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Screening Sorghum Populations for Resistance to *Striga hermonthica* (Del.) Benth in Northern Cameroon

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ABSTRACT

To evaluate the effects of leaf mulches from three leguminous trees and genotypes, fifteen sorghum accessions were studied in plots inoculated with seeds of root parasite Striga hermonthica during wet 2006 at Moutourwa (northern Cameroon). The same genetic material was screened in pots trials during the 2007 cropping season in Ngaoundéré to assess their varietal response to Striga infestation. In pots and in field, results showed that soghum cultivars differed significantly with respect to number of emerged Striga plants. Under high and uniform infestation, three promising varieties namely S35, CS54 and Défé Gala constantly recorded low number of parasite plants and low host damage score. Mature plant resistance was also expressed by delay of parasite emergence and inhibition of its development, low reduction in sorghum growth and production (dry matter and grain yield) in comparison with susceptible varieties. Globally, in pot trials, Striga infestation reduced sorghum height, panicle weight and grain yield by 36.6%, 33.7% and 56.5% respectively in comparison with uninfected control. Application of leaf mulches from leguminous trees decreased Striga emergence (31.5% at maturity), and host damage (20.47%), and in contrast, increased sorghum height (22.36%), dry matter accumulation (25.15%) and grain yield (23.25%). Fertilization of resistant sorghum genotypes further reduced Striga emergence and partially mitigated its effects on sorghum yield. Adoption of an integrated approach encompassing high yielding Striga resistant and/or tolerant varieties combined with use of organic fertilization may provide a cheap and easy to apply method for Striga control under low-input farming systems.

Key words: sorghum varieties, *Striga hermonthica*, resistance, organic fertilization, northern Cameroon.

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench), an important staple food crops, is grown by subsistence farmers on more than 48 million hectares in sub-Saharan Africa [1, 2]. In the semi-arid regions of Cameroon, sorghum grains are used for human food, beer and feed for animals; the plant stem and foliage are used for green shop, hay, silage, building material and pasture while plant remains are used for fuel [3]. The crop productivity is, however, constrained by the obligate parasitic witchweed, *Striga hermonthica* (Del.) Benth., a scourge of cereal crops, which takes up assimilates and water from their host through haustorial connections [4]. Yield losses varying from 10 to 100% depending on crop cultivar and infestation level, have been reported [5, 6, 7]. In Northern Cameroon, yield losses have been estimated to averagely 40%, but total loss can occur in some years in area of heavy infestation [4]. In view of the fact that *Striga* can cause hunger and poverty, effective *Striga* control and management has become imperative, in order to maximise cereal yield, and improve the socio-economic well-being of people.

Several options, including the use of hand pulling, soil fertility improvement, chemical control, trap crops rotation or intercropping, biocontrol, and resistant or tolerant varieties have been recommended for controlling *Striga* in farmers' fields [2, 8, 9, 10]. In developing countries, most of methods available to date have been costly and beyond the means of farmers [4, 11, 12]. The diversity of the farming systems in Africa and that of the parasite have rendered the use of a single control method ineffective [13]. At present, efforts are being made to alleviate the parasitic weed problem in the badly infested soils through host plant resistance and improvement of soil fertility [3, 14, 15]. A number of basic resistance mechanisms to *Striga* including low stimulant production, mechanical barriers to *Striga* ingress, antibiosis and hypersensitivity, have been suggested in sorghum [9, 16, 17]. Many research works outlined that the severity of *Striga* parasitism increases under low soil fertility [18, 19]. Land depletion and declining soil fertility due to shifting cultivation and declining in fallow periods are increasingly viewed as critical problems affecting agricultural productivity and human welfare in Sudano-Sahelian zone of Cameroon [4]. In this area, the continual cultivation of susceptible cereal crops leads to the production of more *Striga* seeds (ca. 500,000 per plant) and results of unintentional contamination of field [2, 9]. The cropping system based on high frequency of cereals with limited legumes in the rotation and in combination with limited use of fertilizers for fertility worsened the *Striga* situation [4, 20].

The use of resistant varieties and the improvement of soil fertility appear as the most appropriate means of combating *Striga* in resource-poor farming systems [11, 21, 22, 23]. Few reports are available on the reactions to *Striga* infestation of the main sorghum varieties and landraces cultivated in northern Cameroon and on the effects of organic fertilization on the parasite control. Since *S. hermonthica* is an obligate out-crossing parasite, it presents different strains adapted to a wide range of crops and environment [24, 25]. This study was therefore conducted to (i) examine the response of fifteen sorghum populations for traits associated with resistance to *S. hermonthica*, (ii) and determine the effects of organic fertilizer on *Striga* incidence and sorghum grain yield.

MATERIALS AND METHODS

Plant material

The sorghum varieties used in this study comprised seven improved lines (CS-54, CS-61, CS-95, CS-141, CS-210, S-35 (MRV-35), Gueling) and eight indigenous grain genotypes representing the types widely grown in Mayo Danay division (Ajagamaari, Défé Gala, Faragawri, Garé Panaré, Majeeri, Njigaari, Schawchai, Yaassé).

Field Experiment

A field experiment was conducted during wet 2006 at Moutourwa, northern Cameroon (latitude: 09° 045' N; longitude: 11° 774' E; altitude: 868 m) in a 750 m^2 area (25 m x 30 m). The soil of the experimental site is sandy clay with 8.00 mg kg^{-1} organic matter, nutrient-depleted and pH 5.77. The climate of the locality is of the Sudano-Sahelian type, characterized by a rainy season (July to October) and a dry season (November to June). The annual rainfall ranges between 810 to 920 m. The average annual temperature is 25°C, while the annual hygrometry is about 60%. The experiment was laid out in a split plot design consisting of 15 sorghum varieties (treatments), two sub-treatments (mulched plots and control) with three replications. One plot consisted of two rows each 4 m long and 0.5 m wide. Rows and hills were spaced 0.5 m and 0.25 m (one plant per hill) respectively. Organic mulches made of a mixture of fresh pruned leaves derived from three leguminous trees; *Entanda africana*, *Faidherbia albida* and *Prosopis Africana*, were incorporated approximately 10 cm deep, at the rate of 12t ha^{-1} in the soil. Leaf mulches were applied at April, two months before sorghum planting. Mixed leaf litter of these legumes was thus decomposed during two months. One year old *Striga* seeds were infested on the same day as, and prior to sorghum planting. Five grams of *Striga* seeds-sand mixture (2/98 g) was inoculated approximately 5 cm deep in each planting hole and the holes were covered with soils. Sorghum sowing for all the treatments was carried out on 25 June. Three sorghum seeds were planted per infested hill and later thinned to have one plant per hill at two weeks after planting. Weeds other than *Striga* were regularly handpicked.

Data were collected from the central part of each plot. *Striga* count was calculated per 0.5m^2 and the host plant damage was rated based on the scale of 1 to 9 (1= normal growth, no visible damage symptoms, 9 = severe damage or death) at 110 DAS (days after sowing) [2, 26]. Plant height (cm) was measured from the soil surface to the tip of the main head as an average of ten plants, randomly chosen, just before harvesting. Sorghum dry matter (t/ha) was determined on random sample of plants from four square meters of each plot. For grain yield (t/ha), panicles from the four square meters in each plot were harvested, sun dried, threshed, weighed and converted to t/ha. The relative yield gain (RYG) was calculated as [27]:

$$RYG = [(Yf - Yu) / Yu] \times 100$$

Where *Yf* is the average yield of plants of a specific genotype on fertilized plot and *Yu* is the observed yield of plants grown under *Striga* infestation in unfertilized plot.

Pot trials

Pot trials were conducted during 2007 at the University of Ngaoundéré, Dang campus, Adamawa region, which intersected by 13°34' East longitude and 7°28' North latitude and has an elevation of 1115 m above the sea level. Pots were laid out in a factorial design with 15 varieties (treatments) and two sub-treatments (infested and control) with three replications. Each sorghum line was sown in eighteen 12-l plastic pots of 20 cm in diameter filled with ferruginous topsoil collected from *Striga*-free area. *Striga* seeds were collected at the end of previous season from sorghum fields at different localities around Zouaye and Garoua in northern Cameroon. A 6 cm deep hole dug in each pot was infested by placing 5 g of sand-mixed *S. hermonthica* inoculums (2:98). Pots were watered to allow preconditioning of the *Striga* seeds. After one week, four sorghum seeds were sown into each hole and plants were thinned to one per hill two weeks later. The pots were watering daily to prevent moisture deficit. On infested pots, the numbers of emerged *Striga* seedlings at 110 DAS were averaged over three pots and recorded as final count for each replication. Other data collected include days to emergence of first *Striga* plant, *Striga* height at 110 DAS, sorghum plant height at maturity, panicle weight and grain yield per plant. Days to emergence of first *Striga* were recorded as the number of days from the sowing date to the day on which a *Striga* plant emerged from pot. The mean weight of panicle (g) was based on the random sample of three heads from each experimental unit. The relative yield loss (RYL) was calculated as outlined by Rodenburg *et al* [27]:

$$RYL = [(Yc - Ys) / Yc] \times 100$$

Where Yc is the average yield of control plants of a specific genotype and Ys is the observed yield of plants grown under *Striga* infestation

Data analysis

All data were subjected to descriptive statistics and analysis of variance (ANOVA) using computer program Stagraphics Plus. If the F-test was significant at $p \leq 0.05$, varietal differences was tested by Least Significant Difference (LSD) at 5% level of probability. The mulch effects in field and the infestation effects in pots were tested by t-test at 5% level of probability.

RESULTS AND DISCUSSION

Variance Analysis

Analysis of variance showed that in the field, *Striga* infestation, host damage, sorghum height, sorghum dry matter and sorghum grain yield were influenced by both genotypes and fertilization, while their interaction affected significantly ($p \leq 0.05$) only cereal height and dry matter production (Table 1). Non-significance of organic fertilization x variety interaction ($p \geq 0.05$) for *Striga* count suggested that varieties had the same response to organic mulches application, irrespective to their reaction to *Striga*. These observations agree with Kamara et al. [15] for nitrogen rate x variety interaction in maize.

Table 1: F-values from variance analysis of 15 sorghum varieties tested in field under mulch amendments and *Striga* infestation

Source of variation	Df	*Striga* count at 70 DAS	*Striga* count at maturity	Host damage	Sorghum height	Dry matter	Grain yield
Genotypes (G)	14	3.69**	2.87**	3.03**	2.04**	3.98**	5.09**
Fertilization (F)	1	6.23**	6.23**	7.70**	3.00**	3.22**	2.68**
G x F interaction	14	1.22^{ns}	0.87^{ns}	0.43^{ns}	1.98**	2.11*	1.44^{ns}
Repetition	2	0.56^{ns}	0.74^{ns}	1.01^{ns}	0.66^{ns}	0.96^{ns}	0.47^{ns}

***, * and ^{ns}: Significant at $P \leq 0.01$ and $P \leq 0.05$ and insignificant, respectively.*

Variability in host plant resistance

Striga emergence, at 70 DAS and at maturity, and host damage score showed differential response to crop cultivar and to organic mulch application (Table 2). The plots with mulches had an average of 4.45 and 5.13 *Striga* counts $0.5m^{-2}$, while the control had 5.97 and 7.44 *Striga* counts $0.5m^{-2}$ respectively at 70 DAS and at maturity. Visual evaluation of *Striga* damage symptoms varied approximately from 2 (scattered small and vague whitish leaf blotches visible; normal growth) to 7 (extensive streaking/scorching turning gray and necrotic; severe stunting; noticeable reduction in height, in stem diameter and in panicle size). Host plant damage symptom rating represents a visual assessment of the extent of leaf chlorosis, scorching and reduction in plant height as well as panicle size of the host plant caused by *Striga* [1]. The varieties S35, CS54 and Défé Gala had low damage score.

Also, in infested pots, analysis of variance showed that the number *Striga* at 110 DAS, the date of emergence of first *Striga* plant and the *Striga* height varied significantly ($P \leq 0.01$) among the fifteen sorghum varieties (Table 3). The mean number of emerged *Striga* plant^{-1} ranged from 2.15 (S35) to 9.87 (Gueling). Haussmann et al. [5] considered entries as resistant when they supported significantly fewer emerged *Striga* plants. In addition to S35, the lines CS54, and Défé Gala also exhibited reduced *Striga* emergence. The emergence of parasite was slow and delayed by about two weeks in resistant cultivars CS54 and Défé Gala compared to susceptible lines Yaassé and Gueling. Similar reports were outlined by Gebremedhin et al. [24] on two contrasted sorghum varieties. Ezeaku and Gupta [11] pointed out that the genetic differences between sorghum cultivars affect time of parasite attachment, with tolerant varieties showing later attachment and later parasite emergence than sensitive cultivars. The observed reduction and delay in *Striga* emergence may be attributed to reduced germination, reduced haustorium initiation and attachment [25].

Table 2: Varietal response and leaf mulches effects on *Striga* emergence and host damage score of fifteen sorghum varieties

Genotypes	*Striga* count (no./0.5 m^2) at 70 DAS			*Striga* count (no./0.5 m^2) at maturity			Host damage score (1-9)		
	Cont.	Fert.	%R	Cont.	Fert.	%R	Cont.	Fert.	%R
CS-54	4.22^{a}	2.27^{a}	46.21**	4.38^{a}	2.95^{a}	32.63**	3.83^{bc}	2.67^{ab}	30.28**
CS-95	7.25^{h}	6.64^{h}	8.41^{ns}	9.04^{h}	7.67^{g}	15.15*	6.33^{fgh}	4.67^{fg}	26.22**
CS-141	6.68^{f}	3.72^{c}	44.31**	7.30^{de}	3.98^{b}	45.47**	5.83^{f}	4.50^{ef}	22.82**
CS-210	5.45^{c}	5.00^{f}	8.26^{ns}	6.86^{cd}	5.88^{e}	14.28*	5.00^{e}	4.25^{de}	15.00*
S-35	4.02^{a}	1.91^{a}	52.48**	4.23^{a}	2.86^{a}	32.38**	3.33^{b}	2.75^{b}	17.42**
Gueling	8.57^{i}	7.53^{i}	12.13*	10.83^{i}	8.50^{h}	21.51*	7.08^{i}	5.25^{h}	27.84**
Ajagamaari	6.86^{fg}	3.97^{cd}	42.13**	8.85^{h}	4.87^{cd}	44.97**	4.40^{cde}	4.00^{d}	11.11*
Défé Gala	4.04^{a}	3.15^{b}	22.03**	4.30^{a}	3.21^{a}	25.35**	2.67^{a}	2.33^{a}	12.73*
Faragawri	5.93^{d}	4.42^{e}	25.46**	6.76^{c}	4.76^{cd}	29.59**	6.00^{fg}	5.08^{h}	15.33**
Garé Panaré	4.64^{b}	3.95^{cd}	14.87*	5.70^{b}	5.06^{d}	11.22^{ns}	4.00^{cd}	3.50^{c}	12.50*
Madjeeri	6.97^{g}	5.58^{g}	19.94**	8.15^{g}	6.02^{e}	26.13**	6.50^{ghi}	5.17^{h}	20.46*
Safaari 2	6.63^{f}	4.33^{de}	34.69**	8.02^{g}	4.77^{cd}	40.52**	7.00^{i}	4.92^{gh}	29.71*
Schawchai	5.53^{c}	5.00^{f}	9.58^{ns}	5.83^{b}	5.10^{d}	12.52*	3.83^{bc}	3.25^{c}	15.14*
Yaassé	6.59^{f}	4.22^{de}	35.96**	7.48^{ef}	4.60^{c}	38.50**	6.75^{hi}	4.92^{gh}	27.11**
Zouayé	6.24^{e}	5.08^{f}	18.59**	7.80^{fg}	6.70^{f}	14.10**	4.50^{de}	4.00^{d}	11.11^{ns}
Mean	5.97	4.45	25.46**	7.44	5.13	31.05**	5.13	4.08	20.47**
CV	21.61	22.02	-	23.12	19.88	-	14.42	15.20	-
LSD 5%	0.28	0.38	-	0.49	0.41	-	0.64	0.39	-

*Cont.: Control; Fert.: Fertilized with leaf mulches; %R: Percent reduction due to organic mulches; LSD: Least significant differences; Values within one column followed by the same letter are not significantly different at $P\leq 0.05$; **, * and ^{ns}: Significant at $P \leq 0.01$ and $P\leq 0.05$ and insignificant, respectively.*

By 110 DAS, *Striga* height varied from 19.23 to 36.55 cm (mean = 28.87cm). The *Striga* plants in sorghum lines CS54, Défé Gala, S35 and Schawchai were on average shorter by about 50% than in varieties Madjeeri, Gueling, CS95 and Faragawri. *Striga* plant vigour that is commonly measured by biomass and height influenced above-ground mortality and seed production capacity [21, 27]. According to Berner et al. [2] height of *Striga* is highly correlated with biomass and capsule number, and it gives adequate discrimination among treatments in many cases. Rodenburg et al. [27] also identified host resistance as an important determinant of *Striga* reproduction. Sorghum cultivars that withstand *Striga* infection could be resistant to the parasite by diminishing its growth, development, and survival or tolerant to the effects of a large number of attached parasites to their roots. Our results clearly reveal the presence of genetic variability among sorghum germplasm in their response to *S. hermonthica* parasitism in pot and field experiments. The number of *Striga* plants per host and their pattern of emergence differ by an order of magnitude in sorghum cultivars. These findings corroborate earlier reports on the genetics of resistance to *S. hermonthica* [3, 11, 22, 23] and *S. asiatica* [5] in sorghum. Many workers have reported that resistance could depend on differences in virulence in *Striga* strains [22, 25]. Some studies have demonstrated that the number of emerged *Striga* plants recorded aboveground is significantly correlated with the number of *Striga* attached to the root in sorghum [27, 28] and maize [29]. Several mechanisms, including low germination stimulant production like sorgolactone, sorgoleone and strigol [9, 21], reduction in successful establishment of parasitic plants on roots [9], and reduced capacity to elicit haustorial induction of *Striga* [21], have been implicated in lowering the number of emerged *Striga* plants. Marley et al. [12]; Showemimo et al. [18] had also summarized other potential postgermination mechanisms of resistance that impede attachment and emergence of *Striga* in crops. The difference in having low *Striga* density may be attributed to the low level of germination stimulant as the few parasite plants emerged in CS54, S35 and Défé Gala lines were clustered near the host plants. Mohamed et al. [17] revealed that in resistant cultivars Framida and Debbs, attached *Striga* were discouraged from penetration and further development, while in SRN 39, IS9830 and 555, other resistant lines, any hypersensitive response to *Striga* infection was exhibited. El-Hiweris [28] mentioned that roots of some sorghum cultivars that are tolerant to *Striga* have great total phenolics than those of sensitive genotypes.

Table 3: Days to first *Striga* emergence, *Striga* counts per pot and *Striga* height of fifteen sorghum varieties in infested pots

Varieties	Emergence of first *Striga* plant (DAE)	Emerged *Striga* per pot at 110 DAS	*Striga* height at 110 DAS (cm)
CS-54	34.92±0.38^{a}	2.5±0.51^{f}	21.98±1.54^{f}
CS-95	23.62±0.57^{h}	5.50±0.88^{d}	34.32±1.44^{abc}
CS-141	26.25±1.14^{fg}	6.93±0.85^{c}	30.14±2.82^{d}
CS-210	28.58±0.52^{d}	6.71±0.54^{c}	30.33±1.05^{d}
S-35	30.00±1.00^{c}	2.15±0.30^{f}	21.86±2.33^{f}
Gueling	22.50±0.90^{i}	9.87±0.55^{a}	35.22±5.13^{ab}
Ajagamaari	27.50±0.50^{de}	6.80±0.95^{c}	31.94±1.92^{bcd}
Défé Gala	35.92±0.80^{a}	3.86±0.55^{e}	19.23±1.11^{f}
Faragawri	31.04±0.40^{bc}	4.23±0.48^{e}	36.55±1.60^{a}
Garé Panaré	25.91±0.32^{fg}	6.52±0.63^{c}	31.49±2.07^{cd}
Madjeeri	24.51±0.60^{gh}	7.07±0.59^{c}	35.41±0.56^{a}
Safaari 2	26.66±0.28^{ef}	8.09±0.56^{b}	28.66±1.66^{de}
Schawchai	31.45±0.56^{b}	5.30±0.16^{d}	20.52±0.71^{f}
Yaassé	21.83±0.28^{i}	6.60±0.41^{c}	26.21±1.19^{e}
Zouayé	23.81±0.75^{h}	8.07±0.20^{b}	29.18±0.92^{de}
Mean	27.63±4.25	6.01±2.12	28.87±5.84
LSD (5%)	1.09	0.98	3.43

DAE: Days after sorghum emergence; DAS: Days after sorghum sowing; LSD: Least significant differences; Data are means ± SE; Values within one column followed by the same letter are not significantly different at $P \leq 0.05$

In Northern Cameroon, Kenga [3] also noted that improved varieties S35 and CS54 were widely promoted for uses because of emergency situations related to *Striga* and drought. Over the past few years, several resistant crop varieties have come into use in various parts of Africa, but full immunity to *Striga* has not yet been found [9]. It appears that genes that impart a reduced level of parasite infection are present at low initial frequencies in these populations. The identification of different genes controlling low stimulation of *S. hermonthica* seed germination and their combination in sorghums cultivars can be expected to enhance degree and durability of resistance to *Striga* [30].

Effects of infestation on sorghum yield

Under infestation, sorghum growth, as indicated by height, total dry matter and grain yield were differentially affected by variety and fertilization (Table 4). Lower reduction for these traits was noted on resistant varieties. In northern Cameroon, Ayongwa et al. [4] noted that most farmers named reduction of sorghum growth and stunting as main symptoms of *Striga* infestation. In Ethiopia, Gebremedhin et al. [24] observed that under infestation, *Striga* effect on stem height of susceptible sorghum cultivar IS9302 was significant while no significant reduction was noted resistant SRN39. In pot trials, uninfected plants yielded significantly higher than *Striga*-infected plants, with a mean reduction in grain yield of 56.54% (Table 5). Panicle length and plant height of uninfected sorghum was significantly different from that of infected plants. Infection of sorghum by *Striga* resulted in 33.76 % lower panicle height and 22.36 % lower plant height than infected plants. Reduction in panicle weight and grain yield under infestation was more pronounced in varieties CS95, Gueling, Faragawri, Saafari 2 and Garé Panaré, in comparison with Défé Gala, S35, CS54 and Schawchai. *S. hermonthica* has devastating effects on grain yield of susceptible sorghum by robbing its host of carbon, nitrogen, and inorganic salt [22, 31] while at the same time diminishing the growth and photosynthetic capacity of the cereal [12]. Gebremedhin et al. [24] noted that under the competition for water and nutrients with *Striga*, the sorghum plants may strategically divert their dry matter to roots and leaves so that the morphological changes due to the parasite were best observed on stem and panicle. Infected sorghum plants are prone to water stress, carbon partitioning to the parasite and reduced CO_2 flux. Depending on sorghum cultivar, Mohamed et al. [17] reported yield losses of 10-70% from damage by *Striga*. Losses in grain yield of up to 100% have been recorded by Ransom [8] in susceptible maize variety artificially infested with *S. hermonthica*.

Table 4: Genotypes and fertilization effects on plant height, dry matter and grain yield of fifteen sorghum varieties under *Striga* infestation

Genotypes	Sorghum height (cm)		Dry matter (t/ha)		Grain yield (t/ha)	
	Control	Fertilized (RHG)	Cont.	Fertilized (RMG)	Cont.	Fertilized (RYG)
CS-54	156.33^{cd}	186.40^{de} (19.25**)	2.67^{ef}	3.32^{ef} (24.34**)	0.984^{bc}	1.236^{ab} (25.61**)
CS-95	137.66^{fg}	172.40^{fg} (25.24**)	2.17^{gh}	3.03^{fg} (39.63**)	0.708^{fgh}	0.914^{def} (30.00**)
CS-141	145.56^{ef}	175.12^{ef} (20.31**)	2.98^{cde}	3.59^{de} (15.06*)	0.945^{bc}	1.096^{bcd} (15.98*)
CS-210	166.15^{bc}	198.22^{cd} (19.30**)	3.64^{b}	4.44^{ab} (21.98*)	0.818^{def}	1.024^{cde} (25.18**)
S-35	148.00^{de}	184.45^{ef} (24.63**)	3.76^{b}	4.59^{a} (22.07**)	1.156^{a}	1.343^{a} (16.18*)
Gueling	128.43^{gh}	136.11^{i} (5.89^{ns})	1.88^{hi}	2.36^{i} (25.53**)	0.652^{gh}	0.861^{ef} (32.05**)
Ajagamaari	179.13^{a}	219.30^{ab} (22.43**)	3.35^{bc}	4.13^{bc} (23.28**)	1.004^{bc}	1.286^{ab} (28.09**)
Défé Gala	149.65^{de}	186.34^{de} (36.69**)	3.14^{cd}	3.90^{cd} (24.20**)	1.067^{ab}	1.264^{ab} (18.46**)
Faragawri	175.54^{ab}	227.34^{a} (29.51**)	2.91^{de}	4.08^{bc} (40.21**)	0.777^{ef}	0.982^{cdef} (26.38**)
Garé Panaré	108.44^{i}	148.99^{h} (37.40**)	1.73^{ij}	2.29^{i} (32.37**)	0.606^{h}	0.786^{f} (29.70**)
Madjeeri	105.67^{i}	124.53^{i} (17.84**)	1.34^{j}	1.76^{j} (31.34**)	0.645^{gh}	0.845^{ef} (31.00**)
Safaari 2	178.49^{a}	207.45^{bc} (16.22**)	2.84^{de}	3.88^{cd} (36.62**)	0.934^{cd}	1.167^{abc} (24.95**)
Schawchai	119.86^{h}	153.22^{h} (27.83**)	2.36^{fg}	2.86^{gh} (21.19**)	0.750^{fg}	0.878^{ef} (17.06*)
Yaassé	182.45^{a}	231.11^{a} (26.67**)	4.23^{a}	4.66^{a} (10.17*)	0.911^{cd}	1.014^{cde} (11.31^{ns})
Zouayé	134.41^{g}	160.22^{gh} (19.20**)	2.08^{ghi}	2.50^{hi} (20.19**)	0.878^{cde}	1.134^{bc} (29.16**)
Mean	147.72	180.75 (22.36**)	2.74	3.43 (25.18**)	0.856	1.055 (23.25**)
CV %	9.63	7.68	13.14	11.95	19.39	17.36
LSD 5%	9.91	12.09	0.42	0.38	0.125	0.204

*Values within one column followed by the same letter are not significantly different at $P \leq 0.05$; Numbers in parenthesis are RHG (Relative plant height gains), RMG (Relative dry matter gains) and RYG (Relative grain yield gains) due to fertilization; **, * and ^{ns}: Significant at $P \leq 0.01$ and $P \leq 0.05$ and insignificant, respectively.*

Table 5: Plant height, panicle length and grain yield of fifteen sorghum varieties, and their relative losses due to *Striga* infestation in pot trials

Varieties	Sorghum height		Panicle weight (g)		Grain yield/plant (g)	
	Control	Infested (RHL)	Control	Infested (RWL)	Control	Infested (RYL)
CS-54	166.08	141.15 (15.02)	537.44	485.11(9.94)	18.11	13.14 (27.44)
CS-95	138.46	64.76 (53.23)	580.36	286.57 (50.62)	23.66	6.50 (72.53)
CS-141	119.00	67.92 (42.94)	439.72	298.33 (32.15)	22.45	7.83 (65.12)
CS-210	164.77	70.55 (57.18)	413.50	259.48 (37.25)	16.66	7.47 (55.16)
S-35	148.50	128.67 (13.35)	594.90	538.68 (9.45)	20.46	15.77 (22.92)
Gueling	138.65	66.54 (52.00)	349.15	201.66 (42.24)	12.34	2.58 (79.09)
Ajagamaari	155.10	107.16 (30.91)	608.22	363.44 (40.24)	24.11	8.49 (64.78)
Défé Gala	163.77	132.15 (19.30)	524.00	432.78 (17.41)	22.76	14.97 (34.22)
Faragawri	185.22	107.33 (42.05)	630.50	319.93 (49.26)	18.87	5.33 (71.75)
Garé Panaré	102.90	73.02 (29.04)	407.58	232.29 (43.00)	13.63	3.94 (71.09)
Madjeeri	98.17	62.11(36.73)	394.05	273.87 (30.50)	11.45	5.00 (56.33)
Safaari 2	151.63	91.91(39.38)	527.84	286.00 (45.81)	17.88	4.96 (72.25)
Schawchai	122.75	94.93 (22.66)	414.39	304.10 (26.61)	13.44	7.67 (42.93)
Yaassé	162.89	79.02 (51.48)	467.19	282.62 (39.50)	15.66	5.77 (63.15)
Zouayé	132.04	84.28 (36.17)	606.77	400.02 (33.95)	21.22	9.15 (56.88)
Mean	144.00	91.30 (36.60)	499.71	330.99 (33.76)	18.18	7.90 (56.54)
LSD (5%)	16.67	8.95	37.22	31.07	3.02	1.46

Numbers in parenthesis are RHL (Relative plant height losses), RWL (Relative panicle weight losses) and RYL (Relative grain yield losses) due to infestation

Response of sorghum to leaf mulches application under *Striga* infestation

Percent reduction of *Striga* emergence due to fertilization ranged from 8.26 to 52.48% (mean = 25.45%) at 70 DAS, and 11.22 to 45.47% (mean = 31.05%) at maturity while inhibiting effects of the organic manure for host damage score varied from 11.11 to 30.38% (Table 2). Results also displayed that leaf mulches application increased sorghum height, dry matter and grain yield depending to variety (Table 4). Organic fertilization increased sorghum height by 10.17 to 40.21% (mean = 25.18%). Moreover, mulch treatment improved sorghum dry matter and grain yield by 25.18% and 23.25% respectively in comparison with unmulched control. Ayongwa et al. [4] observed a patchy distribution of *Striga* occurrence in several fields, with low infestation close to tree species. This has been attributed to the presence of nutrients in the biomass which might ameliorate deficiencies of these nutrients in the soil and possibly also because of an improvement of soil physical characteristics. Researchers from many agricultural experiments have shown striking benefits from mulch applications including the nutrients recycling, conservation of moisture, maintenance of a uniform soil temperature, reduction of soil erosion and compaction from heavy rain and increase of water penetration [13, 33, 34]. Reduction in the *Striga* density and shoot growth as a result of application of fertilizer has been reported previously [1, 14, 15, 18, 26]. In the Sudan savannah zone of Ghana, Abunyewa and Padi [13] noted that under legume cultivation, soil organic carbon increased while the number of *Striga* seeds per square meter decreased. Sinebo and Drennan [1] and Ahonsi et al. [33] also showed that land-based management strategies to enhance soil nitrogen like legume rotation and inorganic fertilizers appear to directly enhance soil suppressiveness to *S. hermonthica*. Application of NPK (15:15:15) fertilizer at 90 kg ha^{-1} to maize also reduced the number of emerged *Striga* by over 80% and increased cereal biomass by over 45% compared with no fertilizer application [33].

In natural woodland areas and where trees are abundant, leaf mulches can be used extensively as a major component of the integrated nutrient management because it is sustainable way to improve soil nutrient in an economically viable farming. Mulches from leaves of leguminous had a beneficial effect on soil agrochemical properties and deterrent effects on *Striga* germination. In highly infested areas, growing of resistant varieties combined with improved soil fertility management was recommended to reduce *Striga* infestation, reverse land degradation and improve crop production [14, 15].

CONCLUSION

Among the fifteen sorghum lines studied, cultivars S35, CS54 and Défé Gala were the most promising source of resistance to obligate root parasite *S. hermonthica* and can be recommended for future use in breeding programs in northern Cameroon. Use of *Striga*-resistant/tolerant sorghum varieties per se will have little beneficial effects if soil nutrients are very low. These varieties should be a major component of integrated control packages including organic fertilization. Future research efforts should be directed towards understanding host resistance mechanisms, improvement of field screening and infestation techniques, and development of stable high yielding *Striga* resistant varieties that are acceptable to farmers.

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