Available online at www.worldscientificnews.com

World Scientific News

WSN 53(3) (2016) 204-215 EISSN 2392-2192

Influence of intercropping sorghum with legumes to control striga (*Striga hermonthica*) in Pawe, North Western Ethiopia

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ABSTRACT

Striga hermonthica, is a major constraint to sorghum production in Sub-Saharan Africa. The study was conducted to assess the potential role of intercropping sorghum with different legumes for control of striga. Two types of cropping system (simultaneous and relay) and two row arrangements (single and double alternate) were used for intercropping with groundnut and soybean. The experiment included a standard treatment of sole crop of sorghum, grou dnut and soybean. The experiment was laid out in a randomized complete block design (RCBD) with three replications for two cropping seasons of 2014 and 2015. From the result intercropping of sorghum with soybean and groundnut has significantly reduced the striga counts per plot as compared to sole sorghum. Lowest number of striga count (29.5) at vegetative stage and (19.7) at heading stages was recorded from simultaneous cropping of sorghum-soybean in double alternate row arrangements. The combined analysis result showed that sorghum grain yield and its components were significantly ($P \leq 0.05$) affected by intercropping with groundnut and soybean. Significantly higher ($P < 0.05$) grain yield of sorghum (1.9 t ha^{-1}) was obtained from single alternate row arrangement of sorghum-groundnut in relay intercropping. The study also demonstrated sorghum yield increment by 29.1% over the control sole crop. Higher yield was obtained from soybean intercropped with sorghum compared to groundnut due to higher competition for growth resources with sorghum. Land equivalent ratio of the system indicates that in both seasons of soybean and groundnut intercropped with sorghum resulted in a significant greater LER. The mean LER (1.9) of the system indicates that intercropping sorghum with this legume crops gave yield advantage and land productivity.

***Keywords*:** Striga; Sorghum; Soybean; Groundnut; LER

1. INTRODUCTION

Striga hermonthica (Del.) Benth (*Scrophulariacae*) is one of the major production constraints to sorghum, millet, rice and maize production in the dry land zones of Africa (Rao and Musselman, 1987; Gebisa, 2007). It is also a problem in the subsistence agriculture regions of Ethiopia. The problem in those areas is aggravated by the inherent low soil fertility, recurrent drought and overall natural resource degradation because of decades of continuous cereal monoculture and deforestation. The spread of striga has increased with a consequent decrease in food production in many countries (Fasil, 2002). The losses attributed to striga weed range between 30 and 100 percent in most areas (Gebisa, 2007), and are often exacerbated by low soil fertility. In traditional African cropping, prolonged fallow, crop rotation and intercropping were the common practices that kept Striga infestation in tolerable level. This parasitic weed cause estimated yield losses that range from 40 to 100% when the infestation is very serious, especially in northern, north western and western parts of the country where sorghum cropping is the most suitable choice for farmers (Kidane, 2014) (Figure 1).

Figure 1. *Striga hermonthica*

The most damaging species in sub-Saharan Africa is *Striga hermonethica* which affects maize, sorghum, rice, finger millet and sugarcane. *Striga* is difficult to control as it produces numerous tinny seeds which can remain viable in the soil for up to 20 years (Worshan and Egley, 1990). In fact, *Striga* produces a lot of toxins that interfere with other crop species. Seeds are stimulated by crop exudates to germinate and infest the host crop while reproducing and increasing the *Striga* seed bank in the soil, thus; escalating the reduction of yields (Okonkwo, 2006).

In Ethiopia, Sorghum is the third most important cereal crop in terms of area of production next to tef *Eragrostis tef* (Zucc.) Trotter] and maize (*Zea mays* L.) (CSA, 2012). Sorghum is one of the most widely grown staple cereal crops on which the lives of millions of poor Ethiopians depend. Sorghum was cultivated on 1.78 million ha with a production of 3.47 million metric tons and the average yield of 1.95 t /ha during 2010-11(CSA, 2012). Sorghum grain is mostly used for local markets and most of the sorghum produced in Ethiopia is consumed at household levels. It is one of the leading traditional food crops ranking third in the country following *teff* and maize and second to *teff* for its *injera* (national pancake or bread) making quality (Tewdros *et al*., 2005). It is one of the most important cereal crops of the tropics grown extensively over wider areas with altitude range from 1400 to 2100 meters above sea level (m.a.s.l). Sorghum is the major source of energy and protein for millions of people living in the arid and semi - arid regions of the world. It occupied third position in Africa after maize and wheat and fifth in the world after maize, rice, wheat and barley (FAO, 2009). Its ability to adapt to adverse environmental conditions has made sorghum a popular crop worldwide. The crop plays a significant role for millions of poor Ethiopians (Asfaw, 2007) and grows in a wide range of agro-climatic zones, especially in the lowlands.

Sorghum is a major food crop grown in Metekel zone, accounting for about 26.5% area coverage (2010/11 crop assessment data from BOA). Ethiopian national average yield of sorghum amounts to 1302 kg/ha (CSA, 2005). As compared to the national average the yield obtained from the area is low. Despite its importance in the livelihood of Ethiopians, sorghum production is constrained by different biotic and abiotic factors. The major sorghum production constraints include low soil fertility, weeds particularly striga, insect mainly stalk borer (*Busseola fusca* and *Chilo partellus*) and birds.

In general, to alleviate yield loss due to striga infestation and to have optimum crop productivity and to ensure food self-sufficiency in the region, agricultural research activities should focus on integrated agronomic striga control measures. Therefore, this research was initiated for effective control of striga using legume crops for intercropping with sorghum.

2. MATERIALS AND METHODS

The study was conducted on selected farmer's fields where striga infestations have been relatively higher at all cropping season. Eleven treatments were laid out in randomized complete block design (RCBD) with three replications. The treatments were included two legumes (soybean (SB) and groundnut (GN)), two spatial arrangements of sorghum to legume rows ratio (1:1 (SA) and 2:1 (DA)), and two temporal arrangements (Simultaneous (S) and relay (R) planting (planting legumes 3-4 weeks after sorghum planting)). In addition sole stand of all crops (the legumes and sorghum) were included as a treatment in all replications. Each experimental plot was 6 m x 3.75 m (22.5 m^2) in size and there were 1m and 1.5 m space between plots and blocks respectively. Local sorghum variety was used for the experiment called "Bobe" due to its sensitiveness to striga infestation, and is widely grown in the districts having high grain yielding potential relative to other varieties. The legumes used were soybean Belessa-95 and groundnut variety called Manipitor which are widely adapted and grown in the area. Sorghum was sown at a spacing of 75 x 15 cm. soybean was drilled at a spacing of 5cm with 60cm interspace and groundnut was sown at a spacing of 40 x 10 cm in sole stands. For both spatial arrangements of 1:1 and 2:1 legumes were planted at 37.5 cm between sorghum rows. Same operations were performed in the following years. Planting was done on early June for sorghum and as a treatment for the legumes simultaneously and relay cropping at both seasons.

All crops were hand weeded at weeding time followed by a careful hand-pulling of other weeds except striga. Fertilizer was applied for both sole and intercropped sorghum using the recommended rate (64:46 kg N: P_2O_5 ha^{-1}). DAP was applied at the rate of 100 kg ha^{-1} (18 kg N and 46 kg P_2O_5 ha^{-1}), at planting. Urea at the rate of 100 kg ha^{-1} (46 kg N ha^{-1}) was applied as top dressing in two splits one-third at 20 days after sorghum emergence (DAE), and two third was applied 6 WAS.

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.

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

2. 1. Data Analysis

All data collected were subjected to analysis of variance (ANOVA) to assess treatment effects (Gomez and Gomez, 1984) and the significant differences between means were determined by LSD at 5% probability level using SAS version 9. To reduce variation in the results of *Striga* count; and make data analysis valid, the data were transformed using square root transformation ($\sqrt{}$ x + 0.5).

3. RESULT AND DISCUSSION

3. 1. Influence of intercropping on number of Striga

Striga counts were generally lower in the intercrops than in the control plots of sole sorghum. Number of striga per m^2 did not show any significant differences at ($P < 0.05$) among treatments over years (Table 1). Intercropping legumes (soybean and groundnut) with sorghum have negatively affect number of striga per m^2 as compared to the sole sorghum though it's not statistically significant. Similarly, Reda *et al*. (2005) found no significant control of *Striga* through intercropping sorghum with different legumes. Also these results corroborate the findings of Oswald *et al*, (2002) who assessed *Striga* control potential of different legumes in different planting arrangements with maize and concluded that reduction in *Striga* populations was not significantly observable. Similar observations were made in sorghum where seasonal *Striga* counts were generally lower in the intercrops than in the control plots Zeyaur R. *et al* (2007).

However lower number of striga was only counted in double alternate simultaneous sorghum-soybean intercrop as compared to single alternate arrangement in sorghum-soybean simultaneous cropping. Neither simultaneous nor relay cropping's were showed significant differences in this study. Large number of striga in the control plots at vegetative stage agrees with the findings of Gurney *et al*. (1999) where early stage striga infestation had more negative effect on the host plant than late infestation. At the later growth stage of sorghum (heading stage) the number of striga per m^2 were decreased as compared with the early stage. The lower number of striga at this stage was attributed to the shading effect created by the vigorous growth of sorghum and by the intercropped legumes through single and double alternate arrangements.

Over years combined analysis result of mean striga number in 2014 indicated higher number of striga/m^2 (7.9) and (5.8) were recorded at vegetative stage as compared to 2015 (2.6) and (3.6) at heading stages. These finding testifies that inclusion of legumes in cereal based cropping system has beneficial effect in reducing the striga incidence.

Table 1. Influence of sorghum-legume intercropping on number of striga at vegetative and heading stages.

Treatment	Number of Striga per m^2	
	At vegetative stage	At heading stage
1) S-SB-SA	5.4(38)	5.3(29.2)
2) S-SB-DA	4.6(29.5)	4.3(19.7)
3) S-GN-SA	5.1(34.3)	4.9(28.5)
4) S-GN-DA	4.9(32.7)	4.2(24.7)
5) R-SB-SA	5.7(38)	4.3(19)
6) R-SB-DA	5.4(35.5)	4.4(20.7)
7) R-GN-SA	4.9(32.7)	4.7(25.7)
8) R-GN-DA	5.4(36.2)	4.9(28)
9) SLS	6.0(43.8)	5.4(37.2)
CV (%)	26.9	33.6
LSD (0.05)	ns	ns

Numbers in the parenthesis are original data (data before square root transformation).

NB. Simultaneous cropping of soybean-sorghum in single alternate row arrangement (S-SB-SA), Simultaneous cropping of groundnut-sorghum in double alternate row arrangement (S-GN-DA), relay cropping of soybean-sorghum in double alternate row arrangement (R-SB-DA), relay cropping of groundnut-sorghum in single alternate row arrangement (R-GN-SA) and susceptible local sorghum (SLS).

Though there is no statistical difference among the treatments in (Table 1) sole sorghum had relatively highest number of striga per m^2 of all the other sorghum treatments. In line with this result (Aliyu and Emechebe, 2006) has found significantly ($P \leq 0.05$) highest number of striga per plot in sole sorghum. The result in (Table 2) indicated that number of striga was not significantly influenced by different intercropping types and row arrangements in 2014 at both stages. While in 2015 striga number was significantly ($P \leq 0.05$) influenced at heading stage rather than vegetative stage.

Table 2. Influence of sorghum-legume intercropping on number of striga.

Treatment	Number of Striga per m^2 in 2014		Number of Striga per m^2 in 2015	
	At vegetative stage	At heading stage	At vegetative stage	At heading stage
1) S-SB-SA	2.73	2.87	8.00	7.97^{a}
2) S-SB-DA	1.83	3.47	7.33	5.23^{b}
3) S-GN-SA	2.27	3.53	7.90	6.37^{ab}
4) S-GN-DA	1.87	2.47	7.87	6.10^{ab}
5) R-SB-SA	3.60	4.03	8.40	4.57^{b}
6) R-SB-DA	2.87	3.63	7.90	5.13^{b}
7) R-GN-SA	2.10	4.00	7.87	5.33^{b}
8) R-GN-DA	2.83	4.00	7.90	5.97^{ab}
9) SLS	3.37	4.50	8.00	6.10^{ab}
CV (%)	50.2	42.9	23.2	25.1
LSD (0.05)	ns	ns	ns	2.55

NS-Non significant, Values along column followed by the same letter (s) are not significantly different ($P < 0.05$)

NB. Simultaneous cropping of soybean-sorghum in single alternate row arrangement (S-SB-SA), Simultaneous cropping of groundnut-sorghum in double alternate row arrangement (S-GN-DA), relay cropping of soybean-sorghum in double alternate row arrangement (R-SB-DA), relay cropping of groundnut-sorghum in single alternate row arrangement (R-GN-SA) and susceptible local sorghum (SLS).

3. 2. Influence of intercropping on sorghum yield and yield attributes

The data on grain yield, biomass, plant height and thousand seed weights of sorghum showed significant differences at ($P \leq 0.05$) among treatments (Table 3).

Grain yield - Relay intercropping of sorghum-groundnut with single and double alternate arrangement gave significantly higher ($P < 0.05$) grain yield of (1.9 t ha^{-1}) and (1.7 t ha^{-1})

respectively than simultaneous cropping of soybean with sorghum in single alternate row arrangements. The yield increment obtained from these treatments over the control sole sorghum was also 29.1% and 19.4% respectively. The pronounced response of sorghum grain yield to intercropping with groundnut in single and double alternate row arrangements might be attributed to the effectiveness of the groundnut trap crop in stimulating the suicidal germination of the striga seeds which would have otherwise attacked and reduced the productivity of the host plant. Aliyu and Emechebe, (2006) pointed out that higher grain yield may also be attributed to the effectiveness of cropping system, which not only reduce the striga seed bank but also increased the nitrogen supply to the host crop.

***Biomass yield* –** In a similar trend to the grain yield, above ground biomass of sorghum also showed high variation among treatments (Table 3). Relay intercropping of sorghum with groundnut in double alternate row arrangement yielded 25521 kg/ha, also resulted in a 10.6% increment over the control. Plots intercropped with treatments produced a significantly ($P < 0.05$) higher aboveground biomass even than relay intercropping of sorghum/ groundnut in single alternate row arrangement. This could be attributed by lower number of plant leaves and stunted growth of sorghum due to the negative impact of striga on sole sorghum.

***Thousand seed weight* –** seed weight of sorghum was significantly ($P < 0.05$) influenced by all the treatments. Plots intercropped with groundnut in relay cropping of single alternate arrangement recorded significantly higher seed weight than their respective treatments. While the least thousand seed weight of sorghum was recorded from relay cropping of sorghum/soybean under double alternate arrangements. Where these results are might be due to the planting time of legumes which was one month after sorghum which might reduce competition for resource. And the row arrangements of legumes where higher seed weight of sorghum was obtained from single alternate row arrangement.

Plant height – sorghum plant height increased in all treatments of intercropping with groundnut and soybean. Significantly lowest plant height (2.36 m) was recorded from the control sole sorghum. Though the difference was not significant among the intercrop treatments except the control, the highest plant height was recorded from sorghum intercropped with groundnut in relay cropping of single (3.03 m) and double (3.02 m) alternate arrangements.

Table 3. Influence of sorghum-legume intercropping on yield, biomass, thousand seed weight and plant height of sorghum.

Treatment	Grain yield (kg/ha)	Biomass yield (kg/ha)	1000 seed weight (gm)	Plant height (m)
1) S-SB-SA	1307.9^{b}	22914^{ab}	22.1^{ab}	2.88^{a}
2) S-SB-DA	1456.8^{ab}	184499^{b}	22.8^{ab}	2.96^{a}
3) S-GN-SA	1766.0^{ab}	23842^{ab}	22.2^{ab}	3.00^{a}
4) S-GN-DA	1586.5^{ab}	21373^{ab}	22.1^{ab}	2.93^{a}

5) R-SB-SA	1667.0[ab]	21946[ab]	22.2[ab]	2.84[a]
6) R-SB-DA	1547.7[ab]	21215[ab]	21.5[b]	2.86[a]
7) R-GN-SA	1912.7[a]	23644[ab]	25.3[a]	3.03[a]
8) R-GN-DA	1769.2[a]	25521[a]	22.8[ab]	2.90[a]
9) SLS	1481.2[ab]	23072[ab]	22.9[ab]	2.80[b]
CV (%)	24.4	23.3	10.112.1	9.7
LSD (0.05)	458.6	6103.6	6.63.22	0.33

NS-Non significant, Values along column followed by the same letter (s) are not significantly different ($P < 0.05$)

NB. Simultaneous cropping of soybean-sorghum in single alternate row arrangement (S-SB-SA), Simultaneous cropping of groundnut-sorghum in double alternate row arrangement (S-GN-DA), relay cropping of soybean-sorghum in double alternate row arrangement (R-SB-DA), relay cropping of groundnut-sorghum in single alternate row arrangement (R-GN-SA) and susceptible local sorghum (SLS).

3. 3. Influence of intercropping on yield of legumes

Both soybean and groundnut planted as pure stands recorded greater yield of (1190.1 kg/ha and 1115.3 kg/ha respectively) than that produced from intercropped with sorghum (Table 4). The higher yield of sole soybean and groundnut 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 intercrops higher grian yield was recorded by soybean (1123.2 kg/ha) when intercropped with sorghum in simultaneous single alternate row arrangements, followed by relay croppings of sorghum-soybean. Grain yield of groundnut was recorded relatively lower in intercropping with sorghum due to severe competition for growth resources.

3. 4. Land equivalent ratios (LER)

Intercropping sorghum with groundnut and soybean at both seasons resulted in a significant greater unit (above 1). In all intercropping types and arrangements individual LER and the mean (1.9) for sorghum/soybean and for sorghum/groundnut (2.0) have highest LER values. LER greater than one are considered to be more efficient systems from a land use point of view than monocrops (Willey, 1979). The highest LER in sorghum/groundnut could be attributed to the highest land coverage of groundnut 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 mono crop.

Table 4. Yield of sorghum, soybean and groundnut and land equivalent ratio (LER) as influenced by cropping system and row arrangements on sorghum-legume intercropping.

cropping system	Sorghum grain yield kg/ha	Soybean grain yield kg/ha	Groundnut grain yield kg/ha	LERs	LERg
S-SB-SA	1307.9	1123.2	-	1.8	-
S-SB-DA	1456.8	1077.0	-	1.9	-
S-GN-SA	1766.0	-	1010.4	-	2.1
S-GN-DA	1586.5	-	1026.3	-	1.9
R-SB-SA	1667.0	1077.2	-	2.0	-
R-SB-DA	1547.7	1077.2	-	1.9	-
R-GN-SA	1912.7	-	959.8	-	2.1
R-GN-DA	1769.2	-	911.7	-	2.0
sole sorghum	1481.2				
sole soybean		1190.1			
sole groundnut			1115.3		

NS-Non significant, Values along column followed by the same letter (s) are not significantly different ($P < 0.05$)

NB. Simultaneous cropping in single alternate row arrangement (Simultaneous-SA), Simultaneous cropping in double alternate row arrangement (Simultaneous-DA), relay cropping in single alternate row arrangement (Relay-SA), relay cropping in double alternate row arrangement (Relay-DA) and susceptible local sorghum (SLS).LERs = land equivalent ratio of soybean and LERg = land equivalent ratio of groundnut.

4. CONCLUSIONS

Intercropping sorghum with legumes consistently provides significant seasonal control of *Striga* and enhanced grain yields. The overall effect however showed that intercropping sorghum with soybean and groundnut led to a reduction in *Striga* number at simultaneous intercropping rather than relay cropping. Intercropping with these legumes therefore showed some promise as a suitable component of an integrated *Striga* management approach for the small holder farmers, but this would need to be combined with other cultural methods such as hand weeding of emerged *Striga* to avoid replenishment of *Striga* seed bank in the soil. Similar studies are also desirable in different environments to assess the performance of the legumes in an array of soil types under different *Striga* densities and moisture levels.

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(Received 24 July 2016; accepted 11 August 2016)

Appendix 1. Monthly rain fall of the trail site in 2014 and 2015 cropping season.