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Effect of Sorghum-Legume Intercropping Patterns on Selected Soil Chemical Properties and Yield of Sorghum at Midland Areas of West Hararghe Zone of Oromia Regional State, Eastern Ethiopia

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Abstract

The experiment was conducted during 2016 and 2017 cropping season. The study was conducted to evaluate sorghum legume intercropping pattern on selected soil chemical properties and yield of sorghumat Tulo and Chiro district, Western Hararghe Zone of Oromia Region, Eastern Ethiopia. The treatments were included two legume crops and four planting patterns (single row of Sorghum and double row of haricot bean (1S;2H) in sequence, single row of Sorghum and single row of haricot bean (1S:1H) in sequence, double row of Sorghum and single row of haricot bean (2S:1H) in alternate, double row of Sorghum and double row of Haricot bean (2S:2H) in alternate, single row of Sorghum and double row of cowpea (1S:2C) in sequence, single row of Sorghum and single row of cowpea (1S:1C) in sequence, double row of Sorghum and single row of cowpea (2S:1C) in alternate, double row of Sorghum and double row of cowpea (2S:2C) in alternate, Sole sorghum, Sole haricot bean (Awash-1) and sole cowpea (ILRI11114-accession number) with testing crop sorghum (chiro variety). The experiment was conducted in Randomized Complete Block Design with three replications. All necessary agronomic data were collected and analyzed by using Statistical Analysis Software version 9.0. Soil samples were analyzed by standard laboratory procedures. The results revealed that maximum sorghum grain yield (37.28qu/ha) obtained from 1S:2L pattern was higher than other planting patterns. Maximum grain yield of haricot bean and cowpea was recorded from1S; 2H and 2S:2L planting patterns respectively. Selected soil chemical properties were improved under intercropping system over sole sorghum. The highest LER (1.36) and the lowest LER (1.19) was recorded in sorghum/haricot bean and sorghum/ cowpea intercropping system. The highest total LER was recorded from single row of sorghum and double row of haricot bean (1S; 2H) in sequence. Highest net income accrued from planting patterns of1S; 2H in sequence. Therefore, based on the finding of the study, planting patterns of single rows of sorghum and double rows of haricot bean in sequence (1S:2H) could be recommended in mid land areas of Western Hararghe Zone and similar agro ecologies.

Keywords: Intercropping • Legumes • Sorghum • Planting patterns

Introduction

The ever increasing global demands for food and the relationship of enhanced food production with food security, and the need to conserve the natural resources, diversification of planting system is necessary. Sustainable agriculture is a type of agriculture that is more efficient in use of resources, for the benefit of humanity, and is in balance with the environment. Intercropping is the practice done closely by small scale farmers is defined as the growth of two or more crops together, in the same field during the growing season to promote the interaction among component crops. It is a cultivation commonly practiced, especially in the tropics and in the developing countries. Cereals –legumes cropping system is the most used by small scale farmers in Sub Saharan Africa because of their compatibility. Intercropping systems help farmers to exploit the principle of diversity, they are helpful to avoid reliance on a single crop and result in a variety of products of a different nature such as forages, oil and pulses. Another key advantage associated with intercropping is its potential to increase the land productivity per unit area and the efficient utilization of farm resources [1]. Cereals intercropping with legumes result in increased resource capture by component crops and improve soil microbial activity along with better efficiency of resource conversion which triggers higher biomass production. Soil fertility is also improved when legumes are intercropped with cereal crops. Cereal-legumes intercropping systems improve nutrient utilization as different crops have varied root lengths and in this way nutrients are absorbed from different soil horizons. The cropping system also increases the productivity per unit of land area due to the atmospheric nitrogen biological fixation (BNF) that takes place in the root nodules of legumes, increase the primary nutrients (N and P) concentration in roots and shoots of crop plants, enhance micronutrients absorption. Report indicated that in cereal-peanut intercropping systems, there was a 2.5 fold greater concentration of zinc and iron in shoots as compared to their monocropping. Potassium concentration in shoots was also increased, while calcium concentration was decreased in shoots of component crops. However, the advantage of intercropping is obtained when correspondent species are differences in the form and spatio-temporal of natural resources in which different physiological and morphological characteristics will be able to make optimal use of environmental factors when cropped in the vicinity of each other. Thus, there are several different modes of intercropping, ranging from regular arrangements of the component crops to cases where the different component crops are intermingled. Intercropping also uses the practice of sowing a fast-growing crop with a slow-growing crop, so that the first crop is harvested before the second crop starts to mature. In Ethiopia, where sorghum is one of most important staple food crops for most rural community, low soil fertility causes serious yield reductions. Sorghum is third important crop after teff in terms of total area production. Its production accounts about 16.89% of the 87.48% annual cereal production in Ethiopia (CSA, 2018). In Oromia region, where the study area located, about 20.8 million quintals of sorghum grain were produced during 2018 main cropping season on around 7 hundred thousand hectare (CSA, 2018). The average grain yield of sorghum in Oromia region is about 28.30 quintals ha^{-1} well below the industrialized world (CSA, 2018). Thus a whole range of growth-reducing factors including low soil fertility are responsible for this low grain yield. In mid land areas of West Harerghe zone, intensive cultivation,

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increased population pressure, deforestation and mismanagement of the resources have been led to severe soil erosion and high fertility loss. Therefore, it is necessary to adopt sustainable soil nutrient managements such as intercropping cereals with legume crops to improve yield of crops and its contribution on nutrient replenishment as one of its main components which improved intercropping systems are part of ISFM technologies [1,2] in order to guarantee improvements in food productivity and thereby food security. Therefore the study was initiated with the objectives; to evaluate the effect of intercropping pattern on yield of sorghum and on selected soil chemical properties.

Materials and Methods

Description of the study Area

The field experiment was conducted in midland areas of West Hararghe zone, Chiro and Tulo district. Chiro district is capital town of the Zone which is found at about 324 km far to East of Finfine, the capital city of the country. The maximum and minimum temperature is 23°C and 12°C respectively. The rainfall is bimodal and erratic nature in which main rainy season is extended from June to September and short rainy season is stretched x from March to May with the mean annual rainfall is 1350mm. The district is mainly characterized as steep slopes and mountains with rugged topography, which is highly vulnerable to erosion problems. The district bordered with Miesso in the North, Gemechis in the South, Guba-koricha in the West and Tulo in the East. Tulo district is situated in the dega and weyna dega agro-ecological zones with 25% in the highlands and 75% in the midland. Mean daily minimum and maximum air temperature is 19°C and 22°C respectively with mean daily air temperature of 20.5°C (BoARD, 2018). The annual average rainfall of the district ranges from 1050 mm. Tulo district is bordered in the south by Mesela district, in the west by Chiro district, in the north by Doba district, and in the east by the east Hararghe Zone. Sorghum, maize, haricot beans, barley and wheat are major crops produced in the area. Cash crops planted in the district are chat, coffee and sugar cane.

The total rainfall of 2016 and 2017 cropping season of study area were 923 mm and 815 mm respectively according to the data recorded at Hunde Lafto metrological station, which found at nearby of the study area.

Experimental materials

Both legume food and feed was selected to intercrop (Additive intercropping system) with sorghum for the experiments. The improved sorghum variety known as Chiro was used as a test crop. The variety has been released by Melkasa Agricultural Research Center and adaptation was done at Machara Agricultural Research Center. Cowpea and haricot bean improved variety namely ILRI#11114-accession number and Awash-1 variety was used as a test crops respectively. Their adaptation was done by Machara Agricultural Research Center. Cowpea (ILRI#11114-accession number) was introduced by International Livestock Research Institute and haricot bean (Awash -1 variety) has been released by Melkasa Agricultural Research Center.

Treatments and experimental design

Cowpea and haricot bean were intercropped with sorghum in four patterns, i.e. Single row of sorghum and single row of legumes in sequence (1S:1L), Single row of sorghum and double rows of legumes in sequence (1S:2L), Double rows of sorghum and double rows of legumes in alternate (2S:2L), Double rows of sorghum and single row of legumes in alternate (2S:1L). The main crop (sorghum) were sown at an appropriate time with spacing of 75 cm between rows and 25 cm between plants and the legumes was sown in a pattern according to treatments in paired and alternating arrangement. The legume intercrops were planted as per their planting pattern simultaneously with sorghum and at the time of first hand weeding of main crops (sorghum). Sole cowpea and haricot bean were sown by 30x20 cm and 40x10 cm respectively. Thus, there were 8 treatment combinations (two legume crops x three planting patterns). Apart from these treatments, sole sorghum, sole cowpea and haricot bean were used for the study. Thus, there were 11 treatments as below.

- ✓ Sorghum + haricot bean (1S;2H)
- ✓ Sorghum + haricot bean (1S:1H)
- ✓ Sorghum + haricot bean (2S:1H)
- ✓ Sorghum + Haricot bean (2S:2H)
- ✓ Sorghum + cowpea (1S:2C)
- ✓ Sorghum + cowpea (1S:1C)
- ✓ Sorghum + cowpea (2S:1C)
- ✓ Sorghum + cowpea (2S:2C)
- ✓ Sole sorghum
- ✓ Sole haricot bean
- ✓ sole cowpea

The experiment was laid out in a randomized complete block design (RCBD) in a factorial arrangement with three replications. Each plot and block was separated by 1m. The plot size was 3.75 m x 3.0 m = 11.25 m². The sorghum were planted in spacing of 75 cm x 25 cm. Sorghum seed was drilled in the rows and thinned to the recommended spacing at 25 cm between plants. Other agronomic management practices were followed as per the recommendation for the crop. Both cowpea and haricot bean were spaced at 18.75 cm from the sorghum rows with intra-row spacing of 20 cm and 10 cm for cowpea and haricot bean respectively. The inter row spacing between the rows of legume crops was depends on the treatments. For the treatments of single row of sorghum and double rows of legumes in sequence and alternatives (1S:2L) and also Double rows of sorghum and double rows of legumes in both alternate and sequence (2S:2L), the inter row spacing of 37.5 cm was between the rows of legume crops. While, 70cm was between the rows of legumes for the patterns of single row of sorghum and single row of legumes in sequence and alternatives (1S:1L).

Soil Sampling and Analysis

Prior to sowing and treatment application, ten sub samples at a depth of 0-20 cm were collected and composited to make one soil sample. Similarly, post-harvest soil samples were collected from each plot receiving different treatments for selected soil physical and chemical analysis (texture, pH, OC, N, P, K, CEC, EC, C:N). Soil samples collected from the field was air dried, crushed and passed through a 2 mm sieve after a careful removal of plant parts and other unwanted materials except for TN and SOM analysis which was sieved through 0.5mm sieve. Particle size distribution was determined by the Bouyoucos hydrometer method [3]. Soil pH was measured by pH meter in the supernatant suspension of 1:2.5 soils: water ratio [4]. Electrical conductivity was measured from the suspension prepared for pH analysis using electrical conductivity meter. Soil organic carbon content of the soil was determined by potassium dichromate wet oxidation procedure [5]. Soil organic matter was calculated from soil organic carbon by multiplying with a coefficient of 1.724. Total nitrogen content of the soil was determined by wet digestion procedures of the Kjeldahl method [6]. The available phosphorus content of soils was determined by calorimetrically using spectrophotometer after the extraction of soil sample with 0.5M sodium bicarbonate adjusted at pH 8.5 following the Olsen extraction method as described by [7]. Exchangeable potassium (K) was determined by ammonium acetate extraction-flame photometry procedure. The cations exchange capacity of the soil (CEC) was measured after saturating the soil with 1N ammonium acetate (NH_4OAc) and displacing it with 1N NaOAc [8].

Data Collection

Sorghum, Haricot bean and cowpea yield was collected. Prior to planting and after harvest soil sample was analyzed for the parameter such as texture, pH, OC, N, P, K, CEC, EC, and C: N was analyzed.

Competitive Indices

Land equivalent ratio (LER) was calculated which verifies the effectiveness of intercropping for using the resources of the environment compared to sole cropping [9,10] When LER is greater than 1, the intercropping favors the growth and yield of the species. In contrast, when LER is lower than one, the intercropping negatively affects the growth and yield of plants grown in mixtures [10-12]. The LER values were calculated as: LER = (LER cereal + LER legume), where LER cereal = (YCL / YC), and LER legume = YLC / YL, where YC and YL are the yields of cereal and legumes as sole crops, respectively, and YCL and YLC are the yields of cereal and legumes as intercrops, respectively.

Data Analysis

The analysis of variance (ANOVA) was carried out using statistical packages and procedures out lined by [13] appropriate to Randomized Complete Block Deign using SAS Computer Software Version 9.0. Mean separations was carried out using least significant difference (LSD) at 5% probability level.

Results and Discussions

Physico-Chemical Properties of soil

The physico-chemical properties of the experimental soil are shown in Table 1. The textural class is clay with the proportion of 10% sand, 62% clay and 28% silt. Also the soil of the study area had moderate level of total nitrogen, medium level of organic matter, Very high level of available phosphorus, potassium, and CEC. The pH (H_2O) of the soil was 5.86 showing moderately acidic nature of the soil. Thus, the pH of the experimental soil was within the range suitable for productive soils.

Grain Yield of Crops

Grain Yields of Sorghum

Statistical analysis depicted that, sorghum yield was significantly (P<0.05) influenced due to main effect of planting pattern and legume crops during 2016 cropping season. However, there was no significance (P>0.05) difference on sorghum yield due to main effect of legume crops and planting pattern during 2017 cropping season. But, the mean of sorghum yield was significantly (P<0.05) affected due to main effect of planting. Also there was no significant variation due to the interaction effect of planting pattern and legume crops. Relatively, the highest mean values of sorghum grain yield (34.91 qt ha^{-1}) were recorded from sorghum intercropped with haricot bean and the lowest grain yield (33.66 qt ha^{-1}) were recorded with cowpea intercropped, however it did not show significant variation among legume crops. Similar to this finding, [14] report indicated that that lowest grain yield of sorghum was registered when cowpea was intercropped with sorghum. Comparatively, the highest mean values of sorghum yield (36.99 qt ha^{-1}) were registered from the patterns of double rows of sorghum in sequence (1S:2L). This might be due to nutrient uptake of crops in different planting pattern. In consistent with the finding, [14-16] report showed that variation in planting pattern could cause variation in nutrient uptake and the general performance of intercropping system. Sole sorghum produced significantly more grain yield (36.61 qt ha^{-1}) than sorghum associated with haricot bean and cowpea. This suggests that association of legume have detrimental effects on plant growth due to competition for light, moisture and nutrients which ultimately reduced the grain yield of associated sorghum. [17] recorded similar increase in grain yield of sole sorghum than intercropped one. The interaction between planting pattern and legumes intercropping as regards grain yield of sorghum was non-significant in both the years of study. Similarly, Abdur, reported that the interaction effect of planting pattern and legume on sorghum yield did not show significant variation. Statistical analysis also depicted that, there was a significant (P<0.05) difference due to effect of treatments on sorghum yield during 2016 cropping season. However, there was no significant (P>0.05) difference on sorghum yield during 2017 cropping season. Thus, higher mean of sorghum yield was obtained from the treatments of single rows of sorghum and single rows of haricot bean (37.25 qt ha^{-1})in sequence (1S:1H). however, the lowest mean values of sorghum yield was decreased (28.26 qt ha^{-1}) from the treatments of double rows of sorghum and single rows of cowpea in alternate (2S:1C). This variation might be occurs due to nutrient uptake of crops in different planting pattern.

Haricot bean and Cow Pea Grain Yields

Analysis of variance was also revealed that, yield of haricot bean had highly significant (P<0.01) difference due to the effect of planting pattern during 2016 cropping season. However, there was no significant (P>0.05) difference due to the effect of planting pattern during 2017 cropping season. Even if it was not statistically different, the highest mean values of haricot bean yield (8.83 qt ha^{-1}) were recorded when it was planted with sorghum in double rows of inter crops in sequence (1S:2L). The mean of haricot bean yield (5.29 qt ha^{-1}) was significantly reduced when it was planted with sorghum in Single rows of inter crops in alternate (2S:1L). Analysis of variance was also revealed that, yield of cowpea had no significant (P>0.05) difference due to the effect of planting pattern. The highest mean values of cowpea yield (1.36 qt ha^{-1}) was obtained when cowpea was planted with sorghum in double rows of inter crops in alternate (2S:2L) and mean yield of cowpea (0.99 qt ha^{-1}) decreased when it's planted with sorghum in single rows of inter crops in sequence (1S:1L). The grain yield obtained from cowpea was significantly below its potential and highly suppressed by main crops (Sorghum). However, according to the observation during the experiments, their biomass is not significantly affected and it was cover the soil surface by their leaf. Further, mean yield of haricot bean (19.18 qt ha^{-1}) and cowpea (5.53 qt ha^{-1}) was higher in sole cropping than intercropping system. Similarly, [18] reported that cowpea yields reduced due to sorghum/ cowpea intercropping system. [19] Also found that grain yield of cowpea was higher in sole cropping than in intercropping mixtures. This was in agreement with the findings of [20] who

Table 1. Selected physicochemical properties of experimental soil before sowing.

Soil Characteristics	Location			
	Tulo	Chiro	Rate	Sources
Sand %	10	62		
Clay %	62	12		
Silt %	28	26		
Texture Class	Clay	Sandy loam		Rowell (1994)
pH (1:2.5 H_2O)	5.86	6.41	Moderately acidic	Tekalign (1991)
OM %	3.74	3.47	Medium	Tekalign (1991)
TN %	0.15	0.25	Moderate	Tekalign (1991)
Avail. P ppm	35.21	35.88	Very high	Tekalign (1991)
Avail. K ppm	399.6		Very high	FAO (2006)
CEC Meq/100g Soil	60.48	31.6	Very high	Hazelton and Murphy (2007)
C:N	14.94	8.04		
EC ms/cm	0.11	0.15	low	

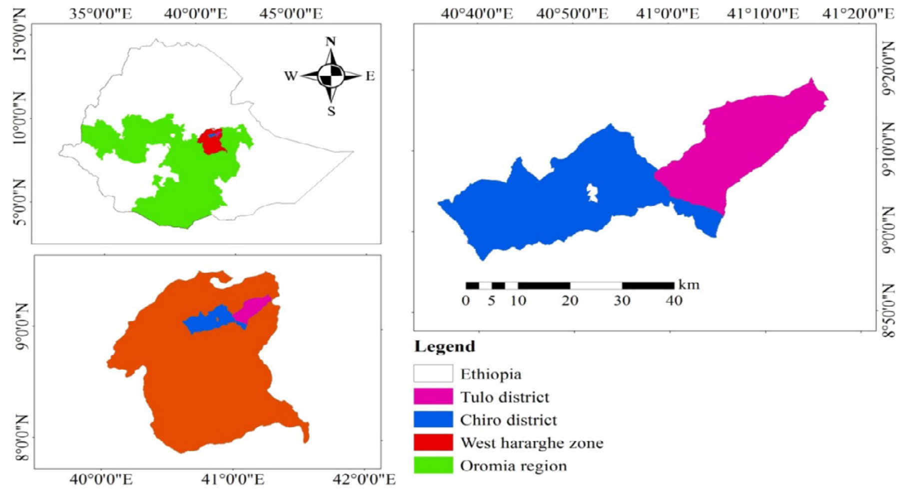

Figure 1. Map of the study area.

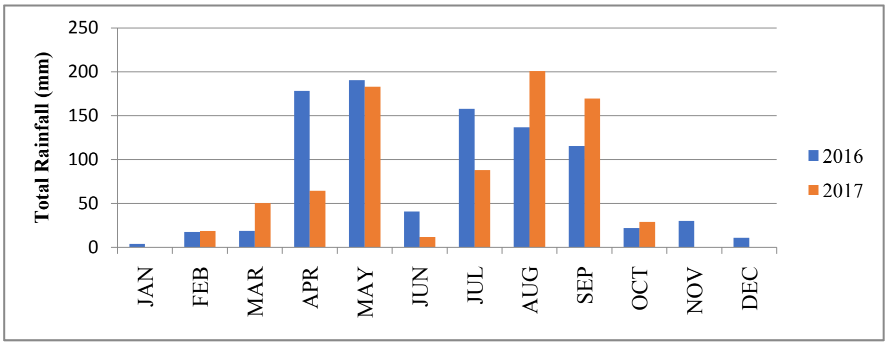

Figure 2. Total rainfall (mm) at Hunde Lafto metrological station during 2017 and 2018 cropping season.

Table 2. Effect of legume crops and planting pattern on yield of sorghum, Cowpea and haricot bean in sorghum intercropping.

Treatments	SG yield qt ha^{-1}			HB yield qt ha^{-1}			CP yield qt l ha^{-1}		
	2016	2017	2016/17	2016	2017	2016/17	2016	2017	2016/17
sole Sorghum	37.23	36.92	36.61						
Sole Haricot bean				21.55	17.32	19.18			
Sole Cowpea							9.45	1.11	5.53
Sorghum-Legume intercrop									
Haricot bean	35.05	35.09	34.91						
Cowpea	32.94	34.39	33.66						
$LSD_{0.05}$	0.61	6.57	3.59						
Planting Patterns									
2S:1L	29.66	31.19	31.72b	5.48	5.11	5.29	1.86	0.39	1.12
1S:2L	36.35	37.28	36.99	12.74	4.92	8.83	1.9	0.28	1.10
2S:2L	34.27	36.73	34.10	8.83	3.88	6.35	2.36	0.37	1.36
1S:1L	35.69	33.06	34.36	6.620	4.20	6.57	1.48	0.51	0.99
$LSD_{0.05}$	4.41	9.30	4.97	3.49	5.27	3.91	NS	0.69	1.26
CV (%)	10.60	22.03	17.62	20.78	54.89	48	50.41	87	91

Single rows of inter crops in alternate (2S:1L) Double rows of inter crops in sequence (1S:2L) HB haricot bean CP cowpea
Double rows of inter crops in alternate (2S:2L) Single rows of inter crops in sequence (1S:1L) SG sorghum

found that cowpea grain yield was depressed by maize cowpea intercropping systems. In the present study, not only the yield of cowpea and haricot bean was depressed by sorghum, but cowpea and haricot bean depressed the yield of sorghum. This results were supported by [14] indicating that yield of sorghum depressed by legume crops (Tables 2 & 3).

Land Equivalent Ratio (LER)

The total land equivalent ratios (LER) were obtained by summing up of the partial land equivalent ration of sorghum and legume crops. The mean values of sorghum partial land equivalent ration were not significantly (P>0.05) influenced due to the main effect of legume and interaction of planting pattern and legumes. However, there were significantly (P<0.05) influenced due to the main effect of planting pattern. Also the mean values of legume partial land equivalent ratio were not significant (P>0.05) difference due to main effect of legume crops, planting patterns and their interaction. Analysis of variance also revealed that, total land equivalent ration were not significantly (P>0.05) difference due to the main effect of legume crop and planting pattern and their interaction. Even if the analysis of variance did not show variation, the higher total LER (1.36) was obtained from sorghum haricot bean than sorghum cowpea (1.19) intercropping system, indicating that 36% and 19% yield advantage respectively over sole crops. Though the

Table 3. Effect of treatments (different haricot bean and cowpea intercropping pattern) on yield of sorghum.

Treatments	**Yield qt ha^{-1}**		
Year	2016	2017	2016/17
1S:1H	36.42	38.07	37.25
1S:2H	36.33	37.70	37.01
1S:2C	35.15	36.97	35.81
1S:1C	34.96	28.97	33.55
2S:2C	34.45	39.64	37.04
2S:2H	34.10	33.82	33.96
2S:1H	32.12	33.05	32.56
2S:1C	27.20	29.33	28.26
LSD	7.27	14.35	6.92
CV$^{0.05}$	12.275	23.25	17.31
LXPP	NS		

Single row of sorghum and single row of haricot bean in sequence (1S:1H)
Single row of sorghum and double rows of haricot bean in sequence (1S:2H)
Double rows of sorghum and double rows of haricot bean in alternate (2S:2H)
Double rows of sorghum and single row of haricot bean in alternate (2S:1H)
Single row of sorghum and double rows of cowpea in sequence (1S:2C)
Single row of sorghum and single row of cowpea in sequence (1S:1C)
Double rows of sorghum and double rows of cowpea in alternate (2S:2C).
Double rows of sorghum and single row of cowpea in alternate (2S:1C).

Table 4. Effect of legume crops and planting pattern on sorghum and legumes PLER and TLER in sorghum intercropped with haricot bean and cowpea.

Treatments	**Sorghum partial LER**			**Legume partial LER**			**Total LER**		
year	2016	2017	2016/17	2016	2017	2016/17	2016	2017	2016/17
Haricot bean	0.94	0.96	0.95	0.42	0.40	0.41	1.36	1.36	1.36
Cowpea	0.88	0.95	0.91	0.21	0.35	0.27	1.09	1.29	1.19
$LSD_{0.05}$	NS	0.19	0.105	0.11	0.28	0.15	0.16	0.38	0.27
2S:1L	0.79	0.86	0.8	0.25	0.40	0.32	1.04	1.25	1.15
1S:2L	0.98	0.99	1.00	0.40	0.38	0.39	1.38	1.37	1.34
2S:2L	0.92	0.98	0.97	0.35	0.31	0.33	1.27	1.29	1.30
1S:1L	0.96	0.89	0.94	0.25	0.41	0.33	1.20	1.30	1.32
$LSD_{0.05}$	0.13	0.13	0.13	NS	NS	NS	0.23	NS	NS
CV (%)	11.57	23.89	18.55	41.19	41.19	78	16.93	35	28.59
Intercropped							1.21	1.32	1.265
Sole sorghum							1	1	1
Sole haricot bean							1	1	1
Sole cowpea							1	1	1
$LSD_{0.05}$							0.08	0.3	0.108
CV (%)							3.55	3.73	3.64

Single rows of inter crops in alternate (2S:1L) Double rows of inter crops in sequence (1S:2L) LER land equivalent ratio
Double rows of inter crops in alternate (2S:2L) Single rows of inter crops in sequence (1S:1L)

yield of haricot bean was higher than the cowpea in an intercropping system, the greater in sorghum yield intercropped with haricot bean than cowpea which has total higher LER of the system. Also highest mean values of total LER (1.34) was registered from sorghum legume intercropping in double rows of inter crops in sequence (1S:2L) patterns than others patterns. While the least was obtained when sorghum planted in Single rows of inter crops in alternate (2S:1L). Analysis of variance also showed that, higher mean of LER (1.265) was observed from intercropping system than sole cropping (1). The total LER in all cases was more than unity showing that intercropping of legumes with sorghum is advantageous in all instances rather than sole planting of sorghum. Higher LER in intercropping than sole cropping has also been reported in maize/soybean by [21] and sorghum/cowpea and soya bean by [14]. The yield advantage could be due to the efficient utilization of growth resources by the intercropped crops or the intercropping advantages of nitrogen fixation and increased light use efficiency [22,23]. Therefore, from this result, we concluded that additional yield could be produced by intercropping sorghum with a suitable legume at an appropriate planting pattern. Thus the findings of this experiment revealed that sorghum-haricot bean intercropping in the planting pattern of double rows of inter crops in sequence (1S:2L) increased the yield advantage indicating 34% than mono cropped and intercropped sorghum in the other planting patterns (Table 4).

Effect of Intercropping selected soil Chemical Properties

The analyzed soil result revealed that, the pH of the soil was within the range suitable for productive soils according to the rate elaborated by [24]. The highest mean percentage of organic matter and total nitrogen was recorded from the field of intercropping system as compared to sole sorghum. The lowest mean values of total nitrogen and organic matter were recorded from the fields of sole sorghum. The increase in total nitrogen and organic matter contents in intercropped treatments compared to sole sorghum might be attributed mainly due to the effect of legume residues on organic matter formation and N-fixation. Moreover, this confirms that intercropping meets one of its motives, i.e. increasing availability of nitrogen and organic matter to the mixed population through fixation by the legume, thus maintaining soil fertility [25,26]. Carbon to nitrogen ratio(C: N) is an index of nutrient mineralization and immobilization whereby low C: N ratio indicates higher rate of mineralization and higher C: N ratio indicates greater rates of immobilization [27]. The highest C: N ratio was obtained from the intercropped treatments and sole legumes than sole sorghum. In effect, the lower the value, the higher is the proportion of N in organic matter (i.e.

lignin and other hard substances that are resistant to decomposition [28].The highest available phosphorus was obtained from intercropped treatments as compared to sole sorghum. This might be due to addition of organic residues to the soil. However, OM is not necessarily the primary supplying source of available P in highly weathered tropical soils; rather than mineral weathering has considerable importance as a source of soil P [29,30]. The intercropped treatment and sole legumes was recorded the highest CEC than sole sorghum. This might be attributed to high accumulation of OM. The surface layer of OM which have negatively charged surfaces act as an adsorption site for positively charged cations (Ca^{+2}, Mg^{+2}, K^{+}, Na^{+}). Thus high organic matter content indicates high CEC of the soil. Therefore, from this result, soil chemical properties could be improved by intercropping system. Thus the findings of this experiment showed that sorghum-haricot bean intercropping in the planting pattern of double rows of inter crops in sequence (1S:2L) provide good soil chemical properties and also increased the yield advantage than other mono cropping of sorghum and other and other planting pattern (Table 5).

Economic Analysis`

According to the economic analysis conducted for intercropping, the highest net income (47,565 ETB ha^{-1}) was obtained from Single row of sorghum and double rows of haricot bean in sequence (1S:2H) while the lowest net income (31,130 ETB ha^{-1}) was recorded from single row of sorghum and single row of cowpea in sequence (1S:1C) planting patterns. The data with regards to sole crop the highest net income (39,582ETB ha^{-1}) was obtained from sole sorghum and the lowest net income (2,390 ETB ha^{-1}) was recorded from sole cowpea. Thus the net income was higher in intercropping system than sole cropping system. This was in agreement with the findings of [31,32] obtained higher monetary returns from intercropping than sole maize, in maize soybean cropping system. Similarly, [33] reported that intercropping sorghum with common bean was more advantageous than sole cropping of either common bean or sorghum (Table 6).

Conclusion and Recommendation

The study indicated that the highest mean yield of sorghum was recorded when it is intercropped with haricot bean than cowpea. In addition, the highest mean yield of haricot bean was obtained than cowpea when intercropped with sorghum. Thus the highest sorghum and haricot bean grain yield was recorded from the planting patterns of single rows of sorghum and double rows of haricot bean in sequence (1S:2H). Partial and total LER of sorghum was highest when intercropped with haricot bean than cowpea. Also Partial and total LER of sorghum was highest in planting patterns of single rows of sorghum and double rows of haricot bean in sequence (1S:2H). Also, sorghum-haricot bean intercropping in this planting pattern provide good

Table 5. Selected soil chemical properties in the study areas.

Planting patterns	Soil chemical properties													
	pH		OC		OM		TN		C:N		Avail.P		CEC	
	Tulo	Chiro	Tulo	Chiro	Tulo	Chiro	Tulo	Chiro	Tulo	Chiro	Tulo	Chiro	Tulo	Chiro
2S:1C	6.22	6.65	2.42	2.01	4.17	3.47	0.16	0.25	14.96	8.04	16.48	38.96	59.92	31.8
2S:1H	6.08	6.50	2.04	1.59	3.52	2.74	0.14	0.23	14.52	6.91	21.19	37.28	60.77	33.8
1S:1H	6.14	6.55	2.15	1.80	3.71	3.10	0.15	0.24	14.46	7.50	17.54	39.24	57.70	32.4
1S:2C	6.18	6.50	2.21	1.37	3.81	2.36	0.14	0.17	15.54	8.06	18.83	38.88	59.28	33.2
1S;2H	6.20	6.60	2.36	5.71	4.07	9.84	0.15	0.27	15.90	21.15	14.34	40.32	60.99	30.8
2S:2C	6.14	6.59	2.25	4.65	3.88	8.02	0.15	0.23	15.52	20.22	16.20	36.36	60.05	30.8
1S:1C	6.16	6.60	2.15	5.71	3.71	9.84	0.15	0.27	14.62	21.15	19.08	40.32	60.42	30.8
2S:2H	6.13	6.54	2.17	3.28	3.74	5.65	0.16	0.24	13.41	13.67	19.22	38.84	60.70	32.6
Sole srg	6.16	6.50	1.97	3.38	3.4	5.83	0.14	0.25	13.93	13.52	15.60	41.16	56.00	30.4
Sole CP	6.15	6.61	2.47	2.64	4.26	4.55	0.15	0.23	16.06	11.48	18.37	37.96	64.06	31.8
Sole HB	6.19	6.48	2.72	1.27	4.69	2.19	0.16	0.21	16.77	6.05	17.46	43.48	66.79	30.4

Table 6. Economic analysis of marginal rates of return on effect of different cropping pattern on yield of sorghum.

treatments	yield obtained from sorghum (qt/ha)	yield obtained from legumes (qt/ha)	costs		Total cost	Income from		Gross income(birr)	Net income
			sorghum	legumes		sorghum	legumes		
2S:1C	33.54	1.23	4350	6700	11050	40248	3690	43,938	32,888
1S:2C	35.81	1.09	4350	9850	14200	42972	3270	46,242	32,042
2S:2C	37.04	1.36	4350	7750	12100	44448	4080	48,528	36,428
1S:1C	33.55	0.99	4350	7750	12100	40260	2970	43,230	31,130
2S:2H	33.96	6.35	4350	3698.13	8048	40752	10477.5	51,230	43,182
1S:1H	37.2	6.57	4350	3698.13	8048	44640	10840.5	55,481	47,433
1S:2H	36.11	8.83	4550	5787.50	10338	43332	14569.5	57,902	47,565
2S:1H	32.56	5.29	4250	2509.63	6760	39072	8728.5	47,801	41,041
Sole SORG	36.61	-	4350	-	4350	43932	-	43,932	39,582
Sole CP	-	5.53	-	14200	14200	-	16590	16,590	2,390
Sole HB	-	19.18	-	10188	10188	-	31647	31,647	21,459

Single row of sorghum and single row of haricot bean in sequence (1S:1H)
Single row of sorghum and double rows of haricot bean in sequence (1S:2H)
Double rows of sorghum and double rows of haricot bean in alternate (2S:2H)
Double rows of sorghum and single row of haricot bean in alternate (2S:1H)
Single row of sorghum and double rows of cowpea in sequence (1S:2C)
Single row of sorghum and single row of cowpea in sequence (1S:1C)
Double rows of sorghum and double rows of cowpea in alternate (2S:2C).
Double rows of sorghum and single row of cowpea in alternate (2S:1C).

HB- haricot bean CP- cowpea SORG- sorghum

soil chemical properties and increased the yield advantage. Highest net income benefit was obtained from 1S:2H planting patterns. The result clearly depicted that the role of legumes intercropped with sorghum increasing production per unit area. Under these scenarios intercropping gave high yield advantage over sole cropping. Therefore, based on the finding of the study, planting patterns of single rows of sorghum and double rows of haricot bean in sequence (1S:2H) could be recommended in mid land areas of West Hararghe Zone and similar agro ecologies. Also in area where livestock and sorghum is the main source of income for farmers, intercropping cowpea and haricot bean at 1S:2L planting patterns could be recommended. Legume crops mainly haricot bean and cowpea should be involved in sorghum crop with the recommended planting patterns.

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