Effects of Intercropping Pearl Millet with Some Legumes on Striga Hermonthica Emergence

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Abstract

Striga hermonthica, (Del.) Benth, an obligate root parasitic plant, constitutes a major constraint to cereals production and a threat to agriculture and food security in sub-Saharan Africa. Many potential control methods were developed against the parasite including physical, cultural, chemical, and biological. However, so far these methods have only a limited impact on controlling Striga and today there is no single control method that can effectively solve this problem. The present investigation was undertaken at the College of Agricultural Studies (CAS), Sudan University of Science and Technology (SUST) at Shambat in 2015 – 2016 to determine the effects of intercropping pearl millet (Sudan Brawn and Wad-Elbshire cv.) with cowpea, green gram, and cluster bean on Striga millet strain incidence and pearl millet growth. Treatments were arranged in Complete Randomized Block Design with three replicates. The results showed that sole millet displayed highest Striga number while Striga number was generally lower in the intercrops. Cowpea intercropped with millet cultivars (Wad–Elbshire and Sudan Brown) at seedbank size of 32 and 64mg/pot, reduced Striga emergence by 57.1 -100%. Intercrops cluster bean with millet cultivars at Striga seedbank size of 32 mg/pot completely suppressed Striga emergence throughout the experiment. However, at Striga seedbank size of 64 mg/pot intercropping cluster bean with millet decreased Striga number by 28.3-70.9%. Green gram intercropped with millet cultivars, irrespective of seedbank size caused considerable reductions of Striga number (14.8-76.7%). All intercrops reduced Striga dry weight, in comparison to the sole millet. Intercropping cowpea with Wad-Elbashir, at Striga seedbank size of 32mg/pot increased significantly millet height by 82.4%. Intercropped Sudan Brown cultivar with cowpea and cluster bean at Striga seedbank size of 32mg/pot increased millet height by 35.7 and 35.1%, respectively. At Striga seedbank size of 64mg/pot, intercropping Wad–Elbashir with cluster bean decreased chlorophyll content significantly. At Striga seedbank size of 32mg/pot, intercropping Wad-Elbashir cultivar with cowpea and cluster bean increased millet dry weight. Cereal-legume intercropping and rotation could be used to combat S. hermonthica in cereals through induction of suicidal germination.

Keywords — *Striga hermonthica, suicidal germination, legumes, intercropping*

I. INTRODUCTION

Pearl millet (*Pennisetum americanum* (L.) belongs to family Poaceae, is one of the most widely cultivated cereals in the world, ranking sixth after rice (*Oryza Sativa* L.), wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), barley (*Hordeum vulgare* L.) and sorghum (*Sorghum bicolor* L) in terms of area planted to these crops (1). It is a principal cereal cultivated in tropical semi-arid regions of the world primarily in Africa and Asia (2). Pearl millet is extensively used in different countries as forage of high nutritional quality (3). However, the use of pearl millet as a food crop is limited to the developing countries in Asia and Africa. It is estimated that over 93% of pearl millet grain is used as food, the remaining divided between animal and poultry feed (7%) (1). Pearl millet is a source of energy, protein, vitamins and minerals for millions of poorest people in the regions where it is cultivated. It has 9 to13% proteins, but large variation among genotypes ranging from 6 to 21% (1).

In Sudan, millet is the second most important cereal crop, following sorghum, with about 12.4% share in total annual cereal production (4), but the third most important in terms of total availability and consumption (5). On average, over 90% of millet production is grown in traditional production systems. Pearl millet is the preferred staple food for the majority of inhabitants in Western Sudan (Kordofan and Darfur regions).

Pearl millet yield is by far below the international average (6). Paramount, among yield reducing factors, is poor soil fertility, low inputs and heavy infestations by root parasitic weed *Striga hermonthica* (Del.) Benth. are of paramount importance (6). *Striga* spp. are prevalent in over 50 million hectares of the cereals growing areas in Africa and inflict considerable damage amounting to

complete crop loss under heavy infestations (7). In Sudan *S. hermonthica* is a major biological constraint to the production of the staple crops of the majority, mainly sorghum and pearl millet (8). *S. hermonthica*, well adapted to its environment and tolerant to a wide range of temperature and soil moisture stress, has developed two distinct strains. The first, specific to pearl millet, is predominant in the drier northern regions of sub-Saharan Africa, while the second attacks sorghum and is found farther south in the wetter regions (7). *S. hermonthica* sorghum and millet strains differ in their response to natural germination stimulants (9).

Many potential control methods were developed against the parasite including physical, cultural, chemical, and biological. However, so far these methods have only a limited impact on controlling *Striga* and today there is no single control method that can effectively solve this problem. Cost effective alternative control methods that are acceptable to small-scale farmer are needed. The roots of several legumes are known to induce suicidal germination of *Striga* seeds. The potentials of cereal-legume intercropping and rotation to manage *Striga* infestation in cereals has been demonstrated under controlled, researcher managed conditions. The effectiveness of cereal/legume intercropping to influence *Striga* germination depends on the effectiveness of the produced stimulant/inhibitors, root development, fertility improvement, shading effect and its compatibility to Striga species because the response of *Striga* to management options is specific (10).

The objectives of this study are to determine the effects of intercropping pearl millet cultivars (Sudan Braun and Wad-Elbshire cv.) with different legumes via cowpea (Vigna ungiculata (L.) Walp), green gram (Vigna radiata L.), and cluster bean (Cyamopsis tetragonoloba L.) on suppression of *S. hermonthica* mille strain parasitism and pearl millet growth.

II. MATERIALS AND METHODS

A. General

A greenhouse experiment was undertaken at the College of Agricultural Studies, Sudan University of Science and Technology (SUST) at Shambat. The goals of the study was to determine the effects of intercropping Pearl millet cultivars (Sudan Braun and Wad-Elbshire) with cowpea, green gram, and cluster bean on *S. hermonthica* millet strain incidence and pearl millet growth.

B. Plant Materials

S. hermonthica seeds (pearl millet strain), were collected in 2012 from under pearl millet in Kordofan State Western Sudan. Seeds of two local Pearl millet cultivars (Sudan Braun and Wad-Elbshire), were obtained from the Agricultural Research Corporation (ARC), Wad-Medani, Sudan.

C. Green House Experiment

The Pot experiment was conducted in a greenhouse at the College of Agriculture Studies, (CAS), at Shambat during the season 2015/2016. The experiment was conducted under artificial *S. hermonthica* infestation. Artificial infestation of soil was achieved by mixing 2g of *Striga* seeds with 1kg soil, followed by subsequent dilution with *Striga* free soil to give the required infestation level (32 and 64 mg /pot). *Striga* free or infested soil was placed in plastic pots (13 cm i .d). Pots filled with *Striga* free soil (0 mg) were included as control for comparison. Pearl Millet cultivars (Sudan Braun and Wad-Elbshire cv.) were sown as sole crop or intercropped with cowpea, green gram, and cluster bean. Pearl millet, cowpea, green gram, and cluster bean seeds (5/pot) were sown at 2 cm soil depth. The pots were immediately irrigated. Subsequent irrigations were carried out every two days. Pearl millet, cowpea, green gram, and cluster bean seedlings were thinned to three plants per pot two weeks after sowing. Treatments were laid out in Randomized Complete Block Design (RCBD) with three replicates.

D. Data Collection

1) Striga

Treatments effects, unless mentioned otherwise, were assessed by determining i) number of Striga emergence per pot at 60 and 90 days after sowing (DAS) and ii) Striga dry weight per pot at harvest (g).

2) Pearl Millet

Data collected on Pearl millet growth attributes were taken 60 and 90 DAS. The data comprised of i) Plant height (cm), ii), number of tillers per plant iii) stem diameter (cm), and iv) shoot dry weight (g).

Average of SPAD readings at 3 points using a chlorophyll meter (SPAD-502, zKonica Minolta Sensing, Japan) was recorded for each leaf

III. STATISTICAL ANALYSIS

Data on millet growth and yield attributes and S. hermonthica millet strain were subjected to analysis of variance (ANOVA) and means were separated for significance by the Least significance Differences (LSD) at P> 5% using Statistic 8, statistical software, Version 2.0 (UK).

IV. RESULTS

A. Effects of Intercropping on S. Hermonthica Millet strain

1) Striga Emergence:

Statistical analysis showed significant differences at ($P < 0.05$) in number of *Striga* per pot between *Striga* seedbank size and also between intercrops. *Striga* count made 60 and 90 DAS showed that *Striga* emergence on millet cultivars display a progressive increase with seedbank size (Table 1). At 60 DAS, average *Striga* emergence on sole millet

Wad–Elbshire and Sudan Brown cultivars at seedbank size of 32 mg/pot was 2.7 and 4.3 plant /pot, respectively. However, increasing *Striga* seedbank size to 64mg/pot increased *Striga* emergence, however, the observed increase was not significant (Table 1).

60 DAS, at Striga seedbank size of 32 mg/pot, intercropping millet (Wad–Elbshire cv.) with cowpea and cluster bean resulted, no *Striga* emergence. However, intercropped Wad–Elbshire with green gram reduced *Striga* emergence by 11.8%, but not significantly. At seedbank size of 64 mg/pot, intercropping Wad–Elbshire with cowpea, cluster bean and green gram reduced *Striga* emergence by 72.3, 29.8 and 21.3%, respectively, albeit not significantly, as compared to the sole millet (Table 1). At 60 DAS, Sudan Brown intercropped with cowpea and green gram at *Striga* seedbank size of 32 mg/pot reduced number of Striga per pot, but not significantly and the observed reductions were considerable (62.8 -76.7 %). However, intercropping Sudan Brown with cluster bean shows no *Striga* emergence (Table 1). Intercropped Sudan Brown with cowpea at *Striga* seedbank size of 64 mg/pot suppression *Striga* emergence by 57.1%, but not significantly. However, intercropped Sudan Brown with cluster bean and green gram reduced *Striga* number significantly, as compared to the corresponding sole millet (Table 1). The observed reductions were considerable (62.9 - 71%).

At 90 DAS, the parasite, irrespective of millet cultivar displayed an average of 4-5 plants /pot at the lowest seedbank size (32 mg/pot). Increasing seedbank size to 64 mg/pot increased *Striga* emergence to 7 and 10.3 plants /pot, on Wad–Elbshire and Sudan Brown, respectively (Table 1). Intercropped Wad–Elbshire with cowpea and cluster bean at *Striga* seedbank size of 32 mg/pot exhibited negligible *Striga* emergence. Wad–Elbshire intercropped with cowpea, cluster bean and green gram at Striga seedbank size of 64mg/pot reduced *Striga* emergence by 62.9, 28.6 and 24.3% respectively, but not significantly, in comparison to the sole crop (Table 1). At *Striga* seedbank size of 32 mg/pot intercropping Sudan Brown with cowpea and green gram decreased number of *Striga* per pot, but not significantly and the observed reductions was considerable (60-74%). However, no *Striga* emergence was observed after intercropped with cluster bean. Intercropping Sudan Brown with cowpea, cluster bean and green gram at *Striga* seedbank size of 64 mg/pot, reduced *Striga* emergence significantly by 61.2, 70.9 and 73.8 %, respectively, in comparison to the sole millet (Table 1).

TABLE I. Effects of intercropping on Striga emergence

Number of *Striga* emergence/pot				
Pearl millet cultivars				
Days After Sowing (DAS)				
Treatments	**60 DAS**		**90 DAS**	
	WadEl-bshire	**Sudan Brown**	**WadEl-bshire**	**Sudan Brown**
S32 (sole millet)	2.7^{bc}	4.3 ab	4.0bc	5.0abc
S64 (sole millet)	4.7^{ab}	7.0a	7.0ab	10.3a
S32+cowpea	0.0^{c}	1.7 bc	0.0c	2.0bc
S32+cluster bean	0.0^{c}	0.0c	0.0c	0.0c
S32+ green gram	2.3^{bc}	1.0bc	4.0bc	1.3bc
S64+cowpea	1.3^{bc}	3.0abc	2.7bc	4.0bc
S64+Cluster bean	3.3^{abc}	2.7bc	5.0abc	3.0bc
S64+ green gram	3.7^{abc}	2.0bc	5.3abc	2.7bc
LSD	**2.11**		**2.96**	
Standard error (±)	**4.31**		**6.05**	
F- value	**0.04**		**0.19**	

*SX=Striga seedbank size (mg/pot).
Means within a column and/or row followed by the same letter(s) are not significantly different according to LSD-Test.

*2) **Striga Dry Weight:***

Statistical analysis showed significant difference in Striga dry weight between intercropping, Striga seedbank size, and showed non- significant differences across the millet cultivars. Striga dry weight on sole millet cultivars progressively increased with Striga seedbank size. At the lowest seedbank size (32 mg/pot) the parasite displayed an average dry weight of 3.7-5.4 g/pot on sole millet (Wad-Elbshire and Sudan-Brown cv). However, increasing Striga seedbank size to 64 mg /pot increased Striga dry weight to 8.8 and 11.7g /pot on Wad-Elbshire and Sudan Brown, respectively. However, the observed increased was significant only in Sudan Brown, in comparison to the lowest seedbank size (Table 2). At Striga seedbank size of 32 mg/pot intercropping Wad-Elbshire with green gram did not reduced Striga dry weight. Wad-Elbshire intercropped with cluster bean and green gram at Striga seedbank size of 64 mg/pot, reduced Striga dry weight by 36.4 and 40.9%, respectively, in comparison to the sole millet. However, the reduction was not significant (Table 2). However, intercropped Wad-Elbshire with cowpea reduced Striga dry weight significantly and the observed reduction was considerable (73.9%).

At Striga seedbank size of 32 mg/pot intercropping millet (Sudan Brown cv.) with cowpea and green gram reduced Striga dry weight, but not significantly. However, the observed reduction was

considerable (70.4-87%). Intercropped Sudan Brown with cowpea, cluster bean and green gram at Striga seedbank size of 64 mg/pot, reduced Striga dry weight significantly by 72.6, 81.2 and 82.1 %, respectively, in comparison to the corresponding sole millet (Table 2).

Table II. Effects of Intercropping on Striga Dry Weight

***Striga* dry weight (g)/pot**		
Pearl millet cultivars		
Treatments	**WadEl-bshire**	**Sudan Brown**
S32 (sole millet)	3.7 bc	5.4 bc
S64 (sole millet)	8.8 ab	11.7 a
S32+cowpea	0.0 c	1.6 c
S32+ cluster bean	0.0 c	0.0 c
S32+ green gram	3.5 bc	0.7 c
S64+cowpea	2.3 c	3.2 bc
S64+ Cluster bean	5.6 bc	.2 c
S64+ green gram	5.2 bc	2.1 c
LSD	**2.94**	
Standard error (±)	**6.01**	
F- value	**0.21**	

S_X=Striga seedbank size (mg/pot).Means within a column and/or row followed by the same letter(s) are not significantly different according to LSD-Test.

B. Effects of Intercropping on Millet Cultivars

1) Plant Height

The results show that at 60 DAS, *Striga* at seedbank of 32 and 64 mg/pot inflicted in-significant decrease in sole Wad-Elbshire height (9.1-13.1%). However, height of sole Sudan Brown reduced significantly at *Striga* seedbank size of 32 and 64 mg/pot by 57.0 and 41.4%, respectively, as compared to the un-infested control (Table 3). Intercropped Wad-Elbshire with cowpea, cluster bean and green gram, irrespective of *Striga* seedbank size reduced millet height, but not significantly, in comparison to the un-infested control and corresponding sole millet (Table 3). Sudan Brown intercropped with cowpea, cluster bean and green gram show a significant reduction in height at *Striga* seedbank size of 32 and 64 mg per pot in comparison to the corresponding *Striga* free control (Table 3). The observed reduction was considerable (23.7- 41.2%). Intercropped Sudan Brown with cowpea, cluster bean and green gram, irrespective of *Striga* seedbank size increased millet height, in comparison to the sole millet. The observed increment was considerable (28.6 - 67.3%).

At 90 DAS, *Striga* free millet, irrespective of cultivars displayed the highest height (57.9-65.5 cm). At the lowest *Striga* seedbank size (32mg /pot) Wad-Elbshire and Sudan Brown height was reduced by 54.7 and 44.4%, respectively, in comparison to the corresponding *Striga* free control (Table 3). Increasing seedbank size to 64mg/pot reduced Sudan Brown height significantly and the observed reduction was 37.5%. At *Striga* seedbank size of 32 and 64 mg/pot, Wad-Elbshire intercropped with cluster bean and green gram exhibited significant reductions in height in comparison to the un-infested control (Table 3). The observed reductions were considerable (40.2-61.7%). Intercropping cowpea with Wad-Elbshire at *Striga* seedbank size of 32mg/pot increased millet height significantly (82.4%), as compared to the sole millet. However, cowpea intercrops with Sudan Brown increased millet height, but not significantly, as compared to the sole millet (Table 3). At *Striga* seedbank size of 32 mg/pot, green gram intercropped Sudan Brown displayed significant reduction in height (42.0%). Intercropped Sudan Brown with cluster bean and green gram at *Striga* seedbank size of 64 mg/pot reduced height significantly by 40.4 and 35.6%, respectively (Table 3).

Table III. Effects of Intercropping on Millet Height

Millet height (cm)				
Days After Sowing (DAS)				
60 DAS			**90 DAS**	
Pearl millet cultivars				
Treatments	**WadEl-bshire**	**Sudan Brown**	**WadEl-bshire**	**Sudan Brown**
S0 (Un-infested control)	17.6^{bcd}	26.3^{a}	65.5^{a}	57.9ab
S32 (sole millet)	15.3^{bcde}	11.3^{de}	29.7^{f}	32.2^{ef}
S64 (sole millet)	16.0^{bcde}	15.4^{bcde}	51.1^{abcd}	36.2^{cdef}
S32+cowpea	13.8^{bcde}	15.4^{bcde}	54.1^{abc}	43.7^{bcdef}
S32+ Cluster bean	12.5^{cde}	18.2^{bc}	33.9^{def}	43.5^{bcdef}
S32+ green gram	15.3^{bcde}	18.9^{b}	29.2^{f}	33.6^{def}
S64+cowpea	14.6^{bcde}	19.8^{b}	50.6^{abcde}	42.4^{bcdef}
S64+ Cluster bean	11.1^{e}	16.4^{bcde}	25.1^{f}	34.5^{def}
S64+ green gram	11.4^{de}	20.0^{ab}	39.2^{bcdef}	37.3^{cdef}
LSD	**6.37**		**18.79**	
Standard error (±)	**3.13**		**9.25**	
F- value	**2.71^{*}**		**0.92^{ns}**	

S_X=*Striga* seedbank size (mg/pot). Means within a column and/or row followed by the same letter(s) are not significantly different according toLSD-Test.
*=P<0.05, Ns= non- significant

2) Number of Tillers

Statistical analysis showed that differences between millet cultivars in number of tillers/ plant were not significant at 90 DAS. However, at 60 DAS significant differences were observed between the cultivars (Table 4). At 60 DAS, *Striga* millet strain at seedbank of 32 and 64mg/pot, irrespective of millet cultivars caused significant reductions in number of tillers and the observed reductions were 70 and 75% (Table 4). In Wad-Elbshire, all intercrops, irrespective of *Striga* seedbank size reduced number

of tillers significantly and the observed reductions were considerable (42.5-100%). Intercropped Sudan Brown with cluster bean increased number of tillers by 30%, thought it's not significantly; in comparison to the un-infested control (Table 4). However, the number of tillers decreased significantly (100%) when intercropped Sudan Brown with cluster bean at *Striga* seedbank size of 64 mg/pot (Table 4).

In sole Wad-Elbshire at 90 DAS, *Striga* seedbank at 32 and 64mg/pot caused significant decrease (100%) in number of tillers. However, in sole Sudan Brown *Striga* at seedbank size of 32 and 64 mg/pot reduced number of tillers by 100 and 69.7%, respectively. At *Striga* seedbank of 32 and 64mg/pot, irrespective of millet cultivars, intercropped with cowpea and cluster bean decreased number of tillers, but not significantly, as comparison to the sole millet (Table 4). However, intercropped millet cultivars with green gram displayed complete reduction in number of tillers.

Table 1V. Effects of Intercropping on Millet Number of Tillers

Number of tillers/plant				
Days After Sowing (DAS)				
60 DAS		90 DAS		
Pearl millet cultivars				
Treatments	Wad El-bshire	Sudan Brown	WadEl-bshire	Sudan Brown
S0 (Un-infested control)	4.0^{a}	1.0^{bc}	3.7^{ab}	3.3^{ab}
S32 (sole millet)	1.0^{bc}	0.3^{bc}	0.0^{c}	0.0^{c}
S64 (sole millet)	1.0^{bc}	0.3^{bc}	0.0^{c}	1.0^{abc}
S32+cowpea	1.3^{bc}	1.0^{bc}	2.0^{abc}	0.7^{bc}
S32+ Cluster bean	1.3^{bc}	1.3^{bc}	1.7^{abc}	0.0^{c}
S32+ green gram	0.0^{c}	0.3^{bc}	0.0^{c}	0.0^{c}
S64+cowpea	2.3^{ab}	1.0^{bc}	3.0^{abc}	3.0^{abc}
S64+ Cluster bean	0.3^{bc}	1.3^{bc}	0.7^{bc}	0.7^{bc}
S64+ green gram	1.3^{bc}	0.0^{c}	0.0^{c}	0.0^{c}
LSD	**2.33**		**3.23**	
Standard error (±)	**1.15**		**1.59**	
F- value	**1.01^{ns}**		**0.46^{ns}**	

S_X=*Striga* seedbank size (mg/pot). Means within a column and/or row followed by the same letter(s) are not significantly different according to LSD-Test. Ns= non- significant.

*3) **Stem Diameter***

Analysis of variance showed that differences between millet cultivars in stem diameter were significant at 60 and 90 DAS. Wad-Elbshire displayed highest stem diameter and Sudan Brown sustained the lowest (Table 5). In general, *S. hermonthica* millet strain, irrespective of seedbank size, millet cultivars and date of observation, with few exceptions decreased stem diameter of millet, but not significantly, as compared to un-infested control (Table 5). The observed reductions were 6.9-30.6%.

At 60 and 90 DAS, intercropped Wad-Elbshire with cowpea, cluster bean and green gram at *Striga* seedbank size of 32 mg/pot reduced stem diameter, albeit not significantly (6.7-28.9%), as compared to the *Striga* free control (Table 5). At 90 DAS, intercropping Wad-Elbshire with cowpea, at seedbank size of 64 mg/pot increased stem diameter by 13.3%, and the observed increment was not significant. At *Striga* seedbank size of 64 mg/pot, cluster bean and green gram intercropped Wad-Elbshire, irrespective of DAD, displayed in-significant reduction in stem diameter (Table 5). At *Striga* seedbank size of 64 mg/pot, stem diameter, irrespective of date of observation increased (10.3-26.7%), when intercropped Sudan Brown with cluster bean, albeit not significantly. At 30, 60 and 90 DAS, intercropped Sudan Brown with green gram at *Striga* seedbank size of 64 mg/pot decreased stem diameter by 33.3, 20.8 and 17.2%, respectively, in comparison to the corresponding control (Table 5).

Table V. Effects of Intercropping on Millet Stem Diameter

Stem diameter(cm)				
Days After Sowing (DAS)				
60 DAS		90 DAS		
Pearl millet cultivars				
Treatments	WadEl-bshire	Sudan Brown	WadEl-bshire	Sudan Brown
S0 (Un-infested control)	3.6^{a}	2.4^{bcd}	3.8^{abc}	2.9cdef
S32 (sole millet)	2.5^{bcd}	2.0^{cd}	2.9^{cdef}	2.3^{f}
S64 (sole millet)	3.6^{a}	2.3^{bcd}	4.2^{ab}	2.7^{def}
S32+cowpea	2.9^{abc}	2.7^{abcd}	3.3^{abcde}	3.0^{cdef}
S32+ Cluster bean	2.6^{bcd}	2.4^{bcd}	3.0^{cdef}	2.9^{cdef}
S32+ green gram	2.5^{bcd}	1.9^{d}	2.7^{def}	2.3^{f}
S64+cowpea	3.6^{a}	2.9^{abc}	4.3^{a}	3.3^{abcde}
S64+ Cluster bean	3.2^{ab}	2.7^{abcd}	3.7^{abcd}	3.2^{bcdef}
S64+ green gram	3.0^{abc}	1.9^{d}	3.3^{abcd}	2.4^{ef}
LSD	**1.0**		**1.03**	
Standard error (±)	**0.49**		**0.50**	
F- value	**0.76^{ns}**		**0.62^{ns}**	

S_X=*Striga* seedbank size (mg/pot). Means within a column and/or row followed by the same letter(s) are not significantly different according to LSD-Test. Ns= non-significant.

*4) **Chlorophyll Content***

Chlorophyll content, irrespective of millet cultivars and DAS, was not influenced by *Striga* seedbank size (Table 6). At 60 DAS, millet cultivars displayed comparable chlorophyll content, however, at 90 DAS Wad-Elbshire sustained heights chlorophyll content and Sudan Brown displayed the lowest.

At 60 DAS, *Striga* millet strain, irrespective of seedbank size and millet cultivars decreased millet chlorophyll content, but not significantly. The observed reductions were 10.8-33.1%. Intercropped Wad-Elbshire with green gram at *Striga* seedbank size of 32mg/pot increased chlorophyll content by 63.4%, in comparison to the sole millet. At seedbank size of 64 mg/pot, intercropped Sudan Brown with cluster bean increased chlorophyll content by 44.6%, in comparison to the sole millet (Table 6). However, all intercrops, irrespective of *Striga* infestation and millet cultivars with few exceptions reduced chlorophyll content (2-45.9%), but not significantly, in comparison to the un-infested control and sole millet (Table 6).

At 90 DAS, *Striga* infestation did not reduced sole Wad-Elbshire chlorophyll content. *Striga* at seedbank size of 32 and 64mg/pot, decreased Sudan Brown chlorophyll content by 12.7 and 18.1%, respectively (Table 6). Intercropped Wad-Elbshire with cowpea, cluster bean and green gram, irrespective of *Striga* infestation displayed in-significant increased in chlorophyll content (26.2-92.6%), but only at the highest *Striga* seedbank size (64mg/pot) effected a significant increased when intercropped with cowpea. The observed increment was considerable (127%), over the un-infested control (Table 6). Intercropped Sudan Brown with cowpea, cluster bean and green gram, irrespective of *Striga* infestation, displayed insignificant decreased in chlorophyll content (16.7-39.4%), in comparison to the un-infested control (Table 6).

Chlorophyll content /plant				
Days After Sowing (DAS)				
	60 DAS		**90 DAS**	
Pearl millet cultivars				
Treatments	**WadEl-bshire**	**Sudan Brown**	**WadE-lbshire**	**Sudan Brown**
S0 (Un-infested control)	40.8^{ab}	40.3^{abc}	19.2^{bcde}	22.1^{abcd}
S32 (sole millet)	27.3^{bcd}	30.6^{abcd}	20.4^{abcde}	19.3^{bcde}
S64 (sole millet)	36.4^{abcd}	27.6^{bcd}	23.5^{ab}	18.1^{bcde}
S32+cowpea	25.8^{bcd}	25.1^{cd}	19.3^{bcde}	15.5^{cde}
S32+ Cluster bean	26.0^{bcd}	25.8^{bcd}	18.8^{bcde}	14.6^{de}
S32+ green gram	44.7^{a}	23.1^{d}	23.0^{abc}	18.4^{bcde}
S64+cowpea	40.0^{ab}	21.8^{d}	27.8^{a}	15.0^{de}
S64+ Cluster bean	24.8^{cd}	34.8^{abcd}	15.4^{de}	13.4^{e}
S64+ green gram	27.5^{bcd}	21.8^{d}	17.5^{bcde}	14.1^{e}
LSD	**15.54**		**7.59**	
Standard error (±)	**7.65**		**3.74**	
F- value	**1.74^{ns}**		**1.26^{ns}**	

Table VI. Effects of Intercropping on Millet Chlorophyll Content

S_X=*Striga* seedbank size (mg/pot). Means within a column and/or row followed by the same letter(s) are not significantly different according to LSD-Test. Ns= non- significant.

*5) **Millet Shoot Dry Weight***

Statistical analysis showed that highly significant differences ($P<0.01$) in plant dry weight between millet cultivars. Wad-Elbshire sustained the highest dry weight (99.8 g), while Sudan Brown displayed the lowest one (73.6g). In Wad-Elbshire, *Striga* free control displayed a dry weight of 95.0 g. At *Striga* seedbank size of 32 and 64 mg/pot, sole Wad-Elbshire displayed slight non-significant (15.8%) decrease in dry weight, in comparison to the *Striga* free control (Table 7). Intercropped Wad-Elbshire with cowpea at *Striga* seedbank size of 32 and 64 mg/pot, increased millet dry weight by 29.8 – 36.8% and 54.1- 62.5%, respectively, in comparison to the *Striga* free control and sole millet (Table 7). At *Striga* seedbank size of 32mg/pot, intercropped Wad-Elbshire with cluster bean increased millet dry weight by 10.5-31.3%, albeit not significantly, as compared to the un-infested control and sole millet. However, increasing *Striga* seedbank size to 64mg/pot resulted non- significant reduction in Wad-Elbshire dry weight

and the observed reductions were 16.3-29.8 % (Table 7).

Wad-Elbshire intercropped with green gram at *Striga* seedbank size of 32mg/pot showed not significant reduction in dry weight (15.8%), as compared to the un-infested control (Table 7). At *Striga* seedbank size of 64mg/pot, Wad-Elbshire intercropped with green gram resulted slight non-significant (19.3-41.6%) increment in millet dry weight, in comparison to the un-infested control and sole millet (Table 7).

In Sudan Brown, *Striga* free control displayed highest dry weight (96.7g). *Striga* seedbank size of 32 and 64 mg/pot, reduced Sudan Brown dry weight by 31.0 and 10.3%, respectively, in comparison to the un-infested control (Table 7). Intercropped Sudan Brown with cowpea, cluster bean and green gram, at *Striga* seedbank size of 32 and 64 mg/pot, showed non- significant reductions in millet dry weight and the observed reductions were (19.0-31.7), (22.4-27.6) and (32.8-39.7%), respectively, in comparison to the un-infested control (Table 7).

Table VII. Effects of Intercropping on Millet Dry Weight

Millet shoot dry weight (g)/pot		
Pearl millet cultivars		
Treatments	**WadEl-bshire**	**Sudan Brown**
S0 (Un-infested control)	95.0^{abcd}	96.7^{abcd}
S32 (sole millet)	80.0^{abcd}	66.7^{cd}
S64 (sole millet)	80.0^{abcd}	86.7^{abcd}
S32+cowpea	130.0^{a}	66.0^{cd}
S32+ cluster bean	105.0^{abcd}	70.0^{cd}
S32+ green gram	80.0^{abcd}	58.3^{d}
S64+cowpea	123.3^{ab}	78.3^{bcd}
S64+ Cluster bean	66.7^{cd}	75.0^{bcd}
S64+ green gram	113.3^{abc}	65.0^{cd}
LSD	**50.72**	
Standard error (±)	**24.96**	
F- value	**0.71^{ns}**	

*S_X=*Striga* seedbank size (mg/pot). Means within a column followed by the same letter(s) are not significantly different according to LSD-Test.

V. DISCUSSION

Cereal legume intercropping is a predominant cropping system in Sub-Sahara African countries where it is used for maximizing use of limited farmlands, food security and improving soil fertility. Use of legume trap crops is an important low cost method for depletion of *Striga* seedbank in the soil.

Striga counts at 60 and 90 DAS were generally lower in the intercrops than in the control pots of sole millet. The results showed that sole millet sustained highest *Striga* emergence. This is in agreement with the findings of (11) who reported higher number of *Striga* in sole sorghum as compared to sorghum when intercropped with cowpea. At *Striga* seedbank size of 32 and 64 mg/pot, cowpea intercropped with millet cultivars (Wad–Elbshire and Sudan Brown cv.) reduced *Striga* emergence by 57.1 -100%. The results revealed that intercrops cluster bean with millet cultivars at *Striga* seedbank size of 32 mg/pot completely suppressed *Striga* emergence throughout the experiment. However, at *Striga* seedbank size of 64 mg/pot intercropping cluster bean with millet decreased *Striga* number by 28.3-70.9%, as compared to the sole millet. Suppression of *Striga* emergence by intercropping with different legumes is in consistent with several reports, of which (12) found that mixed cropping of cereals and cowpea reduce *Striga* infestation significantly. (10) also observed that intercropping cereals and cowpea has been observed to reduce *Striga* infestation significantly. Intercropping of sorghum with soybean and groundnut has significantly reduced *Striga* counts per plot as compared to sole sorghum (13). Similarly, (14) reported that cowpea cultivars reduced *Striga* emergence by 40%. This reduction may be due to shading effects from the cowpea canopy that created unfavorable conditions for *Striga* germination (15).

Intercropped millet cultivars (Wad–Elbshire and Sudan Brown cv.) with green gram at seedbank size of 32mg/pot displayed suppression of *Striga* emergence by 14.8-76.7%, as compared to the sole millet. At *Striga* seedbank size of 64 mg/pot green gram intercrops with millet cultivars with few exceptions, significantly reduced *Striga* number and the observed reductions were considerable (21.3-74.8%). This result is in consistent with the report of (16) who observed that in pooled analysis across seasons that intercropping sorghum with green gram, cowpea and crotalaria, and maize with crotalaria significantly reduced *Striga* populations. (17) also found that intercropping maize with green gram had significantly lowered *Striga* counts when compared with maize that was artificially infested with *Striga*. The green gram provides a good ground cover to the soil thus reducing the emerging *Striga* and other weeds. The reduced *Striga* counts during intercropping could be attributed to smothering of emerging *Striga* by the spreading vegetation of the non-host crops, low soil temperatures (18) and the exudates could be inhibiting attachment. Increased humidity and lowered temperatures under the intercrops reduced the growth of emerging *Striga* (9). Intercropping with legumes also improves soil fertility through fixation of atmospheric nitrogen. Addition of nitrogen to the soil is generally considered to alleviate the effects of *Striga* and to lower the amount of *Striga* supported by the host.

All intercrops reduced *Striga* dry weight, in comparison to the sole millet. Cowpea, cluster bean and green gram intercropped with millet cultivars, irrespective of *Striga* seedbank size reduced *Striga* dry weight by (70.4-72.6%), (40.9-82.1%) and (36.4-81.2%), respectively. The reduction in *Striga* dry

weight is consistent with the reductions in emergence caused by intercropping with different legumes (cowpea, cluster bean and green gram). These results corroborate the findings of (19) who reported integrated *Striga* management controls based on intercropping system, *Fusarium*-inoculum or both in combination significantly reduced *Striga* dry biomass. (19) reported that when the cowpea plants covered the soil, the temperature decreased while the air humidity increased under cowpea leaves and stalks. The interaction of these environmental factors may create a micro-climate that would affect the emergence and the growth of *Striga* plants and then *Striga* biomass should be significantly reduced.

At 60 and 90 DAS, Wad-Elbshire height reduced when intercropped with different legumes. At 60 and 90 DAS, all intercrops, irrespective of *Striga* seedbank size reduce Sudan Brown height, in comparison to un-infested control and this could be attributed to the competition between the intercrops in growth resources and also due to the effect of *Striga*. This is probably because *Striga* affects cell elongation as it takes photosynthesis away from the millet crop leading to shorter millet internodes and stunted growth. At 60 DAS, intercropped Sudan Brown with cowpea, cluster bean and green gram, irrespective of *Striga* seedbank size increased millet height, in comparison to the sole millet and the observed increment was considerable (28.6 - 67.3%). Similar results was obtained by **(**13), who found that sorghum height increased in all treatments of intercropping with groundnut and soybean. Desmodium intercrops that significantly enhanced plant height in maize and sorghum (16).

At 90 DAS, all intercrops, irrespective of *Striga* seedbank size and millet cultivars did not reduced stem diameter per plant, but decreased number of tillers per plant, as compared to the sole millet. This is probably due to competition between millet and the legumes for growth factors such as soil moisture and nutrients.

At 60 and 90 DAS, all intercrops, irrespective of *Striga* infestation and millet cultivars with few exceptions reduced chlorophyll content, but not significantly, in comparison to the un-infested control and sole millet. This is probably the legumes intercrop that affected the partitioning of photosynthesis to the sink.

Intercropping Wad-Elbshire with cowpea, irrespective of *Striga* seedbank size, increased millet dry weight, in comparison to the *Striga* free control and sole millet. Intercropping Wad-Elbshire with cluster bean at *Striga* seedbank size of 32mg/pot, increased millet dry weight by 10.5-31.3%, albeit not significantly, as compared to the un-infested control and sole millet. At *Striga* seedbank size of 64mg/pot, Wad-Elbshire intercropped with green gram resulted in slight non-significant (19.3-41.6%) increment in millet dry weight, in comparison to the un-infested control and sole millet. A similar result was obtained by (20) and (21). Intercropping Sudan Brown with cowpea, cluster bean and green gram, at *Striga* seedbank size of 32 and 64 mg/pot, showed non-significant reductions in millet dry weight, as compared to the un-infested control. This was is in agreement with the findings of (22), who reported a decline in dry weight of cowpea intercropped sorghum, irrespective of *Striga* infestation. This could be attributed by lower number of plant leaves and stunted growth of millet due to the negative impact of *Striga* and also due to the intercrops system.

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