop residue, compost etc. is important. The soil reaction (pH) of the experimental site was 7.3 which rated as neutral according to Tekalign (1991) who rated in the range of 6.73 to 7.3 as neutral soils. FAO (2000) reported that the preferable pH ranges for most crops and productive soils to be from 4 to 8. Thus, the pH of the experimental soil was within the range for productive soils. Tekalign (1991) has classified soil total N content of 0.25% as high. According to this classification, the soil samples were found to have poor level of total N (0.12%) (Table 2), indicating that the nutrient is a limiting factor for optimum crop growth. As sorghum is highly exhaustive crop for nitrogen, the production potential of it is highly affected by N deficiency (Onwueme and Sinha, 1991). Therefore, there is a need to apply nitrogen to the crop. The analysis revealed that the available P of the soil was 16.42 mg kg^{-1} (Table 2). Indicative ranges of available phosphorus have been established by Cottenie (1980), as 25 mg kg^{-1} of soil (very high). Thus, the soils of the experimental site were considered as medium in available P content which is satisfactory for optimum sorghum growth and yield [28-30].

Table 2: Selected physico-chemical properties of the experimental soil before planting.

Physical properties	Chemical Properties					
Particle size Distribution (%)	OM %	pH	TN %	Av.P (mg kg^{-1})	CEC cmol (+) kg^{-1}	EC (ms m^{-1})
Sand Silt Clay Textural Class						
30 26 44 Clay	2.51	7.3	0.12	16.42	40	0.34

Cation exchange capacity (CEC) is an important parameter of soil as it indicates the type of clay mineral present in the soil and its capacity to retain nutrients against leaching. According to Hazelton and Murphy (2007), top soils having CEC greater than 40 cmol (+) kg^{-1} are rated as very high and 25-40 cmol (+) kg^{-1} as high. Thus, according to this classification, the soil of the experimental site had high CEC (40 cmol (+) kg^{-1} soil) (Table 2). Cation exchange capacity (CEC) describes the potential fertility of soils and indicates the soil texture, organic matter content and the dominant types of clay minerals present. In general, soils high in CEC contents are considered as agriculturally fertile. The EC of the experimental site was 0.34 (ms m^{-1}) and this is rated as non-saline according to Hazelton and Murphy (2007) who rated soils having the EC values less than 4 ms m^{-1} is considered as non-saline and suitable for cereal production.

Influence of legumes intercropping on sorghum growth and yield attributes

Legumes are known for their soil fertility restoration ability (Dhakal *et al*., 2016). Deep rooting, nitrogen fixation, leaf shedding ability, and mobilization of insoluble soil nutrients are some of the unique characteristics of pulses (Ofori and Stern 1987). By improving chemical, biological, and physical environment in the soil, pulses can check the declining productivity trend of the continuous cereal-cereal system (Savci 2012). The inclusion of pulses in intensive cereal-based system itself is a component of Integrated Plant Nutrient Supply (IPNS) system. Therefore, pulses have become a viable alternative to improve the soil health and conserve the natural resources and agricultural sustainability. Here in a nutshell, the effect of pulses as an intercrop with cereal on soil physicochemical and biological properties is discussed. Based on above explanation the data on plant height, panicle weight, thousand seed weights, grain yield, biomass yield and harvesting index of legumes intercropped with sorghum showed significant differences at ($P \leq 0.05$) among treatments (Table 3).

Table 3: Influence of sorghum-legume intercropping on sorghum growth and yield components.

Treatment	PH (cm)	PL (cm)	TKW (gm)	BY ($kgha^{-1}$)	HI
Sole Sorghum	146.6^{b}	28.04	43.66^{b}	5333^{bc}	0.39^{b}
Sorghum+Dekoko	155.3^{b}	25.72	41.26^{b}	5080^{c}	0.43^{b}
Sorghum+mung bean	147.3^{b}	27.45	42.81^{b}	5715^{b}	0.41^{b}
Sorghum+common bean	181.7^{a}	32.74	57.46^{a}	7396^{a}	0.59^{a}
Sorghum+cow pea	164.5^{ab}	24.78	44.37^{b}	5641^{bc}	0.40^{b}
LSD		NS	5.04	603.66	
CV%		17.7	9.2	8.7	

Where: NS=non-significant, Means with the same letters in the same column are not significantly at P < 0.05, PH=plant height, PL=panicle length, PW=Panicle weight, TSW=thousand seed weight, GY=grain yield, BY=biomass yield and HI=harvesting index and also LSD=least significant difference, CV=coefficient of variance.

Plant height: sorghum plant height increased in all treatments of intercropping with dekoko, mung bean, common bean and cow pea. Significantly the maximum plant height (181.7 cm) was obtained from sorghum inter crop with common bean and the lowest plant height (146.6 cm) was recorded from sole sorghum. The height advantages of intercropping over sole cropping could probably be attributed to increase in the complementary use of growth resources such as N and light in space and time. Similar reported that sorghum intercropped with cowpeas exhibited potentiality and recorded high value of plant height and grain yield per plant Rafay *et al*. (2013). But this result was contradict with Ndiso *et al*. (2017) reported no significant difference between plant height of sole cowpeas crop and intercropped cowpeas.

Panicle length: Sorghum panicle length was non-significant difference (>0.05) among treatment. However the maximum panicle length (32.74 cm) was recorded from sorghum intercrop with common bean and the minimum value (24.78 cm) was obtained from sorghum intercrop with cow pea.

Panicle weight : the intercropping of sorghum with legume gave significantly (P<0.05) higher panicle weight of (119.3 gm) was obtained from sorghum intercrop with common bean and the minimum value 92.8 gm was obtained from sole sorghum.

Thousand seed weight: Sorghum thousand seed weight was significant difference (P<0.05) among treatment. The maximum thousand seed weigh of sorghum (57.46 gm) was recorded from sorghum intercrop with common bean. This result complimentary with Hamd Alla *et al*., (2014) observed that cowpeas intercropped with maize increased height and 100 grain weight and also (Singh et al., 2000) also reported that inclusion of legumes as intercrops increased the dry matter accumulation of the intercropping system and the yield attributes like number of cobs/plant, grains/cob and 1,000 grain weight of maize were also increased by intercropping with legumes.

Grain yield: Intercropping of sorghum-common bean gave significantly higher (P<0.05) grain yield of (4276 kg ha^{-1}). Whereas the lower grains yield (2106 kg ha^{-1}) was recorded from sole sorghum. The yield increment obtained from these treatments over the sole cropping of sorghum. Aliyu and Emechebe, (2006) pointed out that higher grain yield may also be attributed to the effectiveness of cropping system, also increased the nitrogen supply to the crop. As legumes have the capacity to fit in different cropping patterns and fix N from the atmosphere in the soil, they may offer opportunities to increase the productivity of the intercropping system (Jeyabal and Kuppuswamy 2001). This may be due to soil fertility enhancement either through the supply of biologically fixed N or root excretion from the associated legume crop (Ghosh 2004).

Biomass yield: In a similar trend to the grain yield, above ground biomass of sorghum also showed high variation among treatments (Table 3). Intercropping of sorghum with common bean was maximum biomass yield and the lower biomass yield was obtained from sole sorghum. Plots intercropped with treatments produced a significantly (P<0.05) higher aboveground biomass than sole cropping. This could be attributed by lower number of plant leaves and stunted growth of sorghum due to the insufficient amount of nutrient on sole sorghum. Addition of yield by intercropped legume to the overall production would give yield advantages (Willey, 1979). Intercropping was a source of fixing nitrogen, biomass in larger amounts of nitrogen, investment of assimilates to leaves and stems increased and finally increased dry matter yield. Complimentary with Zerihun (2015) reported that application of high level of nitrogen kg ha^{-1} gave the highest biomass yield (Figure 1).

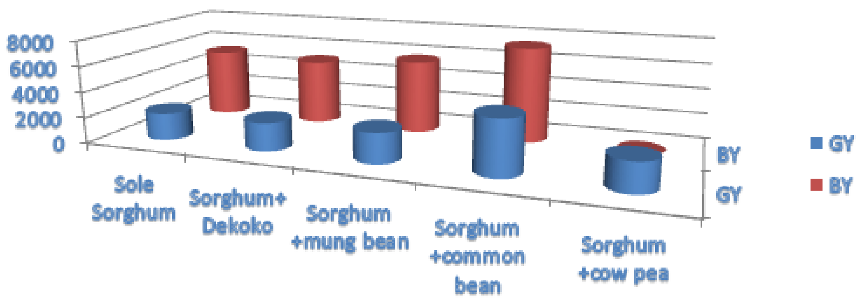

Figure 1: Mean of sorghum grain and biomass yield difference due to intercropping with legume.

Harvest index: The physiological efficiency and ability of a crop for converting the total dry matter into economic yield is known as harvest index. Here, the analysis of variance showed that harvest index was highly significantly ($P \leq 0.05$) influenced by intercropping system (Table 3). The highest harvest index (0.59) was recorded from sorghum intercrop with common bean; in contrast, the lowest harvest index (0.39) was obtained from sole sorghum (Table 3). The highest harvest index intercropping of sorghum with common bean might be that greater improvement in grain yield compared to other intercropped legumes.

Influence of intercropping on growth and yield components of legumes

The data on plant height, pod length, seed per pod, pod per plant, thousand seed weights, grain yield and biomass yield of intercropped legumes showed significant differences at ($P \leq 0.05$) among treatments (Table 2).

In all sole planting legumes (dekoko, mung bean, common bean and cow pea) planted as pure stands recorded greater yield of (1027 kg ha^{-1}, 1085 kg ha^{-1}, 2514 kg ha^{-1} and 1934 kg ha^{-1} respectively) than that produced from intercropped with sorghum (Table 4). The higher yield of sole dekoko, mung bean, common bean and cow pea could be attributed to the least competition in pure stands. In line with these finding Ljoyah M. O (2014) recorded higher yield of soybean form sole cropping than that produced from intercropped soybean due to the shading effect of maize over soybean. Among the different intercropped legumes higher grain yield was recorded by common bean (2514 $kgha^{-1}$). Based on the result common bean intercropping with sorghum is best and important than other relative legumes.

Table 4: Plant height, seed per pod, number of pod per plant, thousand seed weight, grain yield and biomass yield of different legume crops as influenced by intercropping with sorghum.

Treatment	PH (cm)	PL (cm)	SPP	NPPP	TSW (gm)	GY ($kgha^{-1}$)	BY ($kgha^{-1}$)
Sole dekoko	56.77[ab]	10.54	5.63[c]	12.20[bc]	101.7[de]	1027[bc]	3073[cd]
Sole mung bean	33.57[c]	10.56	10.13[b]	10.37[bc]	88.7[e]	1085[b]	1446[d]
Sole common bean	71.07[a]	11.19	5.83[c]	24.60[a]	220.5[ab]	2514[a]	5626[b]
Sole cow pea	70.63[a]	17.56	14.70[a]	11.47[bc]	145.0[cd]	1934[a]	8220[a]
Sorghum + dekoko	70.63[a]	12.02	5.80[c]	9.20[c]	109.7[de]	1012[bc]	1925[d]
Sorghum + mung bean	35.73[bc]	10.36	9.16[b]	7.73[c]	126.1[cde]	723[c]	1396[d]
Sorghum + common bean	63.87[a]	11.86	6.06[c]	18.43[ab]	239.1[a]	2094[a]	5118[bc]
Sorghum + cow pea	72.67[a]	15.73	13.00[a]	10.20[bc]	168.4[bc]	1559[a]	6331[ab]
LSD	21.05	NS	2.08	8.51	54.76	904.32	2492.84
CV%	5.78	4	20.3	12.5	3.1	2.8	11.7

Land equivalent ratios (LER)

One of the most important reasons for intercropping is to ensure that an increased and diverse productivity per unit area is obtained compared to sole cropping (Sullivan, 2003). The benefit of intercropping is most frequently quantified by LER which is defined as the relative land area in pure stands that is required to produce the yields of all products from the mixture (Vandemeer, 1989). Intercropping efficiency was evaluated by using land equivalent ratio:

$$\textbf{LER}=\frac{\text{Intercrop yield of crop A}}{\text{Sole crop yield of crop A}}+\frac{\text{Intercrop yield of crop B}}{\text{Sole crop yield of crop B}}$$

The yield advantages of sorghum could be due to the partial Land Equivalent Ratios (LER) which had significantly shown the advantage of sorghum over pure stand (El Naim et al., 2013). Intercropping sorghum with legumes (dekoko, mung bean, common bean and cow pea) at both seasons resulted in significant greater unit. In all intercropping types of legumes individual LER and the mean (2.03) for sorghum/dekoko, (1.78) for sorghum/mung bean, (1.88) for sorghum/cow pea and for sorghum/common bean (2.86) have maximum LER values. LER greater than one are considered to be more efficient systems from a land use point of view than sole crop or an LER greater than one indicates that less land is needed in the intercrop to equal productivity of the mono crop (Willey, 1979). On the other hand an LER less than 1 indicates that more land is needed in the intercrop to equal the productivity of the mono crop.

The highest LER in sorghum/common bean could be attributed to the highest land coverage of common bean which in turn produce higher yield under sole crop. Similarly Musambasi *et al.* (2001) reported that intercropping maize with different legumes at different locations resulted in greater LER for maize. This indicates that intercropping of sorghum with these legume crops gave advantageous yield than planting them in sole crop. Alemayehu *et al.* (2016) also reported that the highest land equivalent ratio was recorded for maize-common bean intercropped (Table 5).

Table 5: Yield of sorghum, dekoko, mung bean, common bean and cow pea and Land Equivalent Ratio (LER) as influenced by sorghum-legume intercropping.

Intercropping system	Sorghum grain yield (kg ha^{-1})	Dekoko grain yield (kg ha^{-1})	Mung bean grain yield (kg ha^{-1})	Common bean grain yield (kg ha^{-1})	Cow pea grain yield (kg ha^{-1})	LERd	LERmb	LERcp
S+D	2209	1012	-	-	-		-	-
S+Mb	2353	-	723	-	-	-	1.78	-
S+Cb	4276	-	-	2094	-	-	-	-
S+Cp	2258	-	-	-	1559	-	-	1.88
Sole sorghum	2106	-	-	-	-	-	-	-
Sole dekoko	-	1027	-	-	-	-	-	-
Sole mung bean	-	-	1085	-	-	-	-	-
Sole common bean	-	-	-	2514	-	-	-	-
Sole cow pea	-	-	-	-	1934	-	-	-

CONCLUSION

Most researchers believe that the intercropping system is especially beneficial to the smallholder farmers in the low-input/high-risk environment of the tropics. The principal reasons for smallholder farmers to intercrop are flexibility, profit maximization, risk minimization against total crop failure, soil conservation and improvement of soil fertility, weed control and balanced nutrition. Other advantages of intercropping include potential for increased profitability and low fixed costs for land as a result of a second crop in the same field.

Furthermore, intercrop can give higher yield than sole crop yields, greater yield stability, more efficient use of nutrients, better weed control, provision of insurance against total crop failure, improved quality by variety, also cereal as a sole crop requires a larger area to produce the same yield as cereal in an intercropping system. This study revealed advantages of intercropping sorghum with legumes compared to sole cropping. However, lack of participatory approaches and under farmer's conditions, mainly the inclusion of resource-less farmers, could not allow easy adoption by these smallholders. Furthermore, most of the studies that have been done on cereal-grain legume intercropping systems were focused on cereal yields, and were not able to show clearly the amount of nitrogen was fixed by the legume component within the season, probably due to difficult on the measurements procedures.

Based on these results the higher sorghum yield was obtained from intercropping with common bean and also intercropping types of legumes land equivalent ratio (LER) the mean for sorghum/common bean (2.86) have maximum LER values. LER greater than one are considered to be more efficient systems from a land use point of view than sole crop or an LER greater than one indicates that less land is needed in the intercrop to equal productivity of the sole crop (Willey, 1979). Therefore, it is necessary more participatory research that involves smallholder farmers, extension services and other stakeholders on the contribution of the grain legume component to cereal-grain legume intercropping systems, under farmer's conditions. Also, there is need for proper handle of issues of accessibility and affordability of improved seed and appropriate fertilizers, if the gains of cereal-legume intercropping systems in ISFM under smallholder farmers have to be adopted.

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