Evaluation of Western Ethiopian Sorghum Landraces for Resistance to Striga hermonthica (Del.) Benth

Minyahil Kebede Earecho
minishkebe@gmail.com

Ethiopian Institute of Agricultural Research, Assosa Agricultural Research Center

Esubalew Nebiyu
Ethiopian Institute of Agricultural Research, Assosa Agricultural Research Center

Research Article

Keywords: Striga hermonthica, sorghum landraces, Striga resistance

Posted Date: April 22nd, 2024

DOI: https://doi.org/10.21203/rs.3.rs-4269116/v1

Additional Declarations: No competing interests reported.

Abstract

Striga hermonthica (Del.) Benth is an obligate root parasite that causes severe yield losses in sorghum production in semi-arid areas. It reduces yields in sorghum, maize, millets, and rice crops. Striga resistant or tolerant sorghum would form a great part of an integrated Striga control. Thus, this study aimed to determine the response of 48 sorghum genotypes against artificially infested S. hermonthica under pot and field experimentation. Two resistant (Berhan and Framida), and susceptible Assosa-1, Adukara, and/or ETSL102967 were used as a positive and negative checks. The results showed a high variability among sorghum landraces with respect to the effects of Striga parasitism. Early maturing sorghum landraces have the lowest Striga densities and late maturing sorghum landraces are too susceptible to Striga. Sorghum landraces ETSL102969 was found the most resistant sorghum landrace that shown similar Striga number as Birhan (resistant check). Also, ETSL102970 sorghum landraces was found the second resistant landrace with better Striga resistance than Framida (resistant check). Therefore, it is recommended that using ETSL102969 and ETSL102970 as a resistance source to enhance the resistance of sorghum against S. hermonthica in Ethiopia.

Introduction

Striga hermonthica (Del.) Benth., commoly known as purple witch-weed, is a root parasitic flowering weed that belongs to the *Orbanchacea* family (Matusova et al. 2005; Mohamed and Musselman 2008). It is a widespread and damaging parasitic weed found globally (Ejeta and Gressel 2007; Oswald 2005; Parker 2009). It is particularly prevalent in sub-Saharan Africa, including central, western, and eastern Africa (Gethi and Smith 2004; Mohamed and Musselman 2008; Rodenburg et al. 2016).

Striga hermonthica is known to severely attack various crops including sorghum, maize, millets, tef, rice, and even sugarcane (Addisu and Feleke 2021; Atera and Itoh 2011; Atera et al. 2012; Kountche et al. 2016; Parker 2012; Spallek et al. 2013). It dangerously affected the agricultural productivity of small-scale subsistence farmers in sub-Saharan Africa, including Ethiopia. It is also considered the most devastating biological barrier to cereal production in these regions (Omanya et al. 2004). Several studies have highlighted the widespread infestation of *S. hermonthica* in different parts of Ethiopia. Atsbha Gebreslasie et al. (2016) reported moderate to severe infestation throughout Tigray, While Lemma Degebasa et al. (2022) found that *S. hermonthica* was the dominant species (up to 92%) in Eastern and Western Hararghe, Oromia. In Benishangul Gumuz, Ethiopia, *S. hermonthica* poses a serious challenge to sorghum production across almost all districts.

The impact of *S. hermonthica* on sorghum production in Ethiopia is significant and widespread. Various studies have reported yield losses ranging from 65–100% in sorghum due to Striga infestation (Bayable & Marcantonio 2013; Ejeta et al. 2002; Haussmann et al. 2000; Lemma Degebasa et al. 2022; Tesso et al. 2007). In Benishangul Gumuz region, *S. hermonthica* has been identified as the primary factor affecting sorghum production (Mesfin and Girma 2022). The detrimental effects of *S. hermonthica* are not limited to Ethiopia alone, but extended to other Eastern and West African countries (Ejeta and Gressel 2007).

These points highlight the need for developing effective strategies to manage and control *S. hermonthica* in order to mitigate its devastating impact on sorghum production in Benishangul Gumuz region and other affected areas in Ethiopia. The use of resistant crop varieties has been proposed as a practical and cost-effective long-term strategy for managing Striga (Hearne 2009; Mandumbu et al. 2019). Therefore, this study aimed to identify sorghum genotypes that are resistant to *S. hermonthica*.

Materials and Methods

Plant materials

The sorghum genotypes used in the study were selected from landraces collected from farmers' fields in Ethiopia, specifically in Benishangul Gumuz and some parts of western Oromia. A total of 49 genotypes were included in the study, along with four released varieties (Table 1). The resistant checks used in the study, Berhan and Framida, were obtained from Melkassa Agricultural Research Center. The inclusion of check varieties helped for the comparison sorghum genotypes and evaluation of genetic diversity and resistance in sorghum to *S. hermonthica*.

In the pot trials conducted for the study, a total of 48 sorghum genotypes were used. This included both negative (susceptible genotypes) and positive checks (resistant genotype). The susceptible checks used in the pot trials were Assosa-1 variety, which is commonly grown in the Benishangul Gumuz region, and Adukara variety. The resistant check used was Berhan variety.

Out of the initial 48 sorghum genotypes tested in pots, a total of 33 sorghum genotypes were selected for further evaluation in a sick-plot specifically designed to measure their resistance to *S. hermonthica*. Additionally, another resistant check, Framida variety, was included in this evaluation. The sick-plot trial was conducted at the Assosa Agricultural Research Center.

For further validation of the pot and sick-plot trials, seven sorghum genotypes, including resistant check varieties like Berhan and Framida, as well as promising resistant landraces such as ETSL102969, ETSL102970, and ETSL102975, alongside susceptible check varieties like Assosa-1 and ETSL102957 were selected and evaluated under hot-spot farmers' fields in three locations at Assosa, Benishangul Gumuz, Ethiopia.

The Striga seeds used in the study were collected over a period of three years, from 2019 to 2021. These seeds were obtained from sorghum fields that were highly infested with *S. hermonthica* in various districts of Assosa Zone, specifically Bambasi, Abramo, and Ura districts. After collection, the seeds were stored in glass jars, kept in a dark environment at room temperature until they were needed for infesting the pots and sick plots.

Study sites, trial design and procedures

A trial was established at the Assosa Agricultural Research Center (AsARC), situated in Assosa Zone, Benishangul Gumuz region, Ethiopia. The pot trials were laid out in randomized complete block design having two replications in 2020 and 2021 under the Lath-house condition of AsARC. Sand/peat/compost (1:3:1 v/v) mix soil was used to fill 96 pots. Each pot was infested with 4 mg *S. hermonthica* seeds at 5 cm depth and covered with a thin layer of the mix soil. After a 10 day delay to precondition the Striga seed, six sorghum seeds of each genotype were sown in the pot and later thinned to three plants per pot.

A total of 33 sorghum genotypes were also evaluated in *S. hermonthica* sick plot of AsARC in 2022. The trial site was ploughed twice and furrows with 70 cm spacing were prepared. The trial was laid out in RCBD having two replications. The furrows within the trial unit (2 m x 1.40 m) were uniformly infested by *S. hermonthica* seeds collected during 2021 cropping season, Ethiopia. The infested Striga seeds were covered with a thin layer of soil and preconditioned for 10 days. After preconditioning, sorghum genotypes were sown within the furrows at a rate of 10 kg ha^{-1}. Apart from Striga, other weeds were hand weeded when observed. Other agronomic practices were done as recommended for the areas.

The validation trial was designed in RCBD with three replications. Farmers' fields are considered as a replication. The seven chosen sorghum genotype were validated using plot sizes of 4.20 m X 4.05 m for each genotypes. Other than Striga, weeds were manually pulled when they were noticed. We followed the areas' recommended other agronomic procedures.

Data collection and analysis

Data on sorghum and Striga parameters were collected. Data on sorghum included days to 50% anthesis, days to maturity, plant height, number of leafs, biomass and dry mater (g/pot). Striga data includes emerged Striga count and Striga height were carefully inspected at weekly intervals starting from 7th weeks after crop emergence (WACE) to 12th WACE. Also, Striga biomass and dry matter was recorded.

Data analysis

The maximum above ground Striga was determined as suggested by Rodenburg et al. (2006). The area under Striga number progress curve (ASNPC) was calculated as suggested by (Haussmann et al. 2012) as follows:

$$ASNPC = \sum_{i=0}^{n-1}(\frac{Y_i + Y_{(i+1)}}{2})(t_{(i+1)} - t_i)$$

Where n is the number of Striga recording dates, Y_i is the Striga count at the i^{th} assessment date, and t_i is the number of days after sowing at the i^{th} assessment date.

Collected data were subjected to analysis of variance using randomized complete block procedure of R software. The mode used was

$$Y_{ij} = \mu + \alpha_i + \beta_j + \epsilon_{ij}$$

Where, Y_{ij} is observed value for the experimental unit in the j^{th} replication (r) assigned to the i^{th} genotype, *j = 1, 2,. . ., r* and *i = 1, 2,. . ., genotype*, μ is the overall mean, α is the effect due to the i^{th} treatment, β is the effect due to the j^{th} block, and ε_{ij} is the error term where the error terms, are independent observations from an approximately normal distribution with mean equal to zero and constant variance σ^2_ε.

Independent sample t-test was used to assess the significant difference between sorghum genotypes' performance against *S. hermonthica*. Treatment means were separated using Fisher's least significant difference procedure at 5% probability level.

Table 1
List and sources of 49 sorghum genotypes used in the study.

S/N	Genotypes	Standardized name	Sources	S/N	Genotypes	Standardized name	Sources
1	Mok 079/1	ETSL102954	Mao-Komo, BG	26	AScol19-Kok001	ETSL102976	Keshmando, BG
2	ETSCAs 10020-2-116-2	ETSC20001	AsARC/Ethiopia	27	AScol19-SG 002	ETSL102952	Selga, BGR
3	AScol19-Al25	ETSL102971	Assosa, BGR	28	ETSCAs 10015-2-102-1	ETSC19003	AsARC/Ethiopia
4	AScol19-KA021/1	ETSL102972	Kamashi, BGR	29	Y039-1	ETSL102956	Yaso, BGR
5	ETSCAs 10015-2-103-1	ETSC19001	AsARC/Ethiopia	30	AScol19-As-7	ETSL102946	Assosa, BGR
6	AScol19-As-2	ETSL102943	Assosa, BGR	31	AScol19-SG 001	ETSL102951	Selga, BGR
7	ETSCAs 10019-1-110-1	ETSC19002	AsARC/Ethiopia	32	ETSCAs 10007-2-61-1	ETSC19004	AsARC/Ethiopia
8	Ya 036/1	ETSL102957	Yaso, BGR	33	AScol19-As -14	ETSL102940	Assosa, BGR
9	ETSCAs 10001-1-4-1	ETSC20002	AsARC/Ethiopia	34	AScol19-Krm122	ETSL102969	Kurmuk, BGR
10	AScol19-As-6	ETSL102945	Assosa, BGR	35	ETSCAs 10019-1-115-1	ETSC19005	AsARC/Ethiopia
11	AScol19-As-13	ETSL102942	Assosa, BGR	36	Bam075	ETSL102918	Bambasi, BGR
12	AScol19-As-1	ETSL102941	Assosa, BGR	37	Bmb097	ETSL102905	Bambasi, BGR
13	AScol19-JW128	ETSL102973	Jawi, AmR	38	Bmb095	ETSL102920	Bambasi, BGR
14	AScol19-As-8	ETSL102947	Assosa, BGR	39	NJ003	ETSL102912	Nejo, OrR
15	AScol19-Krm 124	ETSL102974	Kurmuk, BGR	40	Mok087	ETSL102925	Mao Komo, BGR
16	AScol19-As-5	ETSL102944	Assosa, BGR	41	Man069	ETSL102922	Mao Komo, BGR
17	ETSCAs 10002-2-13-1	ETSC20003	AsARC/Ethiopia	42	Boj007	ETSL102904	Bambasi, BGR

AmR = Amhara Region/Ethiopia; AsARC = Assosa Agricultural Research Centre; BGR = Benishangul Gumuz region/Ethiopia; MARC = Melkassa Agricultural Research Center/Ethiopia; OrR = Oromia Region/ Ethiopia

S/N	Genotypes	Standardized name	Sources	S/N	Genotypes	Standardized name	Sources
18	Mok 079/2	ETSL102955	MaoKomo, BGR	43	Mok085	ETSL102919	Mao Komo, BGR
19	ETSCAs 10020-2-116-1	ETSC20004	AsARC/Ethiopia	44	ETSC 300382-1	ETSC20006	AsARC/Ethiopia
20	ETSCAs 10003-3-32-1	ETSC20005	AsARC/Ethiopia	45	Qon072	ETSL102896	Qondala, OrR
21	Adukara (Susceptible)	Adukara	Released in 2015	46	Y047	ETSL100053	Yaso, BGR
22	AScol19-Krm123	ETSL102970	Kurmuk, BGR	47	Assosa-1 (2015)	Assosa-1	Released in 2015
23	AScol19-AB126	ETSL102975	Abramo, BGR	48	Berhan (2002)	Berhan	MARC/Ethiopia
24	AScol19-JW127	ETSL102949	Jawi, AmR	49	Framida	Framida	MARC/Ethiopia
25	AScol19-BS 082/1	ETSL102948	Bambasi, BG				

AmR = Amhara Region/Ethiopia; AsARC = Assosa Agricultural Research Centre; BGR = Benishangul Gumuz region/Ethiopia; MARC = Melkassa Agricultural Research Center/Ethiopia; OrR = Oromia Region/ Ethiopia

Results and Discussion

Response of Sorghum landraces to S. hermonthica

Pot-trial

The mean number of emerged Striga plants per pot across all sorghum genotypes was 12.13, while the mean number of Striga plant per sorghum plant was 4.04 (Table 2). This indicates that overall, there is an adequate level of Striga infestation in the study to determine the resistance of sorghum genotypes to Striga.

Table 2
The response of Sorghum landraces to artificially infested *S. hermonthica* (at 12th WACE) in 2020 to 2021 under pot experimentation at Assosa, Benishangul Gumuz, Ethiopia

Genotypes	Striga count at 12th WACE	Striga per plant	Genotypes	Striga count at 12th WACE	Striga per plant
Berhan	0.25^{n}	0.08^{n}	ETSC19004	11.75^{d-m}	3.92^{d-m}
ETSL102969	0.50^{n}	0.17^{n}	ETSL102925	11.75^{d-m}	3.92^{d-m}
ETSL102970	1.00^{mn}	0.33^{mn}	ETSL102944	12.00^{d-l}	4.00^{d-l}
ETSC20003	2.00^{l-n}	0.67^{l-n}	ETSC20006	12.25^{d-l}	4.08^{d-l}
ETSL102971	2.25^{k-n}	0.75^{k-n}	ETSL102948	12.75^{d-l}	4.25^{d-l}
ETSL102975	2.25^{k-n}	0.75^{k-n}	ETSC20001	13.00^{d-k}	4.34^{d-k}
ETSL102904	2.75^{j-n}	0.92^{j-n}	ETSL102922	13.25^{d-j}	4.42^{d-j}
ETSC19001	3.75^{i-n}	1.25^{i-n}	Assosa-1	14.50^{d-i}	4.83^{d-i}
ETSC19003	4.25^{h-n}	1.42^{h-n}	ETSL102942	14.75^{c-h}	4.92^{c-h}
ETSC20005	5.00^{h-n}	1.67^{h-n}	ETSC19005	14.75^{c-h}	4.92^{c-h}
ETSL102949	5.00^{h-n}	1.67^{h-n}	ETSL102972	16.25^{c-g}	5.42^{c-g}
ETSC20002	5.25^{h-n}	1.75^{h-n}	ETSL102946	17.00^{c-g}	5.67^{c-g}
ETSL102920	7.50^{g-n}	2.50^{g-n}	ETSL102918	17.50^{b-g}	5.83^{b-g}
ETSL102974	8.00^{g-n}	2.67^{g-n}	ETSL102952	18.25^{b-g}	6.08^{b-g}
ETSL102941	9.50^{f-n}	3.17^{f-n}	ETSL102955	19.25^{a-f}	6.42^{a-f}
ETSL102951	9.50^{f-n}	3.17^{f-n}	ETSC20004	19.75^{a-f}	6.58^{a-f}
ETSC19002	10.25^{e-n}	3.42^{e-n}	ETSL102956	20.00^{a-f}	6.67^{a-f}
ETSL102912	10.25^{e-n}	3.42^{e-n}	ETSL100053	20.50^{a-e}	6.83^{a-e}
ETSL102976	10.50^{e-n}	3.50^{e-n}	Adukara	20.75^{a-e}	6.92^{a-e}
ETSL102919	10.50^{e-n}	3.50^{e-n}	ETSL102905	21.00^{a-e}	7.00^{a-e}
ETSL102896	11.00^{d-n}	3.67^{d-n}	ETSL102947	21.50^{a-d}	7.17^{a-d}
ETSL102954	11.50^{d-m}	3.84^{d-m}	ETSL102940	25.50^{a-c}	8.50^{a-c}
ETSL102945	11.50^{d-m}	3.84^{d-m}	ETSL102957	28.25^{ab}	9.42^{ab}
ETSL102943	11.75^{d-m}	3.92^{d-m}	ETSL102973	29.75^{a}	9.92^{a}
Mean	**12.13**	**4.04**		**12.13**	**4.04**

Genotypes	Striga count at 12th WACE	Striga per plant	Genotypes	Striga count at 12th WACE	Striga per plant
LSD	**10.765**	**3.59**		**10.765**	**3.59**
CV	**23.34**	**16.80**		**23.34**	**16.80**
P value	**< 0.0001**	**< 0.0001**		**< 0.0001**	**< 0.0001**

The results of the pot experiment results indicate that there is a highly significant difference (P < 0.0001) in the response of sorghum landraces to *S. hermonthica* infestation (Table 2). The average number of emerged Striga plants per pot ranged from 0.25 for the Berhan variety (resistant check) to 29.75 for the ETSL102973 landrace. Similarly, the number of Striga plant per sorghum plant ranged from 0.08 for Berhan to 9.92 for ETSL102973. These findings suggest that ETSL102973 had significantly higher Striga emergence compared to Berhan, indicating its susceptibility to *S. hermonthica* (Table 2 and Fig. 2). On the other hand, sorghum landraces ETSL102969, and ETSL102970 showed reduced Striga emergence compared to other landraces (Table 2 and Fig. 2).

Sick plot trial

The sick-plot experiment revealed that the mean number of emerged Striga plants per plot was significantly varied (P < 0.05) among sorghum landraces at 12 WACE. Sorghum genotypes exhibited varied Striga emergence per plot that ranged from 3.0 for the Berhan and ETSL102969 to 148.5 for the ETSL102944 sorghum landrace. Likewise, emerged Striga plants per sorghum plant ranged from 0.22 for the ETSL102966 to 5.48 for the ETSL102954 (Table 3 and Fig. 2). The result exposed that the resistant check Berhan and sorghum landrace ETSL102969 sustained the lowest (3.0) Striga emergence (Table 3). Sorghum landraces ETSL102970, ETSL102975, ETSL19001, and ETSL100053 also exhibited lower Striga emergence compared to the resistant check variety Framida in the sick-plot trial (Table 3). The results are consistent with the findings from a previous pot trial (Table 2, and Table 3).

Result of this study revealed that the resistant sorghum genotypes were early maturing with maturity period of 125 days for the Berhan, 142 days for ETSL102970, 144 days for ETSL102969 (Table 3). This argued with the finding of Ayana et al. (2019) that reported early maturing sorghum genotypes showed resistance to *S. hermonthica*. Franke et al. (2006) was also reported that earlier maturing sorghum genotypes had positive response to Striga stress.

Moreover, *S. hermonthica* resistant sorghum genotypes of this study were shorter plant heights that ranged from 101.96 cm for ETSL102969 to 139.79 cm for Berhan (Table 3). Similarly, they have lower number of leaves per plant that ranged from 3.45 for ETSL102969 to 5.87 for Berhan (Table 3).

Table 3
The response of sorghum landraces to *S. hermonthica* under artificially infested sick plot in 2022 at Assosa, Benishangul Gumuz, Ethiopia

Genotypes	Sorghum Parameters				Striga parameters		
	Days to flowering	Days to maturity	Sorghum plant height (cm)	Sorghum leafs number	Striga count/plot	Striga plant height	Number of Striga per sorghum
ETSL102969	99.0^{mn}	144.0^{klmno}	101.96^{p}	3.45^{k}	3.5^{e}	26.34^{b}	0.22^{e}
Berhan	98.0^{mno}	125.0^{op}	139.79^{nop}	5.87^{ji}	3.0^{e}	36.63^{b}	0.25^{e}
ETSL102970	73.0^{p}	142.0^{lmno}	121.91^{op}	3.95^{jk}	3.0^{e}	19.84^{b}	0.22^{e}
ETSL102975	116.0^{ijkl}	157.0^{defghijkl}	207.78^{ghijklm}	9.65^{c-h}	7.5^{de}	30.03^{b}	0.31^{de}
ETSC19001	134.0^{d}	161.5^{cdefghijkl}	151.04^{jklmno}	5.30^{jk}	7.5^{de}	22.08^{b}	0.30^{de}
ETSL100053	152.0^{b}	160.0^{defghijkl}	240.30^{cdefghi}	10.25^{abcdefg}	7.5^{de}	38.33^{b}	0.28^{de}
Framida	117.0^{hijkl}	135.0^{mno}	122.89^{op}	5.89^{ij}	8.0^{de}	28.69^{b}	0.59^{de}
ETSL102976	130.0^{de}	180.5^{abc}	234.36^{defghij}	8.90^{fgh}	11.5^{cde}	32.05^{b}	0.53^{de}
ETSL102955	152.0^{b}	169.0^{bcdefg}	258.30^{abcdefgh}	10.15^{abcdefg}	14.0^{bcde}	29.01^{b}	0.52^{de}
ETSL102949	114.0^{kl}	154.0^{efghijklmn}	242.95^{cdefghi}	7.91^{hi}	14.5^{bcde}	30.31^{b}	0.58^{de}
ETSL102925	119.0^{fghijkl}	168.0^{bcdefgh}	265.10^{abcdefg}	11.22^{abcd}	15.0^{bcde}	28.86^{b}	0.53^{de}
ETSC20006	116.0^{ijkl}	160.0^{defghijkl}	209.70^{fghijklm}	9.11^{efgh}	17.5^{bcde}	29.35^{b}	0.79^{de}
ETSL102896	136.5^{cd}	159.0^{defghijkl}	244.97^{cdefghi}	11.81^{ab}	18.5^{bcde}	38.57^{b}	0.62^{de}
ETSC19002	99.0^{mn}	152.0^{fghijklmn}	220.33^{efghijkl}	11.55^{abcd}	19.0^{bcde}	26.01^{b}	0.79^{de}
ETSC20002	94.0^{on}	150.0^{ghijklmn}	154.70^{mnop}	9.83^{bcdefgh}	19.5^{bcde}	93.44^{a}	0.72^{de}
ETSL102974	193.0^{a}	148.0^{hijklmn}	97.60^{p}	4.28^{jk}	20.0^{bcde}	29.77^{b}	0.78^{bcd}
ETSL102951	124.0^{efgh}	169.0^{bcdefg}	171.86^{klmno}	11.25^{abcd}	21.5^{bcde}	33.05^{b}	0.69^{de}
ETSC20003	91.0^{o}	146.0^{jklmn}	161.45^{mno}	9.60^{defgh}	22.5^{bcde}	26.07^{b}	0.99^{cde}
ETSC20005	123.0^{efghi}	158.0^{defghijkl}	201.65^{hijklm}	10.55^{abcdefg}	23.0^{bcde}	22.72^{b}	0.98^{bcd}
ETSC19003	115.0^{jkl}	159.0^{defghijkl}	161.70^{mno}	8.83^{gh}	23.5^{bcde}	39.00^{b}	1.16^{cde}
ETSC20004	152.0^{b}	194.5^{a}	313.00^{a}	10.78^{abcdefg}	23.5^{bcde}	31.14^{b}	0.86^{de}
ETSC19004	119.0^{fghijkl}	155.0^{efghijklm}	198.47^{ijklm}	10.40^{abcdefg}	24.0^{bcde}	30.67^{b}	1.19^{cde}
ETSL102904	126.0^{ef}	169.0^{bcdefg}	267.30^{abcdef}	9.75^{bcdefgh}	25.0^{bcde}	29.84^{b}	1.25^{cde}

Genotypes	Sorghum Parameters				Striga parameters		
	Days to flowering	Days to maturity	Sorghum plant height (cm)	Sorghum leafs number	Striga count/plot	Striga plant height	Number of Striga per sorghum
ETSL102956	$119.0^{fghijkl}$	186.0^{ab}	276.84^{abcde}	$9.72^{bcdefgh}$	25.0^{bcde}	93.35^{a}	0.99^{cde}
Assosa-1	142.0^{c}	177.0^{abcd}	127.85^{op}	$10.71^{abcdefg}$	25.5^{bcde}	27.88^{b}	0.97^{cde}
ETSL102920	157.0^{b}	173.0^{bcde}	289.61^{abcd}	$10.90^{abcdefg}$	28.0^{bcde}	26.85^{b}	0.95^{cde}
Adukara	130.0^{de}	176.0^{abcd}	163.85^{lmno}	11.17^{abcde}	48.5^{bcde}	33.79^{b}	1.51^{cde}
ETSL102940	$115.0^{jghijkl}$	134.0^{on}	194.57^{ijklmn}	$10.85^{abcdefg}$	49.5^{bcde}	26.83^{b}	2.47^{abcde}
ETSL102947	$120.0^{fghijkl}$	105.0^{p}	303.75^{ab}	12.08^{a}	58.0^{bcde}	29.02^{b}	4.14^{abcd}
ETSL102919	125.0^{efg}	169.0^{bcdefg}	$222.09^{efghijk}$	$10.59^{abcdefg}$	58.0^{bcde}	36.19^{b}	2.73^{abcde}
ETSL102912	122.0^{fghi}	171.0^{bcdef}	$258.09^{abcdefgh}$	$10.68^{abcdefg}$	62.0^{abcde}	35.24^{b}	1.94^{abcde}
ETSL102918	152.0^{b}	$165.0^{cdefghij}$	292.84^{abc}	$10.99f^{abcde}$	64.5^{abcde}	34.89^{b}	2.27^{abcde}
ETSL102957	154.0^{b}	$167.0^{bcdefghi}$	$244.92^{cdefghi}$	$10.74^{abcdefg}$	95.5^{abc}	27.71^{b}	4.81^{abc}
ETSL102954	137.0^{cd}	$163.0^{cdefghijk}$	$241.72^{cdefghi}$	11.09^{abcde}	104.5^{ab}	28.08^{b}	5.48^{a}
ETSL102944	124.0^{efgh}	196.0^{a}	$249.90^{bcdefghi}$	11.05^{abcde}	148.5^{a}	24.13^{b}	5.11^{ab}
Mean	**124**	**160.13**	**216.85**	**9.35**	**33.54**	**31.81**	**1.61**
LSD	**7.83**	**21.75**	**58.13**	**2.1**	**87.66**	**37.9**	**3.89**
CV	**3.14**	**6.27**	**13.64**	**11.16**	**58.37**	**59.24**	**58.37**

As illustrated in Fig. 1, the genotypes ETSL102970, Berhan, and ETSL102969 have lower ASNPC values compared to other genotypes, indicating a slower or less severe emergence of Striga plants in these resistant sorghum genotypes. On the other hand, genotypes ETSL102957 and ETSL102944 exhibit higher ASNPC values, suggesting a higher incidence and more rapid emergence of Striga plants in these susceptible sorghum genotypes. The resistant checks (Berhan and Framida) also demonstrate low ASNPC values, indicating their resistance to *S. hermonthica* infestation. These findings further support the potential resistance of sorghum genotypes ETSL102970, Berhan, and ETSL102969 against *S. hermonthica* infestation in Assosa, Benishangul Gumuz region of Ethiopia.

Validation trial at hot-spot farmer's fields

As illustrated in Table 4, the results of the validation trial confirm that the resistant check Berhan and sorghum landrace ETSL102969 have the lowest number of emerged *S. hermonthica* plants per 4m x4m plot. Additionally, sorghum landrace ETSL102970 has a lower number of emerged *S. hermonthica* plants compared to the second resistant check Framida. The number of Striga per sorghum plant is also low for Berhan, ETSL102969, and ETSL102970.

On the other hand, susceptible checks ETSL102957 and Assosa-1 variety have the highest count of emerged *S. hermonthica* plants. These findings indicate that Berhan ETSL102969, and ETSL102970 exhibit promising resistance against *S. hermonthica* infestation. Overall, this validation trial confirms that these sorghum landraces possess comparable or good resistance to *S. hermonthica* when compared to resistant checks like Berhan and Framida.

Table 4
Validation of *Striga hermonthica* resistant sorghum landraces at hot spot farmers' fields in 2023 at Assosa, Benishangul Gumuz, Ethiopia

Genotypes	Striga plant/plot at 13 WACE	Sorghum plant height (cm)	Days to flowering	Striga per Sorghum	Yield (t ha^{-1})
Berhan	47.30^{c}	117.00^{b}	74.33^{d}	1.01^{b}	1.77^{c}
ETSL102969	51.70^{c}	117.93^{b}	81.00^{c}	2.45^{b}	3.84^{a}
ETSL102970	136.33^{c}	196.00^{a}	81.00^{c}	2.51^{b}	3.53^{ab}
Framida	267.67^{c}	173.60^{a}	86.67^{b}	12.06^{ab}	3.14^{abc}
ETSL102975	529.70^{bc}	116.87^{b}	155.00^{a}	30.05^{a}	3.81^{a}
Assosa-1	1156.33^{ab}	133.27^{b}	157.00^{a}	13.72^{a}	2.29^{bc}
ETSL102957	1638.33^{a}	140.53^{b}	155.33^{a}	17.68^{a}	2.11^{bc}
Means	**546.76**	**142.17**	**112.91**	**11.26**	**2.93**
LSD	**360.24**	**31.48**	**2.15**	**27.54**	**1.67**
CV	**19.08**	**12.45**	**1.07**	**21.31**	**23.12**
P value	**0.037**	**0.0006**	**< 0.0001**	**0.022**	**0.05**

The promising sorghum landraces ETSL102969 and ETSL102970 have been found to have higher yielder yield compared to resistant checks in a validation trial. Additionally, the bold seed size and white seed colour of sorghum landrace ETSL102969 are desirable traits by the local farming communities. These traits can be advantageous for the breeding program, as they can be combined with the Striga resistance trait to develop sorghum varieties that have both resistance to Striga infestation and the preferred seed characteristics. By incorporating these additional traits into the breeding program, there is a higher probability of obtaining F-generations that exhibit both white colour and bold sized seeds, along with resistance to *S. hermonthica*. This would not only benefit the farmers but also contribute towards improving productivity and enhancing market value for sorghum in the region.

Conclusions

In conclusion, sorghum landraces ETSL102969 and ETSL102970 possess good resistance to *S. hermonthica*, even outperforming the resistant checks. This suggests that these landraces could be valuable sources of resistance in breeding programs aimed at developing Striga resistant sorghum varieties. Moreover, the fact that sorghum landrace ETSL102969 has the additional advantage of white seed colour, which is highly preferred by farmers, makes it an even more promising candidate for breeding programs. By incorporating this desirable trait along with the Striga resistance trait from ETSL102969 and the enhanced resistance from ETSL102970, it may be possible to develop new sorghum lines that exhibit both Striga resistance and white seed colour.

Declarations

No potential conflict of interest is expected by the authors.

Author Contribution

MKE wrote the main manuscript text, prepared figures and reviewed the manuscript.EN reviewed the manuscript

Acknowledgement

Authors thanks Ethiopian Institute of Agricultural Research for financial support and Assosa agricultural Research Center for vehicle support during Striga hermonthica seed collection and field works.

References

1. Addisu S, Feleke G (2021) Distribution and importance of *Striga hermonthica* on tef [*Eragrostis tef* (Zucc.) Trotter] in Tigray regional state of Ethiopia: a preliminary survey.
2. Mesfin AH, Girma F (2022) Understanding sorghum farming system and its implication for future research strategies in humid agro-ecologies in Western Ethiopia. Journal of Agriculture and Food Research, 10:100456.
3. Atera EA, Itoh K, Onyango JC (2011) Evaluation of ecologies and severity of Striga weed on rice in sub-Saharan Africa.
4. Atera EA, Itoh K, Azuma T, Ishii T (2012) Farmers' perspectives on the biotic constraint of Striga hermonthica and its control in western Kenya. Weed biology and management, 12(1):53–62.
5. Gebreslasie A, Tessema T, Hamza I, Nigussie D (2016) Abundance and distribution of Striga (Striga hermonthica (Del.) Benth.) infestation in selected sorghum (Sorghum bicolour L. Moench) growing areas of Tigray Region, Ethiopia. African Journal of Agricultural Research, 11(45):4674–4682.
6. Ayana TT, Bantte K, Tadesse T (2019) Evaluation of Ethiopian sorghum [Sorghum bicolor (L.) Moench] landraces: low germination stimulant genotypes for Striga hermonthica resistance under field condition. Advances in Crop Science and Technology, 7:.444.
7. Bayable D, Di Marcantonio F (2013) Analysis of incentives and disincentives for sorghum in Ethiopia. Technical Notes Series, MAFAP, Food and Agriculture Organization of the United Nations, Rome, Italy.
8. Ejeta G, Gressel J (2007) Integrating new technologies for Striga control: towards ending the witch-hunt. World Scientific.
9. Ejeta G, Babiker AGT, Butler L (2002. New approaches to the control of Striga, a training workshop on Striga resistance. Melkassa 14–17.
10. Franke AC, Ellis-Jones J, Tarawali G, Schulz S, Hussaini MA, Kureh I, White R, Chikoye D, Douthwaite B, Oyewole BD, Olanrewaju AS (2006) Evaluating and scaling-up integrated Striga hermonthica control technologies among farmers in northern Nigeria. Crop protection 25(8):868–878.
11. Gethi JG, Smith ME (2004) Genetic responses of single crosses of maize to Striga hermonthica (Del.) Benth. and Striga asiatica (L.) Kuntze. Crop science, 44(6):2068–2077.
12. Haussmann BI, Hess DE, Welz HG, Geiger HH (2000). Improved methodologies for breeding Striga-resistant sorghums. Field Crops Research, 66(3):195–211.

13. Haussmann BIG, Hess DE, Reddy BVS, Welz HG, Geiger HH (2000). Analysis of resistance to Striga hermonthica in diallel crosses of sorghum. Euphytica, 116:33–40.
14. Hearne SJ (2009) Control—the Striga conundrum. Pest Management Science: Formerly Pesticide Science, 65(5):603–614.
15. Kountche BA, Al-Babili S, Haussmann BI (2016) Striga: a persistent problem on millets. In Biotic stress resistance in Millets, 173–203. Academic Press.
16. Lendzemo VW, Kuyper TW (2001) Effects of arbuscular mycorrhizal fungi on damage by Striga hermonthica on two contrasting cultivars of sorghum, Sorghum bicolor. Agriculture, ecosystems & environment, 87(1):29–35.
17. Mandumbu R, Mutengwa C, Mabasa S, Mwenje E (2019) Challenges to the exploitation of host plant resistance for Striga management in cereals and legumes by farmers in sub-Saharan Africa: a review. Acta Agriculturae Scandinavica, Section B—Soil & Plant Science, 69(1):82–88.
18. Matusova R, Rani K, Verstappen FW, Franssen MC, Beale MH, Bouwmeester HJ (2005) The strigolactone germination stimulants of the plant-parasitic Striga and Orobanche spp. are derived from the carotenoid pathway. Plant physiology, 139(2):920–934.
19. Mohamed KI, Musselman LJ (2008) Taxonomy of agronomically important Striga and Orobanche species. Progress on farmer training in parasitic weed management, 41(3):7–14.
20. Omanya GO, Haussmann BIG, Hess DE, Reddy BVS, Kayentao M, Welz HG, Geiger HH (2004) Utility of indirect and direct selection traits for improving Striga resistance in two sorghum recombinant inbred populations. Field crops research, 89(2–3):237–252.
21. Oswald A (2005) Striga control—technologies and their dissemination. Crop protection, 24(4):333–342.
22. Parker C (2009) Observations on the current status of Orobanche and Striga problems worldwide. Pest Management Science: formerly Pesticide Science, 65(5):453–459.
23. Parker C (2012) Parasitic weeds: a world challenge. Weed science, 60(2):269–276.
24. Rodenburg J, Demont M, Zwart SJ, Bastiaans L (2016) Parasitic weed incidence and related economic losses in rice in Africa. Agriculture, ecosystems & environment, 235:306–317.
25. Rodenburg J, Demont M, Zwart SJ, Bastiaans L (2016) Parasitic weed incidence and related economic losses in rice in Africa. Agriculture, ecosystems & environment, 235:306–317.
26. Spallek T, Mutuku M, Shirasu K (2013) The genus S triga: a witch profile. Molecular plant pathology, 14(9):861–869.
27. Tesso T, Gutema Z, Deressa A, Ejeta G (2007) An integrated Striga management option offers effective control of Striga in Ethiopia. In Integrating new technologies for Striga control: towards ending the witch-hunt, 199–212.

Figures

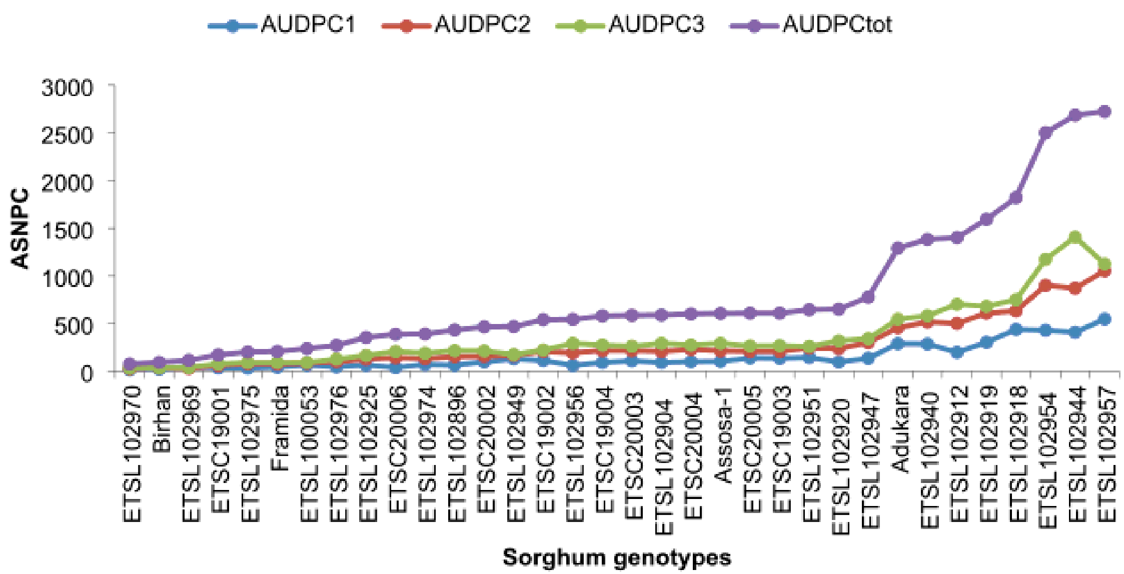

Figure 1

Reaction of sorghum genotypes to area under *S. hermonthica* emergence progress curve in 2022 at Assosa, Benishangul Gumuz, Ethiopia

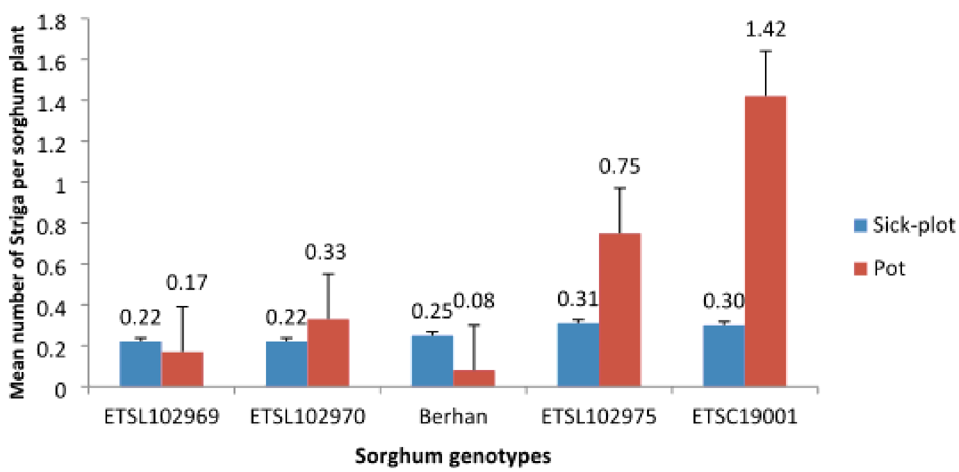

Figure 2

Top five sorghum genotypes with lowest emerged Striga count per sorghum plant from 2020 to 2022 at Assosa, Benishangul Gumuz, Ethiopia

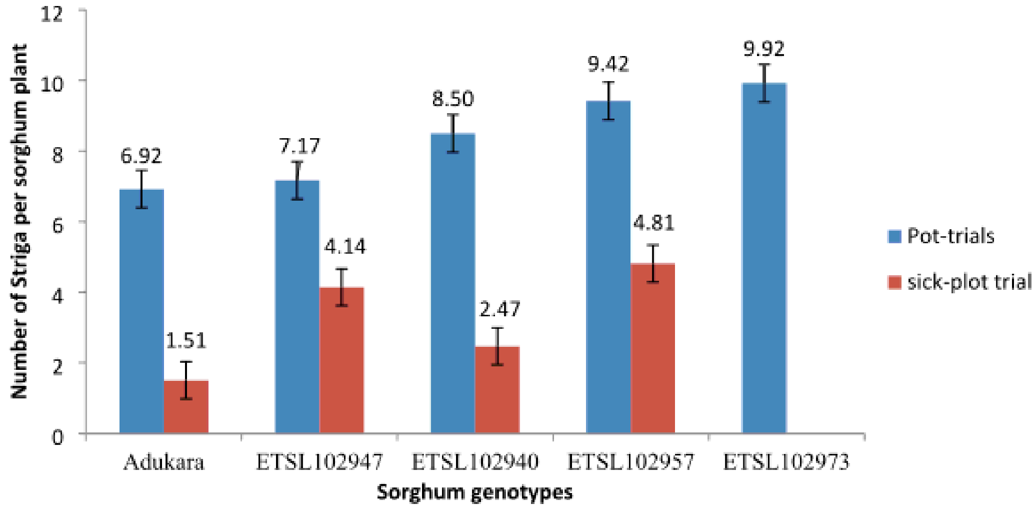

Figure 3

Top five sorghum genotypes with highest emerged Striga count per sorghum plant for 2020 to 2022 at Assosa, Benishangul Gumuz, Ethiopia