Variability in *Striga hermonthica* (Del.) Benth. Populations in Kordofan Area, Western Sudan

Awadallah B. Dafaallah¹
Abd Elgabar T. Babiker²
Mohammed H. Zain El abdeen¹
¹ Crop Protection Department, Faculty of Agricultural Sciences, University of Gezira, Wad Medani, Sudan.
² Plant Protection Department, College of Agricultural Studies, Sudan University of Science and Technology, Khartoum, Sudan.

**ABSTRACT**

Field surveys were conducted during the rainy season, 2008/09, in Kordofan area, Western Sudan, to investigate variability within *S. hermonthica* populations in Kordofan area, Western Sudan.
hermonthica populations with respect to morphological characters. Five locations; Um-Rawaba, El-Rahad, Kadugli, Khour-Tagat and El Obied; were selected at random in Striga hermonthica endemic area in Western Sudan. Variability among S. hermonthica populations was determined by measuring morphological characters including number of plants / m², plant height, number of leaves, number of internodes, capsules / plant and shoot dry weight. Flower characters including number of ribs / calyx, flower width, Length of corolla tube, bracts width, colour of spike and colour at drying. Data on S. hermonthica morphology were collected and subjected to descriptive analysis and analysis of variance (ANOVA). Where the test was significant, separation of means was done by using Duncan's Multiple Range Test (P ≤ 0.05). Data on flower characters were subjected to descriptive analysis and compared with the taxonomic key published by Parker and Riches (1993). The results of the surveys revealed that, S hermonthica was found on both sorghum and millet genotypes in Kordofan area. S hermonthica populations collected from different locations in Kordofan area showed significant differences in morphological characters. However, differences in flower shape, size and colour were often not significant. Average Striga height ranged between 56.2-64.2 cm, leaves production ranged between 44.7-78.1, number of internodes ranged between 22.3-40.4 and density ranged between 33.7-71 plant / m². Average of capsules / plant ranged between 33.6-54.3, seeds per parasite ranged between 23520-37986.7 and Striga shoot dry weight ranged between 1.57-14.23 g. The average of ribs / calyx ranged between 5.3–6.1, flower cross ranged between 1.5-2.3 cm, length of corolla tube ranged between 1.3-1.8 cm, width of bracts was 2.4 cm and spikes had pink flowers that turn dark at drying. The variability in morphological and floral characters revealed by this study could be attributed to a multitude of variables including initial size of Striga seed bank, Striga species, strains or variants, crop genotype, management and climatic and edaphic condition including, spacing, soil fertility and moisture status. Further studies should be conducted to investigate the molecular basis of variability within Striga hermonthica populations and it's interaction with selected hosts in Sudan. 

Keywords: Striga, survey, morphology, flower, taxonomy.

INTRODUCTION

Witchweeds (Striga spp.), member of the family Orobanchaceae (Olmostead et al., 2001), are obligate root parasitic plants that attack agronomically important cereals and legumes (Anonymous, 1993). Striga is the major biotic constraint to cereals production, especially in the non-fertile
Semi-arid region of Sub-Saharan Africa (Haussmann et al., 2000). The parasite negatively affects the lives of over 300 million people (Anonymous, 1993; Kim et al., 2002). In extreme cases, severe infestation of Striga results in complete loss of the crop and the abandonment of productive fields (Butler, 1995). The increasing seriousness of the Striga problem is directly related to increased land-use intensity to produce sufficient food for the burgeoning human populations (Butler, 1995; Berner et al., 1996). In Sudan, Striga hermonthica (Del.) Benth is the most serious biotic problem to cereal production. It attacks sorghum (Sorghum bicolor [L.] Moench), millet (Pennisetum glaucum [L.] R. Br.), maize (Zea mays L.) and rice (Oryza sativa L.) (Abbashier et al., 1998). Musselman and Hepper (1986) believed, on basis of common occurrence on wild grasses, 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 Sudanese people in rural areas (Zahran, 2008). The impact of Striga is compounded further by its predilection for attacking crops already under moisture and nutrient stress, conditions that prevail throughout the semi-arid tropics. Moreover, available evidences strongly suggest that the problem is worsening (Ejeta and Butler, 1993).

Wilson-Jones (1955) reported two strains of S. hermonthica from the Sudan, one specific to sorghum and the other to millet. Sorghum was usually heavily attacked by S. hermonthica on the Central clay plains whereas millet was particularly immune, but the reverse is true on the sandy soils of Western Sudan. The existence of intercrop-specific strains in Striga has been suggested to be based almost entirely on differential response of variants of the species to root exudates from host cultivars (Bebawi and Farah, 1981). However, recent studies showed that differential post-germination development could be a determinant factor in the observed host-specificity (Ali, 2008). Several experiments were undertaken to study variability in S. hermonthica. However, little work has been done on biological basis of variability within S. hermonthica populations and it's interaction with selected hosts in Sudan. Understanding the relationship between variability within and among geographically separated populations and host preference should improve the ability to successfully breed for broad and durable resistance to Striga species among the most common hosts; sorghum and millet (Christopher et al., 2002). Therefore, this study covers different locations in Kordofan area, Western Sudan, with the objective of study variability within S. hermonthica populations with respect
to morphological characters.

MATERIALS AND METHODS

Field surveys

Field surveys were conducted during the rainy season (mid-September to mid-October), 2008/09, in Gadarif area, Eastern Sudan, to study variability within *S. hermonthica* populations with respect to morphological characters. Five locations were selected randomly, i.e. Um-Rawaba, El-Rahad, Kadugli, Khour-Tagat and El Obied. Three sites were selected at random in each location. Three *Striga* infested fields were chosen at random in each site. At time of harvest ten plots (10x10 m) were selected in each field. Ten quadrates (1 m² each) were placed at random in each plot. In each quadrate, variability among *S. hermonthica* was measured.

Variability among *S. hermonthica* populations was determined by measuring morphological characters including number of plants / m², plant height (cm), number of leaves, number of internodes, capsules / plant and shoot dry weight (g). Flower characters including number of ribs / calyx, flower width (cm), Length of corolla tube (cm), bracts width (cm), colour of spike and colour at drying were also observed and determined.

Statistical analysis

Data on *S. hermonthica* morphology were collected and subjected to descriptive analysis and analysis of variance (ANOVA). Where the test was significant, separation of means was done using Duncan's Multiple Range Test (*P* ≤ 0.05). Data on flower characters were subjected to descriptive analysis and compared with the taxonomic key published by Parker and Riches, (1993).

RESULTS

Field surveys

Host plant species and cultivars that were observed to be infested by *S. hermonthica* in the endemic areas in Western Sudan during the rainy season, were; sorghum genotypes; Zinari, Fetarita, Mogud and Local sorghum; and millet genotype; Yellow millet and Local millet (Table 1).

Variability within *S. hermonthica* populations

Variability within *S. hermonthica* populations was studied with respect to general morphological and flower characters.

General *S. hermonthica* morphology

Irrespective of host plants, there were significant differences in *S. hermonthica* growth parameters; number of plants per m², plant height, number of leaves, number of internodes and harvest parameters including; capsules / plant, seeds / plant and shoot dry weight within and between
locations.

At Um-Rawaba location, the number of *Striga* plants / m² was 61, 58 and 60 on Local sorghum site I, Local sorghum site II and Mogud at site III, respectively (Fig. 1A). The corresponding average height of *S. hermonthica* was 44 cm, 63 cm and 52 cm, respectively. The average number of leaves and internodes was 38 and 19 on Local sorghum at site I, 48 and 24 on Local sorghum at site II, and 49 and 24 on Mogud at site III, respectively. The average number of capsules per *S. hermonthica* plant was 52 on Local sorghum at site I, 42 on Local sorghum at site II and 30 on Mogud (Fig. 1B). The average shoot dry weight of *S. hermonthica* was 3.2 g on Local sorghum site I, 2.2 g on Local sorghum site II and 1.9 g on Mogud.

At El-Rahad location, the number of *Striga* plants / m² was 40, 20 and 41 on Zinari at site I, site II and Local sorghum, respectively (Fig. 2A). The corresponding average height of *S. hermonthica* was 55 cm, 57 cm and 57 cm, respectively. Moreover, the average number of leaves and internodes was 64 and 36 on Zinari at site I, 99 and 51 on Zinari at site II, 67 and 34 on Local sorghum, respectively. The average number of capsules / *S. hermonthica* plant was 56 on Zinari at site I, 45 on Zinari at site II and 55 on Local sorghum (Fig. 2B). The average shoot dry weight of *S. hermonthica* was more or less the same identical (14 g) at the three sites.

At Kadugli location, the number of *Striga* plants / m² was 64 and 76 on Fetarita at site I and site II, respectively and 73 on Local millet (Fig. 3A). The average height of *S. hermonthica* was 58 cm, 64 cm and 62 cm on Fetarita at site I, site II and Local millet, respectively. On the other hand, the average number of leaves was 51 on Fetarita at site I, 49 on Fetarita at site II and 86 on Local millet at site III. The average number of internodes was 26 on Fetarita at site I, 24 on Fetarita at site II and 43 on Local millet, respectively. The average number of capsules / *S. hermonthica* plant was 41 on Fetarita at site I, 33 on Fetarita at site II and 44 on Local millet at site III (Fig. 3B). The average shoot dry weight of *S. hermonthica* was 8 g, 7.5 g and 8 g on Fetarita at site I and site II, respectively and Local millet at site III.

At Khour-Tagat location, the number of *Striga* plants / m² on Yellow millet was 74, 66 and 63 at site I, II and III, respectively (Fig. 4A). The corresponding average height of *S. hermonthica* was 64 cm, 63 cm and 57 cm, respectively. Furthermore, the average number of leaves and internodes was 48 and 25 on Yellow millet at site I, 39 and 19 at site II, 47 and 26 at site III, respectively. The average of capsules per *S. hermonthica* plant was 36 at site I and II and 29 at site III (Fig. 4B). The average shoot dry weight of *S.
hermonthica was 1.6g, 1.4g and 1.7 g at site I, II and III, respectively. At El Obied location, the number of *Striga* plants / m² was 66 on Yellow millet, 63 on Mogud and 63 on Fetarita (Fig. 5A). The average height of *S. hermonthica* was 53 cm, 71 cm and 69 cm on Yellow millet, Mogud and Fetarita, respectively. Moreover, the average number of leaves was 59 on Yellow millet, 72 on Mogud and 62 on Fetarita. The average number of internodes was 30 on Yellow millet, 36 on Mogud and 31 on Fetarita, respectively. The average number of capsules per *S. hermonthica* plant was 40 on Yellow millet, 64 on Mogud and 59 on Fetarita (Fig. 5B). The average shoot dry weight of *S. hermonthica* was 7.6 g, 8.1 g and 6.4 g on Yellow millet, Mogud and Fetarita, respectively.

**Description of *S. hermonthica* flower**

*Striga hermonthica* populations collected from different locations in Kordofan area, Western Sudan, showed variations in diagnostic features of flower (Table 2). The average number of ribs on the calyx ranged between 5.3 for populations collected from Khour-Tagat to 6.1 for population collected from Kadugli. The average of flower width ranged between 1.5 cm for populations collected from El-Rahad, and 2.3 cm, for population collected from Kadugli. The average corolla tube length was 1.3 cm for populations collected from El-Rahad to 1.8 cm for populations collected from Um-Rawaba and El Obied. The average bracts width was 2.4 mm across surveyed area. Spikes had pink flowers that turned dark after senescence (Table 2).

**DISCUSSION**

The results of the field surveys during the rainy season revealed that, both sorghum and millet genotypes in *Striga* in endemic area were observed to be infested by the parasite (Table 1). Wilson-Jones (1955) observation that two strains of *S. hermonthica* exist in Sudan. One prevailing in Eastern and central Sudan and attacked sorghum but not millet. While in western Sudan, both millet and sorghum were attacked. Furthermore, the strain on millet did not attack sorghum and vice versa. Sorghum was usually heavily attacked by *S. hermonthica* in the clay soils of the Sudan whereas millet was particularly immune, but the reverse was true on sandy soils.

In Western Sudan, both crops are cultivated often in the same field. Accordingly, hybridization between the two strains is resulting in a progeny capable of attacking both crops. It has to be noticed that *S. hermonthica* autogamous plant and pollinated, mainly, by insects (Parker and Riches, 1993). Furthermore, *Striga* is known to adapt itself to cropping system. 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 infestation of the crop often develops. This phenomenon is most likely due to changes in genetic composition of Striga population. The frequent cropping of maize results in selection and gradual build-up of races which are phonologically and physiologically adapted to the crop. Analysis of this apparent contradictory phenomenon may offer 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).

The results of the field surveys also revealed significant variability within S. hermonthica populations with respect to general morphological and floral characters (Fig. 1–5 and Table 2). This finding is in line with previous reports in existence of morphotypes in Striga (Ejeta et al., 1993). Striga hermonthica height was 59.2 cm in Kordofan area. However, plant height, across the surveyed location ranged between 56.2 cm and 64.2 cm (Table 3). The average number of leaves produced by S. hermonthica plant was 58.8, while the number of leaves ranged between 44.7 and 78.1 across the location surveyed (Table 3). The average of internodes was 30 in Kordofan area. However, internodes ranged between 22.3 and 40.4 (Table 3). The variability in morphological and floral characters was in line with those reported by Andrews (1945) who found that, S. hermonthica has bright to dark green leaves, erect and usually branched stems grow up to 60 cm or more. Stems are stout and quadrangular. Leaves are linear, lanceolate or lanceolate with acuate or acuminate tips, 1-3 in. long, very scabrous. Furthermore, results support the existence of morphotypes.

The results showed that, the average production of capsules / S. hermonthica plant was 44.1 in Kordofan area (Table 4), while, the total number of capsules / plant was 33.6 and 54.3 across surveyed locations (Table 4). A previous report by Parker and Riches (1993) showed that, the number of capsules / plant may be about 14 in S. forbesii, but ranged between 60 and 70 in S. hermonthica and S. asiatica. The average of seeds produced by S. hermonthica plant was 30870 in Kordofan area (Table 4). However, the range across the surveyed area was 23520 to 37986.7 seed (Table 4). This finding is in conformity with that reported by Andrews (1945) who reported that, the number of seeds / capsule is about 700 in S. hermonthica. Visser (1981) working with S. asiatica showed that one plant
is capable of producing up to half a million minute dust like seeds in a single growing season. Parker and Riches (1993) recorded a 7 μg, as an average weight for Striga seed. Moreover, they reported production of 58000 seeds / plant by S. asiatica and number over 200000 can almost certainly occur in well-grown S. hermonthica. The results of this study is in line with the reported seed productivity of S. hermonthica and suggest that S. hermonthica may be less copious seed producer than S. asiatica. The average shoot dry weight of S. hermonthica was 6.684 g in Kordofan area (Table 4). However, the range in shoot dry weight showed considerable variability and was 1.57-14.23 g. Dafaallah (2006) based on pot experiment reported a dry weight of 1.83 g per S. hermonthica plant. The low dry weight recorded by Dafaallah (2006) may be due to, among other factors, restriction of growth of both the host and the parasite inflicted by the available resources. Striga population density displayed considerable variability both within and between locations. The number of Striga plants / m² was 59.2 in Kordofan area (Table 3). However, within surveyed locations, the mean density of the parasite ranged between 33.7 and 71 plants / m². The close association between the Striga its host with and the environment together with copious seed production and ease of destination may maximize the risk of spread of the parasite by the ongoing climate change (Mohamed et al., 2007).

S. hermonthica populations collected from different locations in Kordofan area, showed considerable variations in diagnostic features of the flower (Table 2). Average width of bracts was 2.4 mm. Average of ribs on the calyx was 5.3–6.1. Average length of corolla tube was 1.3-1.8 cm. Furthermore, spikes had pink flowers that turn dark on drying. These results are in agreement with those reported Parker and Riches (1993) who showed that, the inflorescence of S. hermonthica possesses 6-10 open flowers that are pink and 1-2 cm across. Calyx ribs usually 5 or 6 (1 / calyx lobe). Corolla tube is 1.5-2 cm long, bracts below each flower 2-3 mm wide. The variability in morphological and floral characters revealed by this study and elsewhere (Andrews,1945; Parker and Riches (1993) could be attributed to a multitude of variables including initial size of Striga seed bank, Striga species, strains or variants, crop genotype, management and climatic and edaphic condition including, spacing soil fertility and moisture status (Fig. 1 to 5 and Table 2).
CONCLUSIONS AND SUGGESTIONS

- Striga in Kordofan area, Western Sudan, was found on both sorghum and millet genotypes.
- S. hermonthica populations collected from different locations in Kordofan area, Western Sudan, showed significant differences in morphological characters. However, differences in flower shape, size and colour were often not significant.
- The variability in morphological and floral characters reported in this study could be attributed to a multitude of variables including initial size of Striga seed bank, Striga species, strains or variants, crop genotype, management and climatic and edaphic condition including, spacing soil fertility and moisture status.

REFERENCES


Table 1. *Striga hermonthica* collection sites in Kordofan area, Western Sudan, and host plants

<table>
<thead>
<tr>
<th>Location</th>
<th>Host plant Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site I</td>
<td>Site II</td>
</tr>
</tbody>
</table>

10
<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Local 1</th>
<th>Local 2</th>
<th>Mogud</th>
</tr>
</thead>
<tbody>
<tr>
<td>Um-Rawaba</td>
<td>Local*</td>
<td>Local*</td>
<td>Mogud*</td>
</tr>
<tr>
<td>El-Rahad</td>
<td>Zinari*</td>
<td>Local*</td>
<td>Zinari*</td>
</tr>
<tr>
<td>Kadugli</td>
<td>Fatarita*</td>
<td>Local **</td>
<td>Fatarita*</td>
</tr>
<tr>
<td>Khor-Tagat</td>
<td>Yellow**</td>
<td>Yellow**</td>
<td>Yellow**</td>
</tr>
<tr>
<td>El Obied</td>
<td>Yellow**</td>
<td>Mogud*</td>
<td>Fatarita*</td>
</tr>
</tbody>
</table>

**A**

- **Parameter measured:**
  - No. of plants/m2
  - Plant height (cm)
  - No. of leaves
  - No. of internodes

**B**

- **Parameter measured:**
  - Capsules/plant
  - Shoot dry weight (g)
Fig. 1. Means of selected growth and harvest parameters of *S. hermonthica* at Um-Rawaba location. Vertical bar represents ± standard deviation.

Fig. 2. Means of selected growth and harvest parameters of *S. hermonthica* at El-Rahad. Vertical bar represents ± standard deviation.
Fig. 3. Means of selected growth and harvest parameters of S. hermonthica at Kadugli location. Vertical bar represents ± standard deviation.
Fig. 4. Means of selected growth and harvest parameters of S. hermonthica at Khour-Tagat location. Vertical bar represents ± standard deviation.
Fig. 5. Means of selected growth and harvest parameters of S. hermonthica at El Obied location. Vertical bar represents ± standard deviation.

Table 2. Variability within *Striga hermonthica* populations with respect to flower description.
<table>
<thead>
<tr>
<th>Location</th>
<th>No. of ribs / calyx</th>
<th>Flower width (cm)</th>
<th>Length corolla (cm)</th>
<th>Length of tube (mm)</th>
<th>Bracts width (mm)</th>
<th>Colour of spike</th>
<th>Colour at drying</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M ±SD</td>
<td>M ±SD</td>
<td>M ±SD</td>
<td>M ±SD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Um-Rawaba</td>
<td>5.8 0.06</td>
<td>1.8 0.05</td>
<td>1.8 0.01</td>
<td>2.4 0.00</td>
<td>8</td>
<td>Pink</td>
<td></td>
</tr>
<tr>
<td>El-Rahad</td>
<td>5.6 0.56</td>
<td>1.5 0.03</td>
<td>1.3 0.06</td>
<td>2.4 0.20</td>
<td>8</td>
<td>Dark</td>
<td></td>
</tr>
<tr>
<td>Kadugli</td>
<td>6.1 0.38</td>
<td>2.3 0.67</td>
<td>1.7 0.08</td>
<td>2.4 0.00</td>
<td>8</td>
<td>Pink</td>
<td></td>
</tr>
<tr>
<td>Khour-Tagat</td>
<td>5.3 0.15</td>
<td>1.7 0.23</td>
<td>1.7 0.12</td>
<td>2.4 0.20</td>
<td>8</td>
<td>Dark</td>
<td></td>
</tr>
<tr>
<td>El Obied</td>
<td>5.7 0.06</td>
<td>2.2 0.60</td>
<td>1.8 0.04</td>
<td>2.4 0.00</td>
<td>8</td>
<td>Pink</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Means of *Striga hermonthica* growth parameters in different locations

<table>
<thead>
<tr>
<th>Locations</th>
<th>No. of plants / m²</th>
<th>Plant height (cm)</th>
<th>No. of leaves</th>
<th>No. of internodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Um-Rawaba</td>
<td>71.0 a</td>
<td>61.2 b</td>
<td>62.2 c</td>
<td>31.2 c</td>
</tr>
<tr>
<td>El-Rahad</td>
<td>67.6 b</td>
<td>61.2 b</td>
<td>44.7 d</td>
<td>23.6 d</td>
</tr>
<tr>
<td>Kadugli</td>
<td>59.7 d</td>
<td>53.1 d</td>
<td>44.8 d</td>
<td>22.3 e</td>
</tr>
<tr>
<td>Khour-Tagat</td>
<td>64.1 c</td>
<td>64.2 a</td>
<td>64.4 b</td>
<td>32.2 b</td>
</tr>
<tr>
<td>El Obied</td>
<td>33.7 e</td>
<td>56.2 c</td>
<td>78.1 a</td>
<td>40.4 a</td>
</tr>
</tbody>
</table>

Mean 59.22 59.18 58.84 29.94
SE ±0.153 0.209 0.200 0.154
CV % 11.0 12.8 9.8 12.8

* Means in the same column followed by the different letter(s) are significantly different according to Duncan's Multiple Range Test at P ≤ 0.05.