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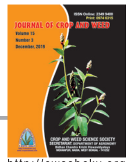

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Intercropping different legumes for *striga (Striga hermonthica* del benth) management and enhancement of sorghum productivity in north west Ethiopia

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ABSTRACT

The dry land zones of Africa sorghum production are seriously constrained by Striga. Despite the numerous ways of Striga control available, sorghum production in North Gondar, Ethiopia is below its potential. A research at Gondar Agricultural Research Center in 2017-2018 was done to evaluate different legumes in sorghum for S. hermonthica control and inter-cropping on system productivity. Four legumes (soybean, haricot bean, mung bean, and cowpea), along with their sole and sole sorghum was laid in RCB design with three replications. Striga count and dry matter, Sorghum yield, and its components were highly significantly (P < 0.01) affected: Striga count and dry matter in sole sorghum and sorghum/cowpea were (314.65, 83.38gms) and (91.1, 31.31gms), respectively, grain yield of sole sorghum and sorghum/cowpea was statistically at par 4.34t and 3.39t ha^{-1}, respectively. Significantly greater mean LER, 1.45, and 1.34 was in, sorghum/cowpea and sorghum/soybean, respectively. The highest mean GMV and MAI at LER (1.46) were 89,352 and 27,826, respectively were in sorghum/cowpea intercropping. This result indicates intercropping sorghum with legume crops gave high yield advantage and land productivity. The present investigation revealed that cowpea is the best legume for striga management in sorghum and can be recommended for the area.

Keywords: Cowpea, haricot bean, mung bean, sorghum, soybean, *Striga*

Background

In semi-arid tropics sorghum is a major staple diet. Globally it ranks as fifth important cereal. Its adaptation to adverse environmental conditions has made sorghum a popular crop worldwide. In Ethiopia, it is one of the most important staple food crops for most rural communities and plays a significant role for millions of poor Ethiopians (Adngna, 2007) and grows in a wide range of agro-climatic zones, especially in the lowlands. In hectarage and production, it is the fourth primary staple food crop in Ethiopia (CSA, 2016). Sorghum is cultivated in almost all areas of the country and covers a total land area of 1.6 million ha (CSA, 2016). The productivity compared to that of several other African countries is low (<1.35 ton h^{-1}) in Ethiopia FAOSTAT (2016). Low productivity of sorghum in Ethiopia is due to several abiotic and biotic stresses, as (Wastmann *et al.,* 2006) among many constraints limiting the productivity in the country, *Striga* infestation is important.

Sorghum cropping is the most suitable choice for farmers in northern, northwestern, and western parts of the country where *Striga* causes serious yield reductions[5]. The losses by *Striga* weed in most areas can be 30 to 100 per cent [6], and low soil fertility often aggravates the problem. *Striga* infestation at a tolerable level in subsistence African agriculture were kept at a tolerable level through, crop rotation, long term fallow and intercropping. *Striga* seeds need crop exudates stimulation to germinate and infest the host crop. When the *Striga* seed increased from time to time it will increase the reduction of yields [7].

Intercropping of cereal with legume is a most common cropping system in Sub-Sahara African countries where it is used for maximizing the use of limited farmlands, food security, and improving soil fertility. Low-cost method for depletion of *Striga* seed bank is incorporation of legume trap crops, like Desmodium, cowpea, and soybeans have been found to release exudates that induce germination of *Striga* but are themselves not parasitized [8]. The *Striga* seed bank reduction and soil fertility improvement and livelihood of farmers can be addressed when legumes are included in the cropping systems. Besides, preliminary works show that some soybean accessions induce *S. hermonthica* germination[9]. Maize/soybean gives good yield, with lower *Striga* infestation [10]. Less *Striga* number in net plot areas is observed when sorghum is intercropped with cowpea [8]. Fasil and Verkleij [11] indicated higher *Striga* count in sole sorghum than sole soybean, sole cowpea, and sole haricot bean.

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Sorghum production in Ethiopia and In North-Western Ethiopia is below its potential. Low soil fertility, and pest damages are the major factors that account for low yield in North Gondar. Infestation of S*triga* in sorghum fields of North Gondar Zone in northwest Ethiopia is so severe. The most severe constriction of cereal production is *Striga* in sub-Saharan Africa and the research area, which is aggravated with depletion of soil fertility[12]. Poor soil condition, intensification of land-use through repeated farming and an increase in cereal production are the causes for the prevalence of *Striga*[13]. This problem is also common in Metema and Sanja, which are the most sorghum producing areas of North Gondar. Sorghum farmers in the study area are seriously suffered from low sorghum productivity that is mainly caused by *Striga* infestation and poor soil condition. North Gondar takes the highest share, 34.04% sorghum area coverage of Amhara region CSA[2]. The average productivity of sorghum in Ethiopia is <1.35 tons h-1, ranking it fifth in Africa.

The management of farmers in the use of agricultural inputs: fertilizer and legume intercropping are almost non-existent because of the escalating fertilizer costs and lack of information on legumes inclusion in the cropping system. Solving the *Striga* problem to achieve sustainable food production with affordable technologies for farmers is crucial. Neither farmer use appropriate legumes in intercropped for managing *Striga* infestation and increase their sorghum productivity, nor have research and extension interventions well addressed this critical constraint for limiting sorghum productivity and production. Therefore, the effect of different legumes (Soybean, Haricot bean, Mung bean, and Cowpea) intercropping with sorghum for *Striga* infestation management and increasing sorghum production and productivity in northwest Ethiopia was investigated.

MATERIALS AND METHODS

A field experiment was conducted in the 2017/2018 main cropping season at Metema and Sanja Research Stations of Gondar Agricultural Research Centre in Metema and Tach Armachiho districts, respectively, in North Gondar Zone, northwest Ethiopia. The map of the study sites is presented in Fig. 1.

The field experiment was conducted at Metema and Sanja areas of Gondar Agricultural Research Institute from June- September 2017/18 in the main cropping season. Metema and Sanja Districts are located in West and North Gondar Zone, respectively of Amhara Regional State, Ethiopia. Metema has latitude, longitude and elevation of 12°47″38′N, 36°23″41′E and 760 m above sea level, respectively. Whereas, Sanja site is located at $13^0$19.6′N latitude and $36^0$44.6′ E longitudes with an altitude of 550 - 1550m above sea level. The climate of Metema and Sanja experimental sites is warm sub-humid with a mean annual rainfall of 898.77mm and 850mm, respectively. The average maximum and minimum temperatures of the Metema site are 32.6^0C and 20.1^0C, while the Sanja site is 35^0C and 19^0C, respectively. At both experimental sites, the daily temperature is high from March to May. The topography of both the experimental sites was almost flat with a 2-5% slope.

Soil analysis

Based on particle size distribution, the soil in the experimental site is clay (Table 7). The results of the analysis showed that the soil was dominated by clay 43.28 at Metema and 44% Sanja. High clay content might indicate better water and nutrient holding capacity of the soil in the experimental site. The soil pH value of the experimental site as described in Table 7 was 6.81at Metema and 6.75 at Sanja. USDANRCS [14] categorized soil pH values (6.6 – 7.3), as neutral. In view of this, soils in the study area had neutral pH. Thus, the pH of the experimental soil was within the range of productive soils (5.5 – 8.5) for sorghum.

Experimental treatments, design, and procedures

The experimental design used in this study was a randomized complete block design with three replications and nine treatments as follows: sole cropping of sorghum, sole cropping of mung bean, sole cropping of soybean, sole cropping of haricot bean, sole cropping of cowpea, and four sorghum: mungbean, sorghum: soybean, sorghum: haricot bean and sorghum: cowpea intercropping pattern. Sorghum variety local ‘Deber’, soybean variety ‘Afgat’, haricot bean ‘Nasser’, mung bean ‘Rasa’ and cowpea variety White wonder, were used for the study.

Thus, there were nine treatments as below:

T_1= Sorghum + Soybean (1:1) planted simultaneously

T_2= Sorghum + Haricot bean (1:1) planted simultaneously

T_3= Sorghum + Mung bean (1:2) planted simultaneously

T_4= Sorghum + Cowpea (1:1) planted simultaneously

T_5= Sole Sorghum

T_6= Sole Mung bean

T_7= Sole Haricot bean

T_8= Sole Soybean

T_9= Sole Cowpea

The experiment was conducted on a hot spot field that has been under natural *Striga* infestation for the last several years. The gross plot size was 3.5m×3.0m

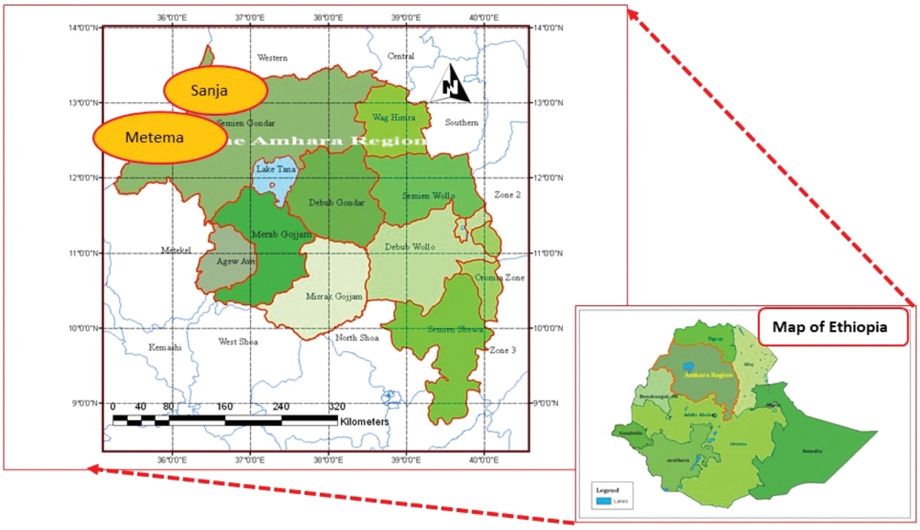

Fig. 1. Map of the experimental sites

($10.5m^2$) with the net plot area of 2m*2.4m ($4.8m^2$). The adjacent plots and blocks were separated with 1.0m and 1.5m wide paths, respectively. The land was ploughed, disked, and harrowed by traditional oxen plow before planting. Planting of sorghum, soybeans, haricot bean, mung bean, and cowpea was done at 75 x 30 cm, 60 x 5 cm, 40 x 10 cm, 30 x 5 cm, and 60 x 25 cm between row and plant spacing, respectively. Thinning was carried out according to the recommended population and spacing for all crops. Except for *Striga*, the experimental plots were kept free from other weeds manually. Beyond the treatments, all other agronomic practices were applied to the experimental plots equally as per their respective recommendations used for sorghum and legumes in the study area.

Striga and crop data collection

Striga count and dry matter were noted at sorghum maturity. *Striga* counts and *Striga* dry matter per plot in the net plot area was taken after the fresh weight was air-dried at the physiological maturity of sorghum.

Data on phenological, vegetative growth and yield-related parameters of sorghum and legumes were collected timely following their respective standard methods and procedures. When the grains of the main shoot reached the black layer stage, sorghum plants in the net plot area were harvested at the ground level and spread to dry with the sun. Biomass, grain yield and harvest index was estimated and converted to percentile. After threshing the heads of well-dried sorghum plants, was also estimated by weighing clean grains of each net plot area with a balance and adjusted to 12.5 moisture level, and then converted to a hectare basis. A thousand grains were randomly taken from clean grains recovered in each net plot area and weighed with a sensitive balance to determine a thousand kernels' weight.

Data analysis

All collected *Striga* and crop data analysis of variance using SAS software version 9.2 (SAS-Institute, 2008) was done and the homogeneity test for all parameters was non-significant, the combined analysis for each parameter over locations. Whenever the result showed a significant difference among treatments for a parameter in question, least significant difference used for mean separation was performed, while the coefficient of variations for considered parameters was lower than 10[15].

Productivity of intercropping

The benefit of intercropping is quantified by **Temporal niche differentiation** (TND)

It was calculated by the formula developed by Yu [16]:

$$TND = \frac{P\ system\ -\ P\ overlap}{P\ system\ P\ system} = 1\ -\ (P\ overlap)$$

where P overlap represents the period of overlap of the growth period of the intercropped species, while the P system represents the duration of the whole intercrop.

RPE% of the system was calculated by following Sankaranarayanan [17]:

$$RPE\% = \frac{(CEYD\ -\ CEYE)}{CEYE} \times 100$$

where CEYD is the CEY under improved cropping system and CEYE is the equivalent yield under the existing cropping system. The inference was that positive results indicated the superiority of the new intercropping system over the existing system, while negative results indicated inferiority. REE% of the system was calculated by following Samant [18]:

$$REE\% = \frac{(NRD - NRE)}{NRE} \times 100$$

where NRE is the net return of the existing cropping system, the NRD is the diversified cropping system. The labor cost man day^{-1} was 80 ETB. The average grain prices were ETB 13.00, 25, 20, and 20.00 kg^{-1} for sorghum, soybean, cowpea, and haricot bean, respectively, based on the average local market prices of the months from October to February.

Land Equivalent Ratio (LER): Intercropping efficiency was evaluated by using the land equivalent ratio. The relative land area in pure stands is required to produce the yields of all products from the mixture Vandermeer[19].

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

Where AI and BI are the yields of two crops in intercropping, and AS and BS are the yields of each crop in a monoculture system. If LER is greater than one, intercropping would be better than monoculture Mazaheri[20].

Area Time Equivalent Ratio (ATER): The ATER was calculated by following Hiebsch and Macollam[21]:

$$ATER = \frac{(PLERSRxTSR) + (PLERLGxTLG)}{T} \times 100$$

where PLERSR and PLERLG are a partial land equivalent ratio of sorghum and legume, respectively; TSR is the duration of sorghum maturity; TLG is the duration of legume maturity and T is the total duration of the intercropping system.

Competition Ratio: Competition between component crops was measured by the CR, Zhang *et al*., [22]. The CR of the component crops was calculated by the formula:

$$CRSR = \frac{PLERSR\ X\ ZLGSR}{PLERLG\ ZSRLG}$$

$$CRLG = \frac{PLERLG\ X\ ZSRLG}{PLERSR\ ZLGSR}$$

Where: CRSR and CRLG are a CR of sorghum and legumes, respectively; PLERSR and PLERLG are a partial land equivalent ratio of sorghum and legume, respectively and ZSRLG and ZLGSR are a seed proportion of sorghum intercropped with legumes and the seed proportion of legumes intercropped with sorghum, respectively. YSRIC and YLGIC are yields of sorghum and legume in an intercropping, respectively, and YSRSC and YLGSC are the yield of sorghum and legumes in sole cropping, respectively.

Gross Monetary Value (GMV) was calculated from the yield of sorghum and soybean to measure the productivity and profitability of intercropping as compared to sole cropping of the associated component crops. Crop value in the system monetary returns values was estimated based on the current market price of produce.

RESULTS AND DISCUSSION

Striga weed component plot^{-1}

The analysis of variance revealed that *Striga* count per plot was highly and significantly (P<0.01) different due to legume crops intercropping. Intercropping legumes with sorghum have negatively affected *Striga* per plot than sole sorghum. (The highest 314 *Striga* from sole sorghum and 91 in sorghum/ cowpea intercrop) (Table 1). Similarly, *Striga* dry matter was statistically highly significantly different (P<0.01) in sorghum/legumes intercropping, the highest 83.38 grams in sole sorghum, the lowest 31.22g at sorghum/ cowpea intercropped.

A higher *Striga* population was recorded in soybean/ sorghum than sorghum with cowpea, haricot bean, or mung bean (Table 3). This result agrees with Fasil and Verkleij[11]who found that higher *Striga* numbers per plot in sorghum/soybean than in sorghum/cowpea intercropped. The result of Odhiambo *et al*. [10]shows lower *Striga* number in maize/soybean with good performance. Least *Striga* is obtained in soybean/ sorghum [8, 23].

Dry matter of *Striga* was very low in sorghum/ cowpea than that of other legumes. Intercropping study indicates that population density and weed biomass may be markedly abridged when intercropping strategies are used [24]. In a similar experiment, Singh and Singh [25] achieved when cowpea was planted closer to sorghum. Weed population is low when maize and mung bean were planted simultaneously [26]. Lower *Striga* population in intercropped plots indicated that sole sorghum could not suppress *S. hermonthica* as compared to intercropped plots. Intercropping blocked *S. hermonthica* by the exudates released from both the legumes. Aliyu and Emechebe[8]confirmed that soybean and cowpea released exudates that initiate the *Striga* germination without being parasitized. This was in agreement with the findings of Kureh [27]who indicated that cowpea/maize reduced emerged *Striga* density, by cowpea shading effects.

Sorghum and legumes growth, yield, and yield components

ANOVA showed that the aboveground dry biomass and grain yield was highly significantly (P < 0.01) affected due to legume crops intercropping. The highest

Table 1: Influence of sorghum-legume intercropping on *Striga* count and *Striga* dry matter at harvesting stage

Treatment	Number of *Striga* plot^{-1}			Dry Weight (gm) plot^{-1}		
	Metema	Sanja	Combined locations	Metema	Sanja	Combined locations
Sorghum SB	102.5bc	106.23bc	104.35bc	35b	36.31b	35.66b
Sorghum HB	113b	112.64b	112.81b	34.38b	34.23b	34.31b
Sorghum MB	97.2bc	101.53bc	99.36cd	33.17b	34.57b	33.87b
Sorghum CP	91.1c	93.76c	92.43d	31.31b	32.22b	31.76b
Sorghum Sole	304.6a	314.65a	309.63a	79.43a	83.38a	81.41a
P	**	**	**	**	**	**
LSD (0.01)	**12.58**	**10.19**	**7.5**	**9.69**	**8.37**	**4.85**
S.E (1%)	**3.75**	**3.04**	**2.67**	**2.89**	**2.49**	**1.73**
CV (%)	**3.24**	**2.55**	**2.75**	**8.29**	**6.92**	**10.33**

***SB**= Soybean; **HB**= Haricot bean; **MB**= Mung bean and **CP**= Cowpea*

(15.56t h^{-1}) aboveground dry biomass yield of sorghum was recorded in sorghum/soybean, which was statistically at parity with sole sorghum (15.40 t h^{-1}) (Table 2). The lowest yield (9.53 t ha^{-1}) of sorghum was from sorghum/haricot bean intercropping.

Biomass was affected highly significantly by legume type. Solely planted legumes yielded higher than their respective intercropped with sorghum. The increment in sole crops from the intercropped trend was; 63.69, 49.5, 42.01, and 13.62% in sorghum/haricot bean, mung bean, soybean, and cowpea, respectively.

Sorghum and legumes grain yields were highly significantly influenced by the type of legumes in combined over locations, whereas, non-significant in both locations for all legumes under study. Sole sorghum recorded the highest (4.34t h^{-1}) followed by 3.93t h^{-1} in sorghum/cowpea intercropping (Table 2). The least (2.22t h^{-1}) was in sorghum/haricot bean intercropping at Metema. The type of legume had a highly significant ($P < 0.01$) difference for yield of legumes (Table 2). Significantly higher grain yields were recorded in sole mung bean (3.49t h^{-1}) than their yield from the intercropped with sorghum. The increments in grain yield in sole were 57.57, 51.51, 45.14, and 37.04% in sorghum/mung bean, haricot bean, soybean, and cowpea, respectively from their corresponding intercrop grain yield.

Sorghum and legume seed weight was highly significantly ($P < 0.01$) affected due to legume type and intercropping. Thousand seed weight of sorghum was 31.61 and 22.61g, in sorghum/soybean and sorghum/ mung bean, respectively (Table 3). The highest 100-seed weight of legumes, 18.12g in sole haricot bean, and lowest 5.56gms were recorded in sorghum/mung bean (Table 3).

Interspecific competition was higher than intraspecific for differences in grain [28]. Reduction of 69.7% in yield due to sorghum/cowpea was observed by Oseni and Aliyu [29] and the higher grain yield in sole cropping. Langat *et al*. [30] got a yield reduction in sorghum/groundnut.

The interspecific competition and depressive effect of sorghum results reduction in soybean yield in intercropping, as a C4 species on soybean, a C3 crop. A higher seed yield of sole over sorghum/soybean was obtained by Muneer[31]. Shading effects difference in crop canopy in a mixture could reduce the photosynthetic ability of slow growing plants and ultimately lower yields [32]. In a wheat/chickpea study, yield of chickpea in mixture highly decreased [33]. A 55.3% cowpea yield reduction in sorghum/ cowpea intercropping system was reported by Oseni and Aliyu [29]. The grain cowpea yield was higher in sole cropping than in intercropped (Oseni[34]). Egbe [35]found that similar observation in maize-cowpea intercropping systems, but in this research both the yield of cowpea was depressed by sorghum and vice versa.

Temporal niche differentiation, Land equivalent ratio and area time equivalency ratio

The result of TDN shows higher values for sorghum, (0.69) sorghum/soybean, and lowest (0.61) in sorghum/ haricot bean intercropping (Table 4), this indicates the competitive ability of sorghum from the treated legumes. Statistically LER was highly significantly greater than 1.00 in intercrops. The highest value of LER (1.46) was recorded in sorghum/cowpea while the lower LER (1.11) was found in sorghum/mung bean. In all the treatments, LER values were greater than the ATER (Table 4). On the other hand, ATER values were greater than 1.00 in all the cases, the highest and lowest values were 1.33 and 1.0 in the intercropped sorghum/cowpea and sorghum/mung bean, respectively (Table 2).

Table 2: Yield of Sorghum, Soybean, Haricot bean, Mung bean and Cowpea and Land Equivalent Ratio (LER) as influenced by Legume type and Cropping System on Sorghum-legume intercropping.

CS	Legumes Grain yield T/ha			Sorghum Grain yield T/ha			Sorghum LER			Legume LER			Total LER		
	M	**S**	**C**	**M**	**S**	**C**	**M**	**S**	**C**	**M**	**S**	**C**	**M**	**S**	**C**
SSB	1.28f	1.24fg	1.26d	3.33a	3.47a	3.4b	0.52ab	0.58a	0.55a	0.79a	0.8a	0.79a	1.31ab	1.39a	1.34ab
SHB	1.46ef	1.54ef	1.5cd	3.22a	3.39a	3.30b	0.42b	0.46ab	0.44a	0.76a	0.78a	0.77a	1.18b	1.24ab	1.25b
SMB	1.29f	1.18g	1.23d	3.28a	3.46a	3.37b	0.62ab	0.32b	0.42a	0.78a	0.80a	0.79a	1.4ab	1.11b	1.21b
SCP	1.88de	1.76e	1.8cd	3.73a	3.93a	3.83ab	0.63a	0.64a	0.63a	**0.88a**	**0.90a**	**0.89a**	1.44a	1.46a	1.45a
Sl SR	-	-	-	4.23a	4.34a	4.29a	-	-	-	-	-	-			
Sl SB	2.47c	2.12d	2.3bc	-	-	-	-	-	-	-	-	-	-	-	-
Sl HB	3.49a	3.36b	3.43a	-	-	-	-	-	-	-	-	-	-	-	-
Sl MB	2.08cd	3.73a	2.91ab	-	-	-	-	-	-	-	-	-	-	-	-
Sl CP	2.98b	2.78c	2.88ab	-	-	-	-	-	-	-	-	-	-	-	-
P	**	**	**	Ns	ns	**	**	**	ns	ns	ns	ns	**	**	**
LSD	**2.87**	**2.21**	**1.65**	**10.33**	**9.86**	**9.53**	**.147**	**.127**	**.163**	**.101**	**.125**	**.054**	**.177**	**.159**	**.164**
S.e	**0.96**	**0.74**	**0.85**	**.289**	**.565**	**1.545**	**.04**	**.034**	**.057**	**.027**	**0.034**	**.019**	**.048**	**.043**	**.057**
CV	**5.58**	**4.11**	**4.79**	**.969**	**1.896**	**4.34**	**8.7**	**8.8**	**8.62**	**11.86**	**5.24**	**4.09**	**4.51**	**7.89**	**7.51**

Means within a column followed by the same letter(s) are not significantly different;*** = very highly significant at **P**< 0.001; ** = highly significant at **P**< 0.01; * = significant at **P**< 0.05; **ns** = non-significant at **P** e" 0.05; **CS=** Cropping System; **SSB=** Sorghum Soybean Intercropping; **SHB=** Sorghum Haricot Bean; **SMB=** Sorghum Mung Bean; **SCP=** Sorghum Cowpea; **Sl SR**= Sole sorghum; **Sl SB=** Sole Soybean; **Sl HB=** Sole Haricot bean**; Sl MB=** Sole Mung bean**; Sl CP=** Sole Cowpea**; LER=** Land Equivalent Ratio; **M=** Metema; **S=** Sanja; **C=** Combined over locations; **LSD**= Least Significant Difference; **SE** = standard error; **CV** = coefficient of variation.

Table 3: Yield Components of Soybean, Haricot bean, Mung bean and Cowpea as influenced by Sorghum-legume intercropping.

Trt	Legume above ground dry biomass			Sorghum above ground dry biomass			Legume Hundred grainweight(g)			Sorghum 1000-grain weight(g)		
	M	**S**	**C**	**M**	**S**	**C**	**M**	**S**	**C**	**M**	**S**	**C**
SSB	48.53a	45.67b	47a	15.56a	15.27a	15.42a	12.80b	15.47bc	14.13c	31.18a	31.61a	31.39a
SHB	10.37c	10.7e	10.53d	9.53b	13.64a	11.58b	16.86a	17.74ab	17.30ab	23.69bc	23.95bc	23.82c
SMB	19.37bc	10.67e	15.02c	11.21ab	13.39a	12.30ab	5.56c	5.85d	5.71d	22.82c	22.61c	22.7c
SCP	13.0c	13.5de	13.25cd	14.96a	14.55a	14.76ab	12.96b	13.63c	13.3c	28.56ab	28.50ab	28.53b
Sl SR	-	-	-	14.85a	15.40a	15.13a	-	-	-	28.38ab	29.47a	28.93b
Sl SB	51a	51a	51a	-	-	-	15.84a	17.33ab	16.59ab	-	-	-
SlHB	13.58c	12.58de	13.08cd	-	-	-	17.22a	18.12a	17.67a	-	-	-
Sl MB	23.53b	24.13c	23.58b	-	-	-	6.05c	6.03d	6.04d	-	-	-
Sl CP	15.5bc	14.97d	15.23c	-	-	-	15.17ab	16.68ab	15.92b	-	-	-
P	**	**	**	**	Ns	**	**	**	**	**	**	**
LSD	**6.20**	**2.51**	**3.05**	**8.11**	**7.54**	**7.64**	**1.74**	**1.64**	**1.09**	**4.63**	**4.08**	**4.15**
S.e	**2.08**	**0.84**	**1.11**	**.875**	**.89**	**.88**	**0.59**	**0.55**	**0.4**	**1.02**	**0.91**	**0.60**
CV	**10.49**	**4.51**	**8.12**	**2.937**	**2.986**	**2.47**	**5.6**	**4.86**	**5.15**	**3.42**	**3.04**	**1.69**

Means within a column followed by the same letter(s) are not significantly different;*** = very highly significant at **P**< 0.001; ** = highly significant at **P**< 0.01; * = significant at **P**< 0.05; **ns** = non-significant at **P** e" 0.05; **CS=** Cropping System; **SSB=** Sorghum Soybean Intercropping; **SHB=** Sorghum Haricot Bean; **SMB=** Sorghum Mung Bean; **SCP=** Sorghum Cowpea; **Sl SR**= Sole sorghum **; Sl SB=** Sole Soybean; **Sl HB=** Sole Haricot bean**; Sl MB=** Sole Mung bean**; Sl CP=** Sole Cowpea**; M=** Metema; **S=** Sanja; **C=** Combined over locations; **LSD**= Least Significant Difference; **SE** = standard error; **CV** = coefficient of variation.

Table 4: Area Time Equivalent Ratio (ATER) and Temporal Niche Differentiation (TND) as influenced by Legume type and Cropping System on Sorghum-legume intercropping.

CS	Legume ATER			Sorghum ATER			Total ATER			Sorghum TND			Legume TND		
	M	**S**	**C**	**M**	**S**	**C**	**M**	**S**	**C**	**M**	**S**	**C**	**M**	**S**	**C**
SSB	0.36ab	0.41c	0.38ab	0.79a	0.8a	0.79a	1.15a	1.20a	1.17ab	0.69a	0.69a	0.69a	0.31a	0.31a	0.31b
SHB	0.26a	0.28b	0.27b	0.76a	0.78a	0.77a	1.02a	1.06a	1.04b	0.61a	0.62a	0.61b	0.39a	0.38a	0.39a
SMB	0.40a	0.21b	0.31ab	0.78a	0.8a	0.79a	1.18a	1.0a	1.09b	0.65a	0.65a	0.65ab	0.35a	0.35a	0.35ab
SCP	0.41a	0.42a	0.42a	0.89a	0.91a	0.9a	1.3a	1.33a	1.32a	0.65a	0.65a	0.65ab	0.35a	0.35a	0.35ab
P	**	**	**						**	ns	ns	**	ns	ns	**
LSD	**.094**	**.085**	**.107**	**0.295**	**.282**	**.131**	**.309**	**.301**	**.166**	**.118**	**.097**	**.049**	**.118**	**.097**	**.049**
S.e	**.025**	**.023**	**.037**	**0.08**	**.076**	**.045**	**.083**	**.081**	**.058**	**.032**	**.026**	**.017**	**.032**	**.026**	**.017**
CV	**8.45**	**8.39**	**8.2**	**11.85**	**11.39**	**10.72**	**8.81**	**8.62**	**8.1**	**6.0**	**4.9**	**4.5**	**11.2**	**9.3**	**8.5**

Means within a column followed by the same letter(s) are not significantly different; ** = highly significant at **P**< 0.01; * = significant at **P**< 0.05; **ns** = non-significant at **P** e" 0.05; **CS=** Cropping System; **SSB=** Sorghum Soybean Intercropping; **SHB=** Sorghum Haricot Bean; **SMB=** Sorghum Mung Bean; **SCP=** Sorghum Cowpea; **ATER**=Area Time Equivalent Ratio; **TND=** Temporal Niche Differentiation **M=** Metema; **S=** Sanja; **C=** Combined over locations; **LSD**= Least Significant Difference; **SE** = standard error; **CV** = coefficient of variation.

Table 5: Aggressively Index (AI) and Competition Ratio (CR) as influenced by Legume type and Cropping System on Sorghum-legume intercropping.

CS	Aggressively						Competition Ratio					
	Legume			Sorghum			Sorghum CR			Legume CR		
	M	**S**	**C**	**M**	**S**	**C**	**M**	**S**	**C**	**M**	**S**	**C**
SSB	-0.54a	-0.43	-0.48a	0.54a	0.43a	0.48a	1.52ab	1.37b	1.45bc	0.66a	0.73a	0.69ab
SHB	-0.68a	-0.64a	-0.66a	0.68a	0.64a	0.66a	1.82a	1.7ab	1.76ab	0.55a	0.59ab	0.57b
SMB	-0.32a	-0.96a	-0.64a	0.32a	0.96a	0.64a	1.26b	2.53a	1.9a	0.80a	0.40b	0.60b
SCP	-0.51a	-0.55a	-0.53a	0.51a	0.55a	0.53a	1.28b	1.31b	1.3c	0.79a	0.78a	0.79a
P	Ns	ns	ns	ns	ns	ns	ns	**	**	**	**	**
LSD	**.66**	**.598**	**.425**	**.66**	**.598**	**0.425**	**0.336**	**0.589**	**0.263**	**0.21**	**0.203**	**.121**
S.e	**.178**	**.161**	**.147**	**.178**	**.161**	**0.147**	**0.10**	**0.157**	**0.088**	**.063**	**0.06**	**0.41**
CV	**8.45**	**8.39**	**8.2**	**16.55**	**17.65**	**18.44**	**8.74**	**11.11**	**9.54**	**10.82**	**11.42**	**10.59**

Means within a column followed by the same letter(s) are not significantly different; ** = highly significant at **P**< 0.01; * = significant at **P**< 0.05; **ns** = non-significant at **P** e" 0.05; **CS=** Cropping System; **SSB=** Sorghum Soybean Intercropping; **SHB=** Sorghum Haricot Bean; **SMB=** Sorghum Mung Bean; **SCP=** Sorghum Cowpea; **ATER**=Area Time Equivalent Ratio; **CR=** Competition ratio; **M=** Metema; **S=** Sanja; **C=** Combined over locations; **LSD**= Least Significant Difference; **SE** = standard error; **CV** = coefficient of variation.

Table 6:@Sorghum Equivalent Yield, Relative Production Efficiency (RPE), Relative Economic Efficiency (REE) and Gross Monetary Value (GMV)) as Influenced by Legume type and Cropping System on Sorghum-legume intercropping.

CS	SEY			RPE			REE			GMV		
	M	S	C	M	S	C	M	S	C	M	S	C
SSB	5.79a	5.85a	5.82bc	37.31a	35.06a	36.18bc	21.26a	18.4a	19.83b	75230a	75983a	75606b
SHB	6.03a	6.35a	6.19ab	42.61a	46.26a	44.44ab	29.54a	36.67a	33.11ab	76370a	80139a	78223a
SMB	5.26a	5.27a	5.26c	24.64a	21.51a	23.07c	3.19a	-2.41a	0.39b	68364a	68475a	68419b
SCP	6.63a	6.64a	6.63a	57.79a	53.98a	55.88a	57.84	51.22a	54.53a	89425a	89278a	89352a
P	**	**	**	ns	ns	**	ns	ns	**	**	**	**
LSD	**1.35**	**1.34**	**.624**	**33.68**	**32.94**	**15.31**	**58.71**	**56.18**	**26.4**	**21435**	**17474**	**8992**
S.e	**.353**	**.361**	**.217**	**9.08**	**8.89**	**5.32**	**15.84**	**15.16**	**9.17**	**5782**	**4713**	**3124**
CV	**7.54**	**7.33**	**6.9**	**25.4**	**24.5**	**23.1**	**26.4**	**27.5**	**26.5**	**9.16**	**7.36**	**7.7**

Means within a column followed by the same letter(s) are not significantly different;*** = very highly significant at **P**< 0.001; ** = highly significant at **P**< 0.01; * = significant at **P**< 0.05; **ns** = non-significant at **P** e" 0.05; **CS**= Cropping System; **SSB**= Sorghum Soybean Intercropping; **SHB**= Sorghum Haricot Bean; **SMB**= Sorghum Mung Bean; **SCP**= Sorghum Cowpea; **SEY**= Sorghum Equivalent Yield; **RPE**= Relative Production Efficiency; **REE**= Relative Economic Efficiency; **GMV**= Gross Monetary Value; **MAI**= Monetary Advantage Index; **M**= Metema; **S**= Sanja; **C**= Combined over locations; **LSD**= Least Significant Difference; **SE** = standard error; **CV** = coefficient of variation.

Greater TND in intercrops showed differential resource demands between component crops at different times that resulted in higher yields of both component crops Yu [16]. Baker and Yusuf [36]suggested that there should be at least a 30 to 40-day maturity difference between the component crops to get the intercropping advantages.

The reason LER is more than unity is perhaps because of fixing and absorbing nitrogen in intercropping sorghum and legumes. The present findings are in line with Koocheki [37] in intercropping corn/bean. In wheat/lentil, Akter [38] obtained maximum LER in lentil and wheat cropping system. Higher LER in intercropping than sole cropping was observed in maize/soybean by Ullah [39]. Growth resources were efficiently used by the crops and their nitrogen fixation and increased light use efficiency make this increment [40].

Aggressivity and competitive ratio

The competitive ability of the four legume crops and sorghum intercropping shows highly significant variation ($P < .01$) and depended on the crop architecture (Table 5). In all treatments, the CR of sorghum and legumes were above one. This highest value of CR indicated sorghum's superior ability of competition. The highest CR was 2.53 in sorghum/mung bean intercropping. Finally, a poor competitor in association with sorghum than the four legumes tested is mung bean. The aggressively index (A) and the CR clearly confirm sorghum was dominant in its intercrop with legumes (Table 5).

The Competition between component crop values was highly significant due to legume type and value ranges 0.4–0.8 and 1.26–2.53 for legumes and sorghum, respectively. This shows that sorghum was more competent in the intercropping with legumes. Mung bean and cowpea were better than haricot bean and soybean. Yu [16]reported that non-legume–legume intercropping systems have wide TND results in low competition in growth resources between them.

Relative Production Efficiency (RPE), Relative Economic Efficiency (REE) and Gross Monetary Value

Broadly, the ATER and sorghum equivalent yield (SEY) were higher when sorghum intercropped with cowpea than when intercropped with other legumes (Table 4), which might be due to the greater ability of cowpea to smother and suppression effect on *Striga*.

The RPE, REE, and GMV were statistically highly significant due to the effects of legume types intercropped with sorghum. The highest GMV 89,425.00 ETB per ha (LER = 1.44) and lowest GMV

Table 7: Soil physicochemical properties of experimental areas before planting in 2017/18

Soil properties	Metema	Sanja	Category/rating	Optimum rate of Sorghum
pH (H_2O)	6.81	6.75	Neutral	5.5 – 8.5
Total N (%)	0.11	0.12	Low	2.4 – 3.5
CEC (cmol(+) kg^{-1})	76.50	74.5	Very High	High
Avail. P (ppm)	3.87	3.58	Low	3 – 6
Organic carbon (%)	2.80	2.75	High	High
Exch. K^+ (cmol(+) kg^{-1})	0.51	0.50	Medium	Medium
Particle distribution				
Clay (%)		43.28	44	
Sand (%)		26.00	25	
Silt (%)		30.72	31	
Textural class	Clay	Clay		

CEC = cation exchange capacity; P = phosphorus; K = potassium; ppm = part per million; pH = potential of hydrogen; @Blake and Hartge (1986); #Panda (2010); *London (1991)

68364.00 ETB per ha (LER= 1.11) were obtained in sorghum/cowpea and sorghum/mung bean intercropped, respectively (Table 6).

The maximum intercropping GMV was related to cowpea/sorghum and soybean/sorghum with 89,425 and 68,419 ETB, respectively (Table 6). The reason for this result can be the better use of resources such as light, water, and nutrients in these treatments. Higher monetary returns in maize soybean cropping system from intercropping than sole maize was reported by Wondimu [41]and Alice [42]. Biruk[43]in sorghum/common bean reported that intercropping was more advantageous than sole cropping of either common bean or sorghum.

The sorghum/cowpea intercropped generated higher and positive RPE and REE results compared with other intercropping legumes (Table 6). Specifically, among all intercrops, sorghum/cowpea intercropped gave the maximum positive RPE (57.79%) and REE (57.84%). Intercrops were superior to the existing sole crops. Intercropping studies such as cotton–radish and cluster bean-beet root by Sankaranarayanan [17] had also shown higher RPE and REE compared with the respective existing sole cropping system.

CONCLUSION

In general legume intercropping has resulted in lower *Striga* infestation, for better growth and yield of sorghum. Highest *Striga* number and dry matter were recorded in sole sorghum, although there was variability in legume type, cowpea supported the least *Striga.* The relatively lower number of *Striga* counts in sorghum/legume intercropping indicates the capacity of *Striga* seed bank decreasing in the soil. Yield components of sorghum were significantly differed in intercropping. The low *Striga* count coupled with the high sorghum yield in the intercrops can be attributed to the effectiveness intercropping in *S. hermonthica* controlling and the effectiveness of the system.

The productivity of sorghum-cropping systems can be improved by intercropping cowpea between sorghum plants as the high LER and GMV confirmed the system profitability. LER of the system is greater than one in sorghum/cowpea, this indicates that intercropping was advantageous as a result of higher exploitation of limited resources. Highest grain yield, above-ground dry biomass, and thousand seed weights were obtained from sorghum/cowpea treatment. Therefore, based on the economic evaluation and statistical analysis sorghum/cowpea can be recommended for the study area.

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