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Variability Effect of Witchweed [*Striga hermonthica*(Del.) Benth.]Populations on the Performance of [*Sorghum bicolor*) cv. 'Abu sabeen' in Sudan

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Abstract: *Field* surveys and a green house experiment were conducted during season 2009/2010 to investigate variability and host specificity of witchweed *Striga hermonthica* populations. The field surveys were conducted in *S. hermonthica* endemic areas in Gadarif, Gezira and Kordofan to collect seeds from striga plants growing under their respective hosts. A total of fifteen *S. hermonthica* populations were collected. Twelve *S. hermonthica* populations, were collected from under sorghum and three. were collected from under millet. Laboratory and green house experiments were undertaken at the horticulture nursery, Faculty of Agricultural Sciences, University of Gezira, Sudan, to test the viability and infectivity of seeds of witchweed populations on sorghum, cultivar "Abu-sabeen", a highly susceptible cultivar. Data collected were transformed as necessary and were statistically analysed. Results showed that all *S. hermonthica* seed populations displayed high germination % ranging from 87.0 % to 92.3 %, regardless of the area, location and the host crop. Capsules per plant, shoot dry weight and underground plantlets of emergent striga were highest on the respective host. It is noteworthy that some of the millet striga populations displayed limited emergence at 60 days after crop emergence on sorghum and produced capsules. *S. hermonthica* populations significantly reduced growth and yield of sorghum. However, the magnitude of the damage attained by each population was highest on the respective host, thus indicating the existence of inter-crop specialization and probably the existence of two strains of *S. hermonthica*, one specific to sorghum and the other to millet. These findings may provide clues on the complexity of breeding sorghum

cultivars with high and durable resistance across locations for striga parasite.

Keywords: Striga, variability, specificity, host crop, location, sorghum.

INTRODUCTION

Witchweeds (*Striga* species), member of the family Orobanchaceae (Olmostead *et al*. 2001) [also placed in Schrophulariaceae], are obligate root parasitic plants that attack agronomically important cereal and legume crops (Anonymous 1993). The genus *Striga* comprises at least 30 species. The exact number of species is unclear due to taxonomic uncertainty. Three *Striga* species, S. *hermonthica*, *S. sciatica* and *S. gesnerioides* are among world's weeds (Press and Graves 1995; Babiker 2007). *S. hermonthica* (Del.) Benth. is the major biotic constraint to cereals' production in dry and in-fertile soil in semi-arid region of sub-Saharan Africa (Haussmann *et al*. 2000) and negatively affects the lives of over 300 million people (Kim *et al*. 2002). In extreme cases, severe infestation of *S. hermonthica* results in complete loss of the crop and the abandonment of otherwise productive fields (Butler 1995). The increasing seriousness of the problem is directly related to increased land-use intensity to produce sufficient food for the burgeoning human populations (Berner *et al.* 1996). In Sudan, *S. hermonthica* is the most serious biotic problem to cereals production. It attacks sorghum [*Sorghum bicolor* (L.) Moench], millet [*Pennisetum glaucum* (L.) R. Br.], maize (*Zea mays* L.), sugarcane (*Saccharum officinarum* L.) and rice (*Oryza sativa* L.) (Abbasher *et al.* 1998). Musselman and Hepper (1986) believe, on basis of common occurrence, that *S. hermonthica* has Sudan as centre of origin. The parasite constitutes a major threat to sorghum production and hence a direct threat to food security as sorghum constitutes the main staple food crop for the majority of the populace in rural areas (Zahran 2008).

The most promising and culturally acceptable methods for the management of *S. hermonthica* today are crop rotation with non-host crops and planting of tolerant and/or resistant crop cultivars (Ejeta and Butler 1993; Christopher *et al.* 2002). Resistant cultivars, due to paucity of resistance genes, are limited in number (Ejeta *et al.* 1992). Furthermore, resistance is temporally and spatially unstable. Instability of resistance is attributed to existence of strains and physiological variants of the parasite (Ejeta *et al.* 1993). Furthermore, differential effects, arising from variability according to size of the parasite seed bank and soil fertility, cannot be ruled out. Understanding the relationship between variability within and among geographically distributed populations of the parasitic weed *S. hermonthica* and host preference should improve the ability to successfully breed for broad and durable resistance of the most common hosts sorghum and millet to striga (Christopher *et al.* 2002). Little is known about genetic variation in host resistance and tolerance across host genotypes, in relation to virulence differences across striga species and ecotypes (Rodenburg 2017). Several experiments were undertaken to study host specificity in *S. hermonthica*. However, little work has been done on biological basis of host specificity, physiological and/or genetic variability within *S. hermonthica* populations and it's interaction with selected hosts in Sudan. Therefore, the present work was designed to study the interactions, between *S. hermonthica* populations, collected from different locations, and sorghum cv. ‘Abu-sabeen’ as manifested in i) striga emergence, ii) striga growth and reproduction, iii) underground attachment and iv) sorghum growth and yield attributes.

MATERIALS AND METHODS

Collection of *S. hermonthica* seeds

Field surveys were conducted, during the rainy season of 2008/2010 (mid-September to mid-October) in *S. hermonthica* endemic areas in Gadarif, Gezira and Kordofan, *i.e.* eastern, central and western Sudan, respectively. *S. hermonthica* seeds were collected from plants growing under their respective hosts; sorghum and millet. A total of fifteen populations were collected. Twelve populations, were collected from infected sorghum in Galabat (14° 09' N, 35° 99' E), Sumsum (13° 17' N, 35° 36' E), Gadarif (14° 01' N, 35° 40' E), Butana (13° 93' N, 35° 12' E), El Fau (14° 12' N, 34° 08' E) (Gadarif area); Hasaheisa (14° 74' N, 33° 31' E), Abu-Haraz (14° 12' N, 33° 31' E), Hag-Abdalla (13° 95' N, 33° 56' E), Barakat (14° 23' N, 33° 61' E) and Wad-Rabia (14° 32' N, 13° 19' E) (Gezira area); Um-Rawaba (12° 39' N, 30° 21' E) and El-Rahad (12° 74' N,31° 39' E) (Kordofan area).Three populations, were collected from infected millet in Kadugli (11° 19' N, 29° 69' E), Khour-Tagat (13° 20' N, 30° 30' E) and El Obied (13° 19' N, 30° 21' E) (Kordofan area).

Three sites were selected randomly in each location. Three striga-infested fields were chosen at random in each site. Ten plots (10X10 m) were selected in each field. Ten quadrates (1 m^2 each) were placed at random in each plot. In each quadrate, *S. hermonthica* plants were collected, capsules harvested and seeds were collected. The seeds were surface sterilized by sodium hypoclorite, (NaOCl) 1% solution, for 3 min with continuous agitation. The NaOCl solution was obtained by dilution of commercial sodium hypochlorite (Bleach). Subsequently the seeds were thoroughly washed with sterilized distilled water for several times. Floating seeds were discarded and the remaining ones were stored at room temperature.

Laboratory experiment

Before *S. hermonthica* seeds were used, a laboratory experiment was designed to study the effect of GR24 at concentration of 0.1 ppm on seed germination of collected *S. hermonthica*. This experiment was carried out, in the biology laboratory of Faculty of Agricultural Sciences, University of Gezera, at an average temperature range of 25 - 30°C and the relative humidity ranging from 60 to 70 %. For *S. hermonthica* conditioning, the disc technique described by Dafaallah (2006) was used. About 80-100, Glass Fiber Filter Paper (Whatman GF/C) discs (0.5 mm diameter) were placed in one layer in a glass Petri-dish, 9 cm internal diameter. Striga seeds (25-50) were sprinkled on each disc and the petri-dishes were moistened with distilled sterilized water (4.5 ml), GR 24 was prepared by dissolving GR 24 (1 mg) in 1 ml acetone and completed to 10 ml with sterilized-distilled water. GR 24 at concentration of 0.1 ppm was prepared by dilution of the stock solution with sterilized-distilled water. Discs containing conditioned Striga seeds were placed on top of similar glass fiber filter paper discs in a Petri dish. Aliquots (30µl) at 0.1ppm of the GR 24 solution were applied to each pair of discs. The Petri dishes were sealed with Para film, placed in black polyethylene bags and incubated at 30°C in the dark for 12 days. Treatments were arranged in completely randomized design with three replicates. Seeds were examined under a binocular stereomicroscope for germination 24 h after incubation.

Green house experiment:

An experiment was undertaken in a greenhouse of the horticulture nursery, Faculty of Agricultural Sciences, University of Gezira , Sudan. The experimental site was located at Latitude 14° 24′ N, Longitude 33° 29′ E and 407m above sea level. The experiment was undertaken to study the effect of sorghum c.v ‘Abu-sabeen’ on 12 sorghum populations of *S.*

hermonthica and three millet populations as manifested in i) striga emergence, ii) Striga growth and reproduction, iii) striga underground attachment and iv) sorghum growth and yield attributes. Plastic pots of 10 cm internal diameter and 18 cm high, with drainage holes at the bottom, were filled with Gezira soil and river silt mixed in the ratio 1:1 (%). *S. hermonthica* seeds (30 mg) were added to the soil, in each pot, and hand-mixed in the top 6 cm. The soil was kept moist for 7 days prior to planting the test plants. Sorghum cultivar Abu-sabeen was sown in each pot (5 seeds / pot). The pots, kept free from weeds other than *S. hermonthica*, were irrigated and sorghum seedlings were thinned to 2 plants per pot, 7 days after emergence. Treatments were arranged in a randomized complete block design with three replicates. Treatments effect on the parasitic weed, *S. hermonthica*, was assessed by plants counted 45, 60, 75 and 90 days after crop emergence (DACE). At harvest, number of capsules per plant and number of underground parasite plants per pot were counted and striga. Dry weight was determined. Crop height was measured and number of leaves per plant were counted at 30, 60 and 90 DACE. Crop shoots were cut at ground level. Roots were separated from soil and washed. The shoots and roots were dried in a forced hotair oven at 105^0C for 24 h. and weighed.

Statistical analysis

Data were collected, transformed, and subjected to statistical analysis. Means were separated for significance using the Duncan`s Multiple Range Test at $P \leq 0.5$. Results were presented as means of the original data with the standard error of the means, unless otherwise described.

RESULTS

Striga germination

S. hermonthica seed populations collected from Gadarif area exhibited high germination % ranging from 87.0 % to 92.3% in response to GR24 at 0.1 ppm (Table 1). Germination % among locations was significantly different. Seeds collected from El Fau displayed the highest germination % while Seeds collected from Gadarif displayed the lowest germination. Germination % of striga seed populations from Gezira area ranged between 88.7 % and 92 % and were not significantly different. Striga seed populations from Kordofan area were significantly different regarding response to GR 24 at 0. 1ppm. *S. hermonthica* seeds collected from

El-Rahad displayed significantly the highest germination while those collected from Um-Rawaba showed significantly the lowest germination percent, (Table 1).

Table 1. Effects of GR 24 at 0.1 ppm on germination of *S. hermonthica* seed populations collected from different locations

S. *hermonthica* populations		Germination (%)
Area	Location	
Gadarif	Galabat*	90.0 abc
	Sumsum*	89.3 abc
	Gadarif*	87.0 c
	Butana*	90.0 abc
	El Fau*	92.3 a
Gezira	Hasaheisa*	89.3 abc
	Abu-Haraz*	90.0 abc
	Hag-Abdalla *	91.3 ab
	Barakat*	88.7 bc
	Wad-Rabia*	92.0 ab
Kordofan	Um-Rawaba*	87.0 c
	El-Rahad*	92.3 a
	Kadugli**	90.3 abc
	Khour-Tagat**	89.0 abc
	El Obied**	89.3 abc
	SE ±	1.02
	CV %	5.97

* **= Striga populations collected from under sorghum and millet, respectively.

Means followed by the same letter(s) are not significantly different according to the Duncan's Multiple Range Test at $P \leq 0.05$.

Striga emergence

At 45 DACE, *S. hermonthica* collected from Gadarif area displayed an average emergence range of 0.33 to 3.67 plants per pot (Table 2). Striga from Butana gave the highest emergence, while, that from Galabat showed the lowest emergence. Striga from Gezira area showed relatively high emergence with no significant differences among locations. Populations from Kordofan showed significant difference in emergence among locations. However, Striga from Um-Rawaba displayed, the highest emergence while no striga plant emergence was recorded from El Obied (Table 2).

At 60 DACE, striga populations from Gadarif area showed significantly different emergence which ranged from 1.33 to 7 plants per pot (Table 2). Striga. from Butana displayed the highest and from Glabat the lowest emergence. Striga from Gezira area showed emergence range of 3.67 and 5.67, albeit not significant. Striga from Kordofan area were significantly different regarding plant emergence per pot. The lowest emergences were recorded in Kadugli, Khour-Tagat and El Obied (Table 2).

Table 2. Effects of *S. hermonthica* populations on emergence of the parasite under infected sorghum cv'Abu-sabeen'

S. *hermonthica* populations		Number of emerged *Striga* plants / pot			
		DACE			
Area	Location	45	60	75	90
Gadarif	Galabat*	0.33 cd	1.33 cde	4.00 c	8.00 a
	Sumsum*	2.00 abcd	4.33 abc	7.67 a	8.33 a
	Gadarif*	2.33 abcd	2.67 bcde	4.00 c	6.00 bc
	Butana*	3.67 a	7.00 a	6.00 b	7.33 ab
	El Fau*	3.33 bcd	2.67 bcde	2.67 cd	4.00 d
Gezira	Hasaheisa*	3.33 ab	4.33 abc	4.33 c	6.00 bc
	Abu-Haraz*	3.33 ab	3.67 abcde	4.00 c	5.00 cd
	Hag-Abdalla *	3.33 abc	5.67 ab	6.00 b	6.00 bc
	Barakat*	3.33 ab	4.00 abcd	4.33 c	5.00 cd
	Wad-Rabia*	3.33 ab	4.00 abcd	4.33 c	5.00 cd
Kordofan	Um-Rawaba*	4.00 a	5.67 ab	6.33 ab	7.00 ab
	El-Rahad*	0.67 bcd	4.00 abcd	4.33 c	4.67 cd
	Kadugli**	1.00 abcd	1.00 de	1.00 e	1.00 e
	Khour-Tagat**	1.00 abcd	1.00 e	1.33 de	2.00 e
	El Obied**	0.00 d	1.00 e	1.00 e	1.33 e
	SE ±	(0.284)	(0.276)	0.534	0.598
	CV %	(29.5)	(20.7)	36.2	36.2

* **= Striga populations collected from under sorghum and millet, respectively.
Means in the same column followed by the same letter(s) are not significantly different according to the Duncan's Multiple Range Test (P ≤ 0.05).

At 75 DACE, striga parasite emergence of Gadarif area was significantly different among populations (Table 2). Striga population from Butana and Sumsum showed the highest emergence. emergence from Gezira striga population were significantly different with that from Hag-Abdalla given the highest value. Striga populations from Krdofan area were significantly different regarding parasite emergence. Striga from Um-Rawaba, invariably showed significantly higher emergence than that from El-Rahad. Striga population from El-Rahad displayed significantly higher emergence than population from Kadugli, Khour-Tagat and El Obied.

At 90 DACE, striga population from Gadarif area showed significantly different plant emergence. That from El Fau displayed the lowest emergence while those from Galabat, Sumsum and Butana showed the highest emergence. *S*triga populations from Gezira area showed considerable emergence albeit not significantly. *S*triga population from Kordofan were significantly different. Striga from Um-Rawaba, invariably showed significantly higher emergence than that from El-Rahad. Striga from millet populations, irrespective of collection site, displayed the lowest emergence.

Striga capsules production

At harvest, capsules production per plant of sorghum striga population varied between 20.3 for population collected from Um-Rawaba to 31.7 for population collected from Galabat (Table 3). Striga populations from Galabat, Sumsum, Gadarif and Butana, produced about equal number of capsules. Striga population collected from El Fau produced significantly lower number of capsules per plant. In Gezira area, *S. hermonthica* populations collected from Barakat and Hag-Abdalla produced significantly the highest number of capsules per plant, while the lowest number of capsules were recorded from Wad Rabia. In Kordofan area, the highest capsules production was recorded by El-Rahad population. It worth to mention that populations collected from infected millet at Kadugli, Khour-Tagat and El- Obied displayed the lowest capsules production.

Striga shoot dry weight

In Gezira area, *S. hermonthica* populations collected from Wad Rabia showed significantly the highest shoot dry weight, while the lowest was recorded by Abu-Haraz population. In Kordofan area, *S. hermonthica* populations collected from El-Rahad showed significantly the highest shoot dry weight, while the lowest was recorded from Khour-Tagat population.

Table 3. Number of Capsules per plant, striga shoot dry weight as affected by striga populations from different locations infecting sorghum cv. 'Abu-sabeen'

S. hermonthica populations		Striga	
Area	Location	Number of Capsules /plant	Shoot dry weight (g / plant)
Gadarif	Galabat*	31.7 a	0.19 d
	Sumsum*	31.0 a	0.73 c
	Gadarif*	30.7 ab	1.70 a
	Butana*	30.3 ab	1.57 ab
	El Fau*	28.0 c	0.56 c
Gezira	Hasaheisa*	24.7 de	1.43 b
	Abu-Haraz*	25.0 de	0.55 c
	Hag-Abdalla *	26.7 cd	0.58 c
	Barakat*	28.7 bc	1.61 ab
	Wad-Rabia*	23.7 e	1.77 a
Kordofan	Um-Rawaba*	20.3 f	0.66 c
	El-Rahad*	24.3 e	0.67 c
	Kadugli**	10.0 g	0.03 d
	Khour-Tagat**	10.3 g	0.02 d
	El Obied**	10.0 g	0.03 d
	SE ±	0.704	0.576
	CV %	10.9	15.7

* ** = Striga populations collected from under sorghum and millet, respectively.
Means in the same column followed by the same letter(s) are not significantly different according to the Duncan's Multiple Range Test (P ≤ 0.05).

Number of underground striga seedlings

Among Gadarif area populations, those from Galabat, Sumsum and Gadarif displayed the highest number of underground striga plants (Table 4). However, Striga population collected from Butana and El Fau showed significantly lower numbers of underground striga plants. For Gezira area, irrespective of site, all populations showed significantly comparable underground striga infection.For Kordofan area populations, striga collected from Um-Rawaba and El-Rahad showed about equal number of underground striga plants per pot. Populations from Kadugli, Khour-Tagat and El Obied showed no underground striga plants. Among the regions, striga collected from Gadarif area showed the highest underground striga infection. Total infection, comprising both emergent and underground striga plants was highest for populations collected from Gadarif area followed in descending order by populations collected from Gezira and Kordofan areas (Table 4).

Table 4. Effect of striga populations on incidence of emerged, underground and total number of striga plants per pot, infecting sorghum cv. 'Abu- sabeen'

S. hermonthica population		Number of *Striga* plants		
Area	Location	Emerged plants/ pot	Underground plants/ pot	Total No. of plants/ pot
Gadarif	Galabat*	8.00 a	13.3 a	21.3 a
	Sumsum*	8.33 a	12.3 a	20.7 ab
	Gadarif*	6.00 bc	13.0 a	19.0 b
	Butana*	7.33 ab	9.0 b	16.3 c
	El Fau*	4.00 d	7.7 bc	11.7 de
Gezira	Hasaheisa*	6.00 bc	5.7 d	11.7 de
	Abu-Haraz*	5.00 cd	6.0 cd	11.0 de
	Hag-Abdalla *	6.00 bc	5.3 d	11.3 de
	Barakat*	5.00 cd	6.3 cd	11.3 de
Kordofan	Wad-Rabia*	5.00 cd	6.0 cd	11.0 de
	Um-Rawaba*	7.00 ab	6.0 cd	1.3 f
	El-Rahad*	4.67 cd	5.0 d	7.9 e
	Kadugli**	1.00 e	0.0 e	1.3 f
	Khour-Tagat**	2.00 e	0.0 e	2.0 f
	El Obied**	1.33 e	0.0 e	1.3 f
	SE ±	0.534	0.579	0.700
	CV %	36.2	27.3	22.1

* ** = Striga populations collected from under sorghum and millet, respectively.
Means in the same column followed by the same letter(s) are not significantly different according to the Duncan's Multiple Range Test (P ≤ 0.05).

Effects of *S. hermonthica* populations on sorghum plant growth and biomass

Sorghum plant height

At 30 DACE, *S. hermonthica* population collected from Galabat, resulted in the shortest sorghum plants (Table 5). However, sorghum infected by striga from Sumsum and Gadarif were significantly taller. Striga populations from Butana and El Fau were invariably the least suppressive to the crop. For the Gezira area populations, sorghum infected by striga collected from Hasaheisa, Abu-Haraz and Barakat exhibited comparable heights. However, sorghum infected by striga collected from Wad-Rabia and Hag-Abdalla resulted in significant reduction in height. For Kordofan area, sorghum infected by striga populations from Um-Rawaba and El-Rahad produced shorter plant heights. Than those infected by striga frog Kadugli, Khour-Tagat and El Obied *i.e.* less inflicted damage by millet striga The corresponding heights for sorghum plants infected by striga populations from infected millet at Kadugli, Khour-Tagat and El Obied was 32.3, 34 and 35 cm, respectively (Table 5).

Striga from Butana showed the least suppressive effect to crop growth *i.e* taller plants. (Table 5). Striga collected from Galabat, on the other hand, showed the most suppressive effect. Striga from the Gezira area showed significant difference among population infectivity to sorghum. Striga Population collected from Hag-Abdalla caused the least reduction in sorghum plant height followed in ascending order by populations from Wad Rabia, Barakat, Abu-Haraz and Hasaheisa,. For Kordofan area populations, striga from Um-Rawaba and El-Rahad were the most suppressive to sorghum height. Among all populations, irrespective of locations or region, striga collected from infected millet, resulted in the least reduction in sorghum height.

Table 5. Effects of *S. hermonthica* populations on the plant height of sorghum cv. 'Abu-sabeen'

S. hermonthica populations		Sorghum plan height (cm) DACE		
Area	Location	30	60	90
Gadarif	Galabat*	15.00 i	15.00 i	34.67 h
	Sumsum*	20.00 h	20.00 h	44.33 g
	Gadarif*	22.00 h	22.00 h	52.33 d
	Butana*	34.67 ab	34.67 ab	69.67 d
	El Fau*	34.33 abc	34.33 abc	74.67 c
Gezira	Hasaheisa*	32.00 cd	32.00 cd	52.00 f
	Abu-Haraz*	30.00 def	30.00 def	50.67 f
	Hag-Abdalla *	24.67 g	24.67 g	75.33 c
	Barakat*	30.33 de	30.33 de	46.67 g
	Wad-Rabia*	27.67 f	27.67 f	53.33 f
Kordofan	Um-Rawaba*	29.00 ef	29.00 ef	67.67 de
	El-Rahad*	30.00 def	30.00 def	66.00 e
	Kadugli**	32.33 bcd	32.33 bcd	94.33 a
	Khour-Tagat**	34.00 abc	34.00 abc	89.67 b
	El Obied**	35.00 a	35.00 a	73.67 c
	SE ±	0.753	0.753	0.865
	CV %	10.3	10.3	6.2

*,**= *Striga* populations collected from under sorghum and millet, respectively.
Means in the same column followed by the same letter(s) are not significantly different according to the Duncan's Multiple Range Test ($P \leq 0.05$).

At 90 DACE, striga population collected from Gadarif area showed significant differences in suppressive ability to sorghum plant height (Table 5). Striga collected from Galabat caused the maximum reduction in sorghum plant height followed in descending order by populations from Sumsum, Gadarif, El-Fau and Butana. For Gezira area populations, striga collected from Hag-Abdalla caused the highest reduction in sorghum plant height followed by Wad-Rabia, Abu-Haraz, Barakat and Hasaheisa. Striga from Um-Rawaba and El-Rahad were the most suppressive while those collected from under millet inflicted the least reduction. Striga population from El Obied was the least suppressive.

Sorghum root dry weight

At harvest, striga population collected from Galabat resulted in the highest sorghum root dry weight (Table 6). However, sorghum infected by striga from Sumsum Gadarif, Butana and El Fau inflicted significantly lower root dry weight. In the Gezira area, striga population were not significantly different in effecting root dry weight. Sorghum infected by *S. hermonthica* populations collected from Um-Rawaba and El-Rahad, showed root dry weight of 3.53 and 4 g / plant, respectively. Sorghum infected by striga populations collected from infected millet at Kadugli, El Obied and Khour-Tagat displayed the lowest root dry weight.

Sorghum shoot dry weight

At harvest, striga populations collected from Gadarif area inflicted significantly different reductions on sorghum shoot dry weight (Table 6). Striga from Galabat resulted in the least shoot dry weight. Striga population from Sumsum was less suppressive to sorghum shoot than that obtained from Galabat, albeit not significantly different. Striga collected from Butana and El-Fau inflicted the least reductions on sorghum shoot dry weight. Striga populations collected from Hag-Abdalla, Wad-Rabia and Barakat, were more suppressive thoot dry weight than those from Hasaheisa and Abu-Haraz. Striga populations collected from Um-Rawaba and El-Rahad, significantly reduced sorghum shoot dry weight in comparison to those collected from other locations within the region. Striga populations from under millet were significantly less suppressive. Among all populations, striga from Kadugli and El-Obied were the least suppressive.

Table 6. Effects of *S. hermonthica* populations on root and shoot dry weight and on root/ shoot ratio of sorghum cv. 'Abu-sabeen'

S. hermonthica populations		Dry weight (g/plant)		Root/ Shoot ratio
Area	Location	Root	Shoot	
Gadarif	Galabat*	6.40 a	0.43 h	15.00 a
	Sumsum*	5.17 b	0.70 gh	7.47 b
	Gadarif*	3.40 e	1.13 g	3.04 c
	Butana*	4.43 c	3.10 de	1.43 def
	El Fau*	3.97 cde	3.07 de	1.30 def
Gezira	Hasaheisa*	4.17 cd	3.47 cd	1.21 def
	Abu-Haraz*	3.57 de	2.90 de	1.23 def
	Hag-Abdalla *	4.13 cd	2.33 f	1.78 d
	Barakat*	4.13 cd	2.60 ef	1.59 de
	Wad-Rabia*	4.00 cde	2.77 ef	1.45 def
Kordofan	Um-Rawaba*	3.53 de	3.67 c	0.96 def
	El-Rahad*	4.00 cde	3.37 cd	1.19 def
	Kadugli**	1.20 g	5.13 a	0.23 f
	Khour-Tagat**	2.13 f	4.33 b	0.49 ef
	El Obied**	1.80 f	4.80 ab	0.38 ef
	SE ±	0.194	0.179	0.370
	CV %	5.2	5.7	27.6

*, **= Striga populations collected from under sorghum and millet, respectively.
Means in the same column followed by the same letter(s) are not significantly different according to the Duncan's Multiple Range Test ($P \leq 0.05$).

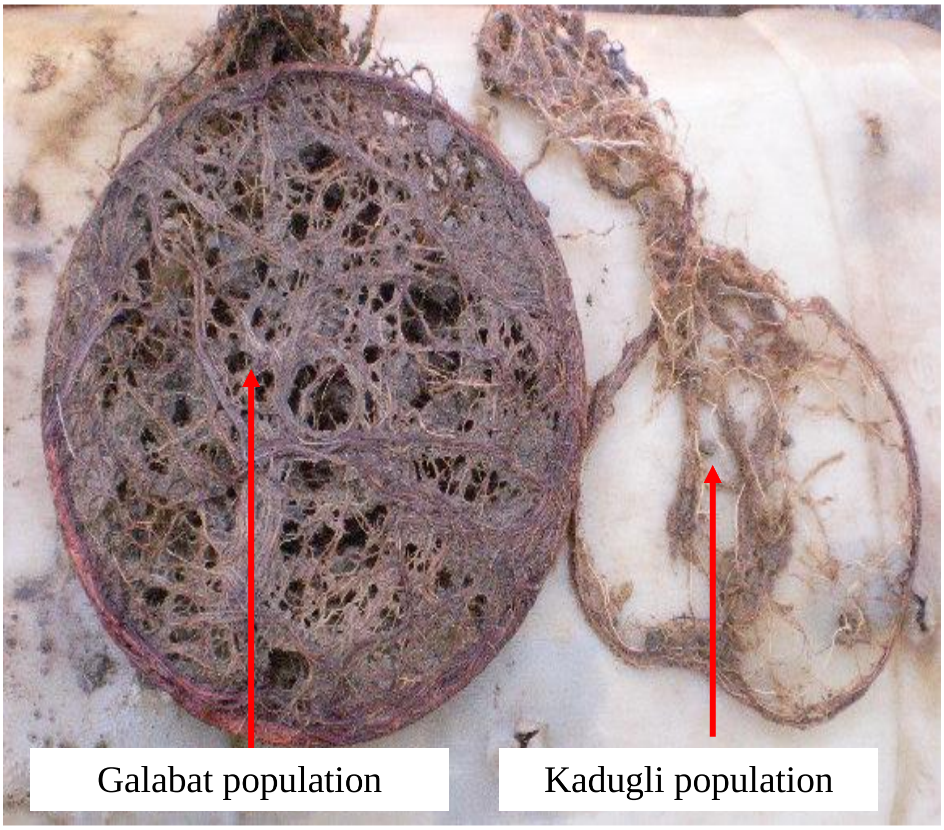

Plate 1. Response of sorghum root to infection by *S. hermonthica*.

Sorghum root/ shoot ratio

Sorghum infected by striga from Galabat, displayed the highest root/shoot ratio followed by sorghum infected by populations from Sumsum, Gadarif, Butana and El Fau (Table 6 and Plate 1). Sorghum parasitized by striga populations collected from Hasaheisa, Abu-Haraz, Hag-Abdalla, Barakat and Wad-Rabia, showed nonsignificant effect on root/ shoot ratio. Sorghum infected by striga populations from Um-Rawaba and El-Rahad and produced higher yet nonsignificant root/ shoot ratio in comparison to sorghum infected by striga populations from El Obied ,Kadugli and Khor Tagat.

DISCUSSION

The results revealed that *S. hermonthica* populations collected from infected sorghum areas, invariably, displayed relatively high virulence, while those from millet were less virulent and less suppressive to sorghum growth. *S. hermonthica* populations exhibited considerable variations in number of capsules per striga plant, shoot dry weight and number of underground striga plants per pot of sorghum plant. Generally, *S. hermonthica*, populations, irrespective of collection location, resulted in significant differences in sorghum growth across all assessment periods. At harvest, *S. hermonthica,* populations collected from different locations, induced significant variations on root and shoot dry weight and root/ shoot ratio. The results also, revealed that striga emergence was influenced by the crop, time after crop emergence and the striga strain used. *S. hermonthica* collected from under sorghum displayed a total number of striga plants per pot ranged between 1.3 and 21.3, while, those collected from under millet displayed total number of striga plants per pot ranged between 1.3 and 2 (Table 2). At 90 DACE, the *S. hermonthica* collected from under sorghum showed an average number of plants per pot ranging between 4.67 and 8.33 plants, while those collected from under millet showed an average ranging between 1and 2 plants per pot (Table 2). At harvest, *S. hermonthica* collected from under sorghum showed an average number of capsules ranging between 20.3 and 31.7 per plant, while those collected from under millet showed an average ranging between 10.0 and 10.3 (Table 3). At harvest *S. hermonthica* collected from under sorghum displayed an average shoot dry weight ranging between 0.19 and 1.77 g, while those collected from under millet resulted an average dry weight ranging between 0.02 and 0.03 g (Table 3). *S. hermonthica* collected from under sorghum showed an average of underground striga plants ranging between 5.00 and 13.3 per pot (Table 4), while those collected from under millet showed no underground striga plants.

These findings are consistent with those of Wilson-Jones (1955) that two strains of *S. hermonthica* exist in Sudan, one prevailing in Eastern and Central Sudan, but only attacks sorghum while in Western Sudan, both millet and sorghum are attacked. The strain on millet is less virulent to sorghum. Moreover, the results are in conformity with those of Doggett (1952) who suggested the existence of physiological strains of *S.*

hermonthica in East Africa. It was observed that varieties of *Sorghum* resistant in one location became susceptible in another (Doggett 1952). Similar observations were made by Ramaiah (1987) following his studies on S. *hermonthica* in West Africa. King and Zummo (1977) reported the existence of physiological specialization in *S. hermonthica* from West Africa following their analysis of parasite virulence on different host crops. Ali (2017) studied specificity and genetic relatedness among *S. hermonthica* strains in Sudan. The study, on the basis of penetration and genetic distance, confirmed clearly the existence of millet and sorghum strains in *S. hermonthica*.

The close association between striga, its host and the environment together with the copious seed production and ease of dissemination may maximize the risk of spread of the parasite by the ongoing climate changes (Mohamed *et al.* 2007). It is noteworthy that *S. hermonthica* collected from under millet attacked sorghum, but its growth was terminated and few striga plants emerged and set seeds (Table 2). This behaviour is intriguing and at the same time is an indicator of a serious problem. In Central and Eastern Sudan sorghum predominates and millet is rarely grown. However, in Western Sudan both crops are cultivated often in the same field. Accordingly, hybridization between the two strains may result in a progeny capable of aggressively attacking both crops. Intercrop and intra-crop specializations have been suggested in striga (Ramaiah and Parker 1982). However, specificity may break down when the cropping system is changed. The change may favour evolution of a new strain that adapts itself to the newly introduced crops fostered, perhaps by selection pressure (Musselman 1987).

It worth noting that *S. hermonthica* is an autogamous plant and is pollinated, mainly by insects (Parker and Riches 1993). Furthermore, striga is known to adapt itself to cropping systems. Differences in host plant adaptation among populations of striga have been reported (Ejeta *et al.* 1993). Introduction of maize into sorghum based cropping system initially decreases striga seed population density in soil, but the effect does not last, and heavy infection of the crop often develops. This phenomenon is most likely due to changes in genetic make up of striga population and/or preferential selection. The frequent cropping of maize results in selection and gradual build-up of races which are phenologically and physiologically adapted to the crop. Analysis of this apparent contradictory phenomenon may offer a better understanding of adaptation (host specificity) and adaptability (exceptions to host specificity) of striga. A similar observation was made in Ethiopia where teff [*Eragrostis tef* (Zuccagni) Trotter] previously, considered immune to *S. hermonthica* was reported to be attacked (Parker and Riches 1993). Further investigation into this phenomenon employing cross inoculations or molecular biology techniques is necessary. Such studies may improve understanding of inter and intra-crop specificity.

CONCLUSIONS

Striga hermonthica from sorghum populations, invariably, displays relatively high virulence, while those from millet are less virulent and less suppressive to sorghum growth. In general, *S. hermonthica* populations exhibits considerable variations in number of capsules per striga plant, shoot dry weight and number of underground striga plants per pot. Moreover, *S. hermonthica,* populations, irrespective of collection site, resulted in significant differences in sorghum growth across all assessment periods. At harvest, *S. hermonthica,* populations collected from different locations, induced significant variations in root and shoot dry weight and root: shoot of host plant. Furthermore, the results indicate the existence of two host-specific strains of *S. hermonthica* in the studied areas. Future indepth studies are needed to facilitate development of stable and durable resistance. They should concentrate on variability in *S. hermonthica* at the molecular level.

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تأثير تباين عشائر البودا (*Striga hermonthica*) على أداء الذرة الرفيعة (*Sorghum bicolor*) صنف أبو سبعين في السودان

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المستخلص: أُجريت مسوحات حقلية وتجربة بيوت محمية خلال الموسم 2009 / 2010 في السودان لدراسة التباين وتخصصية العائل في عشائرالبُودا [*Striga hermonthica* (Del.) Benth.]. أجريت المسوحات الحقلية في المناطق الموبؤة بالبُودا في القضارف والجزيرة وكردفان لجمع البذور من نباتات البُودا النامية على عوائلها الخاصة. جمعت خمسة عشر عشيرة للبُودا. منها اثني عشر عشيرة للبُودا من تحت الذرة الرفيعة، وجمعت ثلاث عشائر من تحت الدخن. أجريت تجربة البيوت المحمية بمشتل البساتين، كلية العلوم الزراعية، جامعة الجزيرة، ود مدني، السودان، لاختبار تلوث بذور عشائر البودا للذرة، الصنف أبو سبعين، المعروف باستجابته العالية. وُضعت الخمسة عشر عشيرة للبُودا في تصميم القطاعات العشوائية الكاملة بثلاث مكررات. تم تحديد مقاييس النمو والحصاد بالنسبة للطفيل والمحصول. حُولت البيانات عند الضرورة وأُخضعت لتحليل التباين. تم مقارنة المتوسطات بإستخدام اختبار دنكن، عندما كان الاختبار معنوياً. أوضحت نتائج تجارب البيوت المحمية أن قمة انبثاق نباتات البُودا في الأصيص، الكبسولات في النبات، الوزن الجاف للمجموع الخضري، عدد نباتات البُودا تحت سطح التربة في الأصيص والعدد الكلى لنباتات البُودا في الأصيص كانت أعلى على عوائلها الخاصة. الجدير بالملاحظة أن بعض نباتات البُودا، عشائر الدخن، أظهرت بزوغاً

محدوداً على الذرة وذلك فقط عند 60 يوم بعد بزوغ المحصول وأنتجت كبسولات. خفضت عشائر البُودا معنوياً نمو وإنتاج الذُرة والدُخن. لكن تحققت أعلى مستويات الضرر لكل عشيرة من البُودا على عائلها الخاص. تقترح نتائج هذا البحث وجود التخصصية بين وداخل نوع المحصول. كما أن النتائج توحي بوجود سلالتان للبُودا واحدة متخصصة في الذُرة والأخرى في الدُخن. أظهرت هذه النتائج بوضوح التعقيد في الحصول على أصناف من الذرة ذات مقاومة عالية وعريضة للبودا في المناطق المختلفة.