

Research Article

Germplasm Bred for Resistance to *Striga hermonthica* Exhibited High Resistance Levels to *Striga asiatica* Compared to Commercial Checks

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Parasitic weeds belonging to the *Orobanchaceae* family are a menace in Sub-Saharan African (SSA). Specifically, the two witchweeds from the genus *Striga*, *S. hermonthica* and *S. asiatica*, are jointly responsible for land abandonments and cereal yield reductions in the SSA. Factorial experiments involving fourteen maize genotypes and two levels of *Striga asiatica* infestation (infested and noninfested) were conducted under pot and laboratory experiments at the Department of Plant Production Sciences and Technologies, University of Zimbabwe, during the 2014/2015 season. A 14 × 2 factorial pot experiment was arranged in a 7 × 4 α -lattice design replicated four times, whereas the laboratory agar gel was arranged in a complete randomized design with four replications. Results revealed significant differences ($p < 0.05$) for *S. asiatica* and genotype main effects for the recorded traits. *S. asiatica*-infested genotypes had lower biomasses than noninfested ones. However, the University of Zimbabwe bred hybrids such as Ax31, Ax28, Ax7, and Ax32 had similar plant heights and stem, leaf, and cob biomass across the two *Striga* levels unlike the local checks, particularly SC513, SC537, and SC637, under *Striga* infestation. Moreover, these genotypes also had the least *Striga* germination percentage and furthest germination distance indicating that they are resistant/tolerant to *Striga asiatica*. The University of Zimbabwe bred hybrids, using *Striga hermonthica* resistance from the International Institute of Tropical Agriculture, exhibited resistance/tolerance to *Striga asiatica* compared to local checks. Therefore, these varieties could offer a better and viable *Striga* spp. control option to farmers in both *S. hermonthica* and *S. asiatica* endemic areas.

1. Introduction

In Africa, many smallholder farmers are seriously facing weed problems in their maize production systems, especially parasitic weeds. Among the most problematic parasitic weeds in Sub-Saharan Africa (SSA) are the two *Striga* species: *Striga hermonthica* (Del.) Benth. and *Striga asiatica* L. Kuntze from the *Orobanchaceae* family [1–3]. However, Mabasa [4] reported *Striga asiatica* as the most prevalent of the *Striga* species in southern Africa with particular

reference to Zimbabwe whereas *S. hermonthica* is more prevalent in the west and east of Africa, causing serious damage and crop yield reductions [5–7]. These two *Striga* species affect maize, sorghum, and rice among other cereals through root attachment and are hence classified as obligate root parasites [8–10].

Striga spp. only germinates in the presence of germination stimulants from the host crop [11, 12]. Germination stimulants known as strigolactones released by host crops such as maize are responsible for *Striga* spp. germination,

hence parasitizing the plant through haustoria formation [11, 13, 14]. *Striga* spp. is one of the biotic factors limiting maize production in Africa and some parts of Asia [14, 15]. Studies have shown that *S. asiatica* has occupied more than 50 million hectares allocated to cereal production in Africa, hence causing a problem of food insecurity among smallholder farmers [16, 17].

In SSA, *Striga* spp. has infested more than 50 million ha of land including 40% of cereal production areas [16, 18]. Locally, fields infested with *S. asiatica* were identified in all provinces but most aggressive in areas such as Chiredzi, Masvingo, Gokwe, and Matopos in Zimbabwe [19]. Several authors have associated *Striga* species' predominance with semiarid tropical type of climatic conditions, which includes infertile sandy soils and erratic rainfall patterns [20–22]. The high affinity of this parasitic weed to soils with low nutrition and poor rainfalls explains why subsistence farmers on marginal soils are the most affected [23, 24].

Yield losses as a result of *Striga* spp. are influenced by crop cultivar, weather conditions, and the severity of infestation [25, 26]. According to Karaya et al. [27] and Midega et al. [28], maize grain yield losses from *Striga* spp. infestation range from 20 to 80% and these losses can sometimes reach 100% in susceptible maize cultivars under severe field infestation. Yield losses converted to monetary value have been estimated to exceed US\$7 billion annually [29]. Different *Striga* control methods have been long devised but the most effective ones are relatively expensive or not feasible for resource-limited smallholder farmers in SSA to implement. Control methods are classified as cultural, biological, and chemical types [30, 31]. Chemical control methods being the most effective involve the use of chemical germination stimulants such as strigol, *Striga* analogues, and ethylene gas for suicidal germination has been implemented with success in the United States [32]. Berner et al. [33] and Kanampiu et al. [34] showed that acetolactate synthase (ALS) resistant maize dressed with imazapyr herbicide was effective in controlling *Striga hermonthica*. However, other control methods (cultural) exist which include intercropping, trap crops, catch crops, and hand pulling though they are not as effective as the chemical controls described earlier but if integrated together, they form a better *Striga* management program [9, 35–37]. Successful *Striga* suppression by green manure cover crops (GMCCs) such as *Desmodium* species has been reported by several authors including [28]. These GMCCs used either in crop rotation schemes or as intercrops suppress the effects of *Striga* spp. through their natural fixation of atmospheric nitrogen into the soil, hence improving soil fertility to the benefit of the host crop as well as hindering the development of the parasite thereby reducing the seed bank density [38, 39].

Currently, it is being emphasized that the exploitation of genotypes' natural genetic defense against *Striga* spp. is the best way to combat the scourge for resource-poor farmers [30, 40, 41]. Karaya et al. [27] stated that the most feasible and effective control strategy is the development of host plant resistance and tolerance. This is considered the most practical option for reducing yield losses caused by *Striga*

spp. for farmers who lack the capital to use high-input management practices. As a definition, resistant maize genotypes allow low *Striga* counts per plant, whilst tolerant ones support high *Striga* counts per plant without any significant yield losses incurred. Several authors have screened different maize, sorghum, and rice genotypes for their resistance or tolerance to *S. asiatica* and *S. hermonthica* [28, 42–45]. In crops such as rice and sorghum, *S. hermonthica* resistant genotypes have been well identified [46, 47]. With reference to Gurney et al. [48], maize genotypes which are completely resistant to *Striga hermonthica* have not yet been identified, but wild relatives such as *Tesosintes* and *Tripsacum* have been recognized as a valuable source of genetic resistance [49]. There are limitations to the development of maize genotypes resistant to *Striga* spp. and among them, there is a lack of knowledge on the mechanisms expressing tolerance in the crops. There is a lack of knowledge on the sources of resistance as well as the complicated genetics associated with weed-crop resistance. However, successes have been forthwith by *Striga* research organizations such as the International Institute of Tropical Agriculture (IITA) and partners including the International Maize and Wheat Improvement Centre (CIMMYT) [50, 51]. In particular, IITA has developed some varieties, which are resistant to *S. hermonthica*; these include the *Zea diploperennis* (ZD05), IWD STR, and TZL pools [40, 50]. The University of Zimbabwe has used the germplasm from IITA that was bred for *Striga hermonthica* to breed new maize hybrids with potential resistance to *Striga asiatica*. The International Maize and Wheat Improvement Centre has also been developing biotic and abiotic stress tolerant genotypes, which are currently under rigorous screening in the region [52].

Most of the locally grown maize genotypes are still susceptible to *S. asiatica* infestation though some have shown some better tolerance levels and this has seriously affected the maize yields, especially in the smallholder farming sector in *Striga* prevalence areas such as Gokwe and Rushinga. Research that has been conducted to evaluate the reactions of the available different maize genotypes to *S. asiatica* infestation in the country is still little. The performance of the new maize hybrids developed by the University of Zimbabwe using resistance sources from IITA germplasm bred for *Striga hermonthica* resistance, locally bred hybrid checks genotypes, and CIMMYT genotypes is not known for resistance/tolerance against *S. asiatica*. As a result, this study was carried out to identify maize varieties with high levels of *S. asiatica* tolerance/resistance by screening local commercial maize hybrids, University of Zimbabwe maize hybrids developed from IITA germplasm, and CIMMYT genotypes. The screening was carried out under artificial infestation using the pot experiment and laboratory agar gel technique.

2. Materials and Methods

2.1. Germplasm Description. The fourteen maize genotypes used in this study were obtained from CIMMYT, the University of Zimbabwe, Seed Co. Pvt. Ltd., and the

TABLE 1: Maize germplasm used in the experiments.

Entry code	Genotype name	Source
1	TH114911	CIMMYT
2	TH14910	CIMMYT
3	TH128799	CIMMYT
4	SC513	Seed Co. Pvt. Ltd.
5	SC537	Seed Co. Pvt. Ltd.
6	SC637	Seed Co. Pvt. Ltd.
7	Ax31	University of Zimbabwe
8	Bx31	University of Zimbabwe
9	Ax28	University of Zimbabwe
10	Ax27	University of Zimbabwe
11	Ax7	University of Zimbabwe
12	Ax32	University of Zimbabwe
13	R201	SIRDA
14	TH14949	CIMMYT

TABLE 2: Analysis of variance for maize traits recorded in a greenhouse experiment at the University of Zimbabwe.

Source of variation	Degrees of freedom	Height	Stem biomass	Leaf biomass	Cob biomass	Root biomass	Total biomass	Root to shoot
Replication	3	1727.2	175.5	414.5	1426.9	87.9	6376	0.06306
Replication block	24	1650.2	237.8	450.3	657	152.4	2025	0.09027
Genotype	13	1545.7**	850.7***	435.8	605.1	159.7	4789***	0.30525***
<i>Striga</i>	1	68754.6***	155.9	2897.5**	4143.9**	1978.8***	39961***	0.02291
Genotype \times <i>Striga</i>	13	4450.6***	256.4*	475.7	985.3	498.7***	4036**	0.10153
Residual	57	682.1	126.8	318.4	595.4	103.6	1340	0.08627
Total	111	2075.4	252.4	404.9	715.3	183.5	2692	0.11337

Cob biomass residual degrees of freedom were 52. The symbols *, **, and *** represent significance at 0.5, 0.01, and 0.001 probability levels.

Scientific and Industrial Research Development Authority (SIRDA) (Table 1).

2.2. Pot Experiment Procedure. *S. asiatica* seeds used in this experiment were collected from farmer fields in Rushinga. The pot experiment was arranged in 14×2 factorial treatments in a 7×4 α -lattice design replicated four times during the 2014/2015 cropping season from 1 November 2014 to 31 January 2015. Factor one was maize variety with fourteen levels, and the second factor was *S. asiatica* infestation with two levels (*S. asiatica* infested and noninfested maize). A total of 112 pots measuring 15 cm diameter and 20 cm height were filled with 3,000 cm³ of sandy soil. Prior to the establishment of this experiment in November 2014, soil samples of the sandy soil used for this experiment were taken from a field at 0–20 cm depth and were fully analysed. The following parameters were characterized: total nitrogen (N), available phosphorus (P), organic matter, and exchangeable bases using the micro-Kjeldahl, Olsen, Walkley-Black, and ammonium acetate methods, respectively [53, 54]. The characteristics of the soil are presented in Table S1. A total of 8 g pot⁻¹ of compound D (7% N; 14% P₂O₅; 7% K₂O) were applied in all the pots to achieve an application rate of 11.2 kg·N·ha⁻¹, 9.8 kg·P·ha⁻¹, and 9.3 kg·K·ha⁻¹ for early root development [55, 56]. In 56 pots, the top 8 cm were thoroughly mixed with 0.05 g of *S. asiatica* seeds (approximately 12 580 seeds). Mixing of *S. asiatica* seeds with soil was done by shaking the soil with seeds in a polythene bag. The pots

were watered to field capacity after the application of *Striga* seeds. Watering was done after four days later and left for two weeks of preconditioning period before planting maize genotypes. Three maize seeds were sown into each top 3 cm deep for all the maize genotypes in both the infested and noninfested pots. All the processes from pot filling to sowing were taking place from noninfested to infested pots to avoid contamination. Seedlings were thinned to one plant pot⁻¹ two weeks after crop emergence (WACE). Watering was done whenever necessary. Other weeds were removed from the pots by hand pulling to allow interaction only between maize and *S. asiatica*. Ammonium nitrate (34.5% N) was applied once as 1 g pot⁻¹ at four WACE to achieve a rate of less than 30 kg·N·ha⁻¹; these low N-levels were used to mimic typical smallholder farmer conditions [50, 57, 58].

2.3. Data Collection. Maize plant height was measured weekly from 2nd WACE until 9th WACE. *S. asiatica* counts and biomass of the emerged plants were recorded. Data were also collected on the root to shoot ratio, leaf, stem, cob, root, and total biomass of maize.

2.4. Data Analyses. Analysis of variance (ANOVA) was carried out using GenStat statistical package version 14 [59]. Repeated measures ANOVA was carried out for weekly plant heights and *Striga* counts. Significant differences among means were separated using Fischer's protected least

TABLE 3: Comparison of *Striga asiatica* main effects (infested and noninfested).

<i>Striga</i>	Height	Stem biomass	Leaf biomass	Cob biomass	Root biomass	Total biomass	Root to shoot ratio
Infested	108	27.83	24.01	27.54	24.06	65.93	0.59
Noninfested	171.4	26.52	12.12	15.24	17.42	106.52	0.49
<i>p</i> value	<0.001	0.272	0.004	0.011	<0.001	<0.001	0.61
5% least significant difference	36.20	NS	24.73	33.82	14.11	50.73	NS

NS: not significant at 5% probability level.

TABLE 4: Means of maize traits recorded during a greenhouse experiment at the University of Zimbabwe.

Genotype	Height	Stem biomass	Leaf biomass	Cob biomass	Root biomass	Total biomass	Root to shoot biomass
Ax28	142.60	39.81	19.04	20.72	20.71	105.47	0.23
Bx31	135.80	22.45	18.62	19.34	20.03	58.14	0.67
Ax31	149.10	33.26	41.42	28.71	17.64	125.35	0.24
R201	144.60	11.31	13.05	3.27	12.67	50.70	0.52
SC 513	144.70	8.11	4.20	3.62	24.00	45.72	0.85
SC 537	144.00	38.07	17.11	29.18	24.74	112.86	0.49
SC 637	114.30	15.62	13.51	5.66	25.74	75.73	1.01
Ax27	141.30	20.60	22.97	29.69	17.27	87.88	0.66
TH114911	101.80	32.19	12.89	30.14	18.81	83.90	0.44
TH128799	141.50	37.13	18.03	27.12	23.55	107.89	0.41
TH14910	175.70	36.88	24.32	31.83	16.86	87.79	0.36
TH14949	150.30	20.88	13.80	20.24	29.77	86.48	0.80
Ax7	143.10	46.49	19.58	18.37	21.80	119.72	0.30
Ax32	126.60	17.70	14.39	24.56	16.82	59.49	0.55
Mean	139.67	27.18	18.07	20.89	20.74	86.22	0.54
<i>p</i> value	0.017	<0.001	0.203	0.45	0.131	<0.001	<0.001
5% least significant difference	19.3	8.3	NS	NS	NS	27.1	0.2

NS: not significant at 5% probability level.

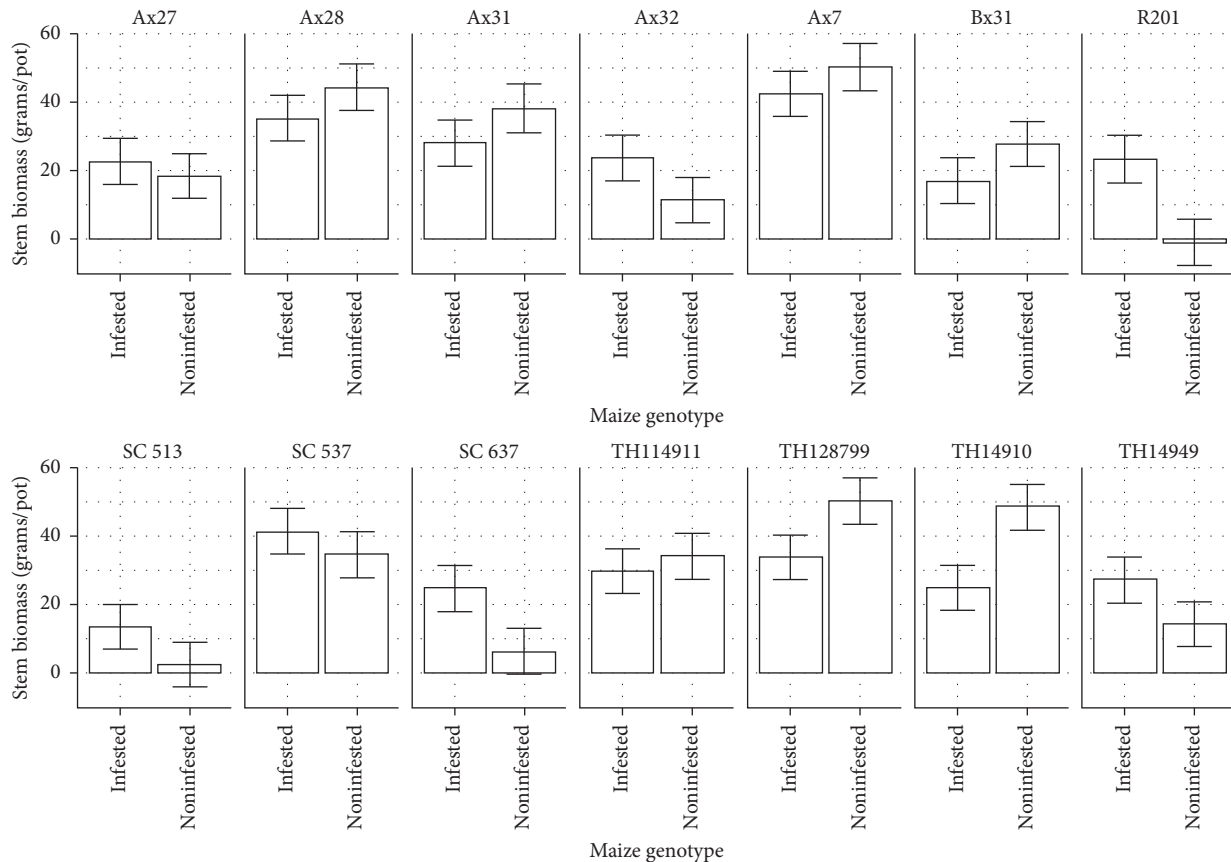


FIGURE 1: Stem biomass weight of individual maize genotypes across *Striga asiatica* infested and noninfested levels in pot experiment. Error bars indicate the standard errors of the difference between means.

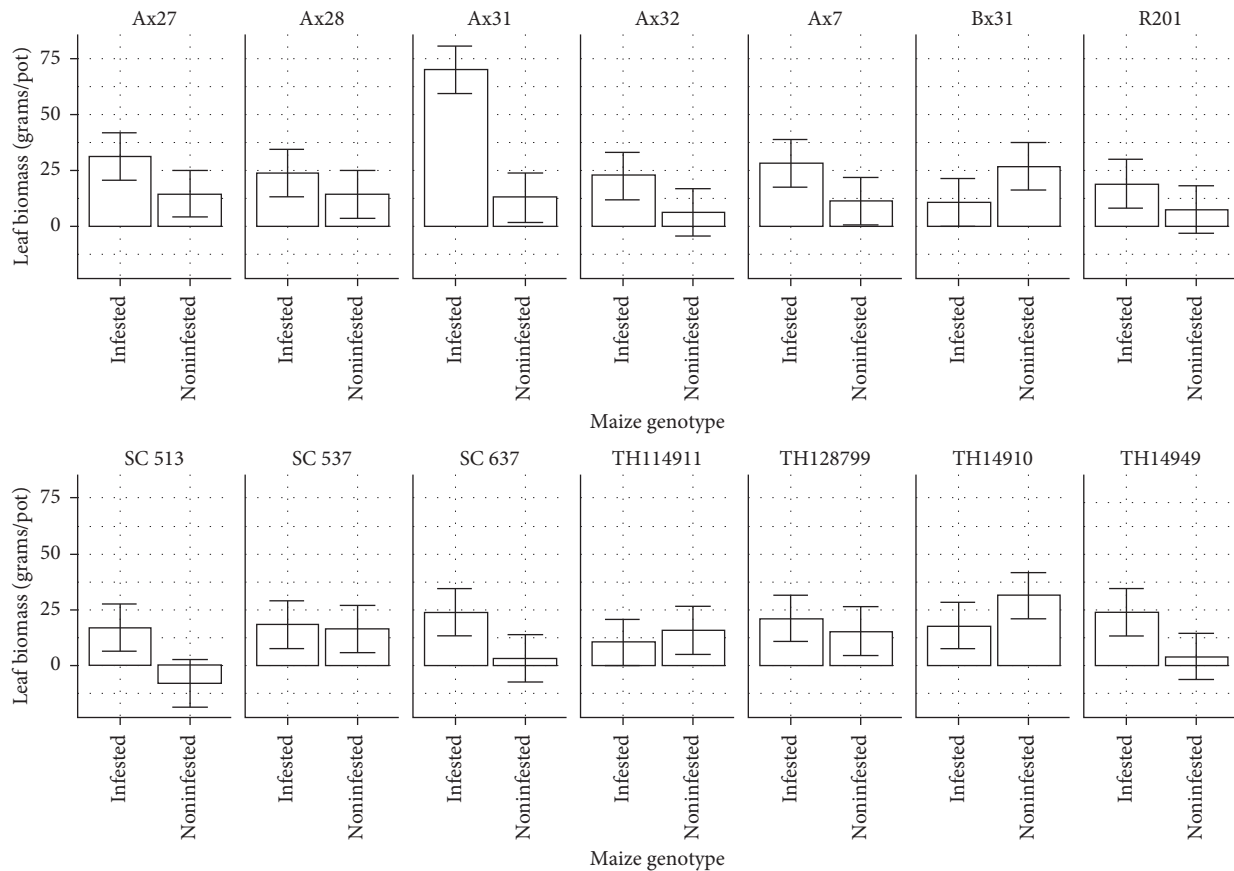


FIGURE 2: Comparison of individual genotypes' leaf biomass across the two *Striga* levels in pot experiment. Error bars indicate the standard errors of the difference between means.

significant differences at 5% probability level. Graphs were plotted using R statistical package version 1.0.136 [60].

2.5. Agar Gel Procedure. The fourteen maize genotypes used for the pot experiment (Table 1) were also tested for stimulant production and haustorium initiation of *S. asiatica* in the Weed Science Laboratory, Department of Plant Production Sciences and Technologies, University of Zimbabwe, using the agar gel technique as described by IITA [55]. The experiment was arranged in a complete randomized design and replicated four times. Sterilization of *S. asiatica* seeds was achieved by immersing them in 1% sodium hypochlorite solution for 30 minutes before setting up the assay. A total of 0.2 g of *Striga* seeds were placed in 50 ml flasks and thereafter rinsed three times in 10 ml of double-distilled water. The seeds were then placed in 9 cm diameter Petri dishes, sealed with a parafilm, and placed in the dark at 25°C for 14 days. Maize seeds were soaked in 1% sodium hypochlorite solution for 30 minutes and afterwards rinsed three times with double distilled water. The maize seeds were then transferred to 9 cm diameter Petri dishes with moist Whatman number 2 filter papers and incubated in the dark at 28°C for 48 hours. Only the healthy-looking germinated seeds were selected for the agar gel assay. The conditioned *S. asiatica* seeds (50 μ l) were pipetted into 9 cm diameter Petri dishes. A total of 30 ml (1.05 mg of agar) of

autoclaved water agar in 150 ml of double-distilled water was poured into the *S. asiatica* seeds in each Petri dish before it solidified. A germinating maize seed was then submerged in the solidifying agar near the edge of the plate, with the root tip pointing across the plate. The Petri dishes were subsequently incubated for 72 hours before the first data recordings.

2.6. Data Collection. Data were collected on *S. asiatica* seed germination percentage and furthest germination distance of *S. asiatica* seed from the maize radicle.

2.7. Data Analyses. Analysis of variance was done and significantly different means were separated using Fischer's protected least significant difference at 5% significant level using GenStat software, 14th edition [59]. Graphs were plotted using R statistical package, version 1.0.136 [60].

3. Results

Significant variations ($p < 0.05$) were recorded on *S. asiatica* and genotype main effects across different traits (Table 2). Genotype and *S. asiatica* interactions were only significant ($p < 0.05$) for plant height, stem biomass, root biomass, and total biomass (Table 2). Moreover, *S. asiatica* infested plants recorded lower plant height and total biomass means than

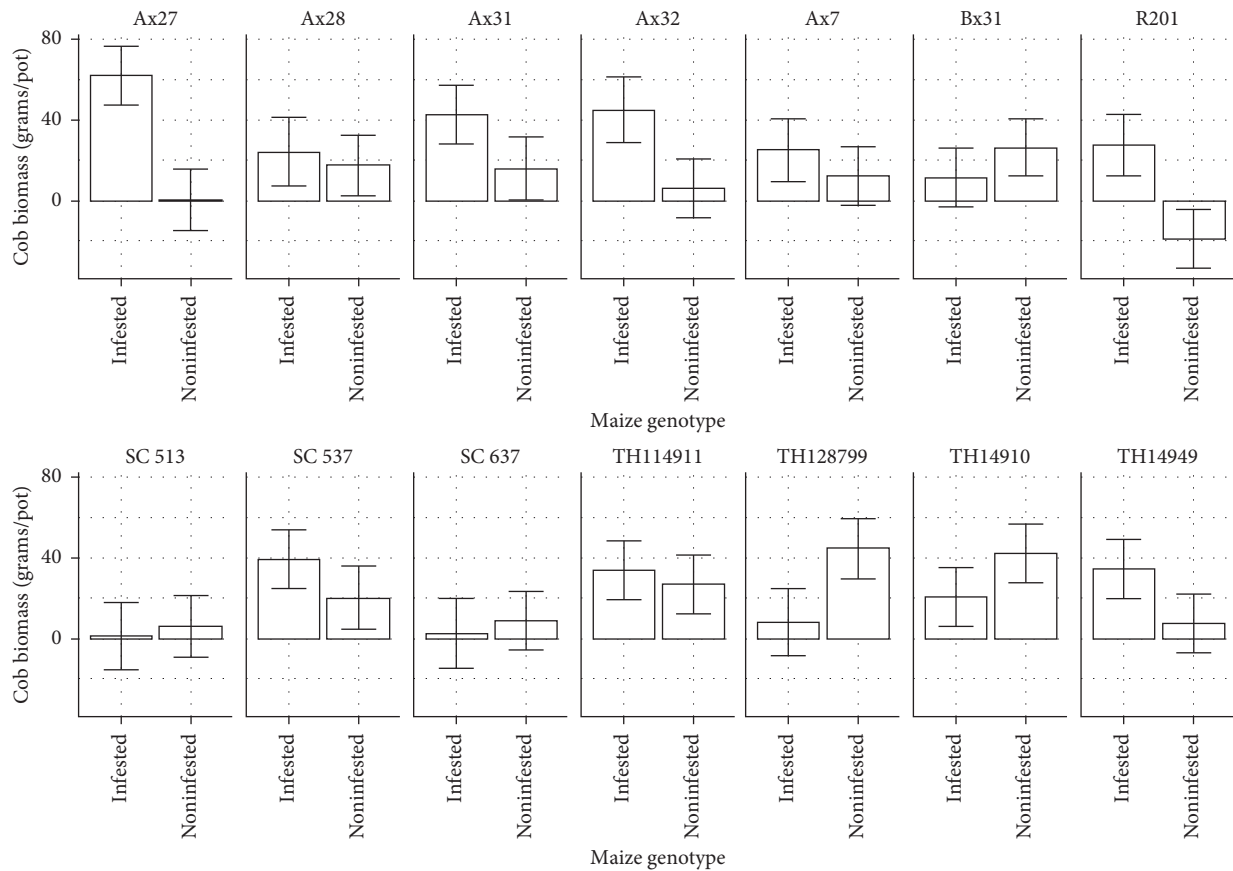


FIGURE 3: Comparison of cob biomass between *Striga* infested and noninfested individual genotypes in pot experiment. Error bars indicate the standard errors of the difference between means.

noninfested varieties (Table 3). The University of Zimbabwe bred varieties, Ax31, Ax28, Ax7, and one local check (SC357), recorded the greatest total biomass at 125.4 g, 105.5 g, 119.7 g, and 112.7 g, respectively (Table 4).

The local checks, SC635, SC513, and SC537, showed significant differences ($p < 0.05$) in terms of stem biomass across the two *Striga* levels (Figure 1). Significant differences ($p < 0.05$) in leaf biomass were also recorded for individual genotypes such as SC513 between *S. asiatica* infested and noninfested levels (Figure 2). Moreover, the genotypes, SC513, SC535, SC637, and TH14910, had significantly different ($p < 0.05$) cob biomass across the two *S. asiatica* levels (Figure 3).

Repeated measures ANOVA revealed significant variations ($p < 0.05$) for genotype and *Striga* main effects and the interaction of time \times genotype \times *Striga* (Table 5). Genotypes such as Ax31, Ax28, Ax7, TH14949, Bx31, and R201 had heights which were not significantly different ($p > 0.05$) across the two *Striga* levels (Figure 4). The rest of the checks showed significant differences ($p < 0.05$) between *Striga* infested and noninfested genotypes in terms of plant height (Figure 4). *Striga* counts over time also showed significant variations ($p < 0.05$) among the fourteen maize genotypes (Table 6).

There were also significant differences ($p < 0.05$) among the varieties in terms of *S. asiatica* germination percentage and furthest germination distance (Table 7).

TABLE 5: Analysis of variance for maize plant height recorded for 2nd WACE to 9th WACE.

Source of variation	Degrees of freedom	Weekly heights
Replication	3	2333.7
Genotype	13	13868.1***
<i>Striga</i>	1	66084.2***
Genotype \times <i>Striga</i>	13	2759.5***
Residual	81	509.1
Time	7	213178.8***
Time \times genotype	91	1176.1***
Time \times <i>Striga</i>	7	9559.4***
Time \times genotype \times <i>Striga</i>	91	562.1***
Residual	588	146.6
Total	895	

The symbols *, **, and *** represent significance at 0.5, 0.01, and 0.001 probability levels.

The University of Zimbabwe bred genotypes such as Ax31, Ax28, Ax7, and Bx31, as well as TH14949 (CIMMYT), recorded the lowest *S. asiatica* germination percentage, which were significantly different ($p < 0.05$) from the checks with the only exception of R201 (Tables 7 and 8). Furthermore, the University of Zimbabwe bred genotypes including Ax31 and the check R201 had the least *S. asiatica* germination distance compared to the rest of the local checks (Tables 7 and 8).

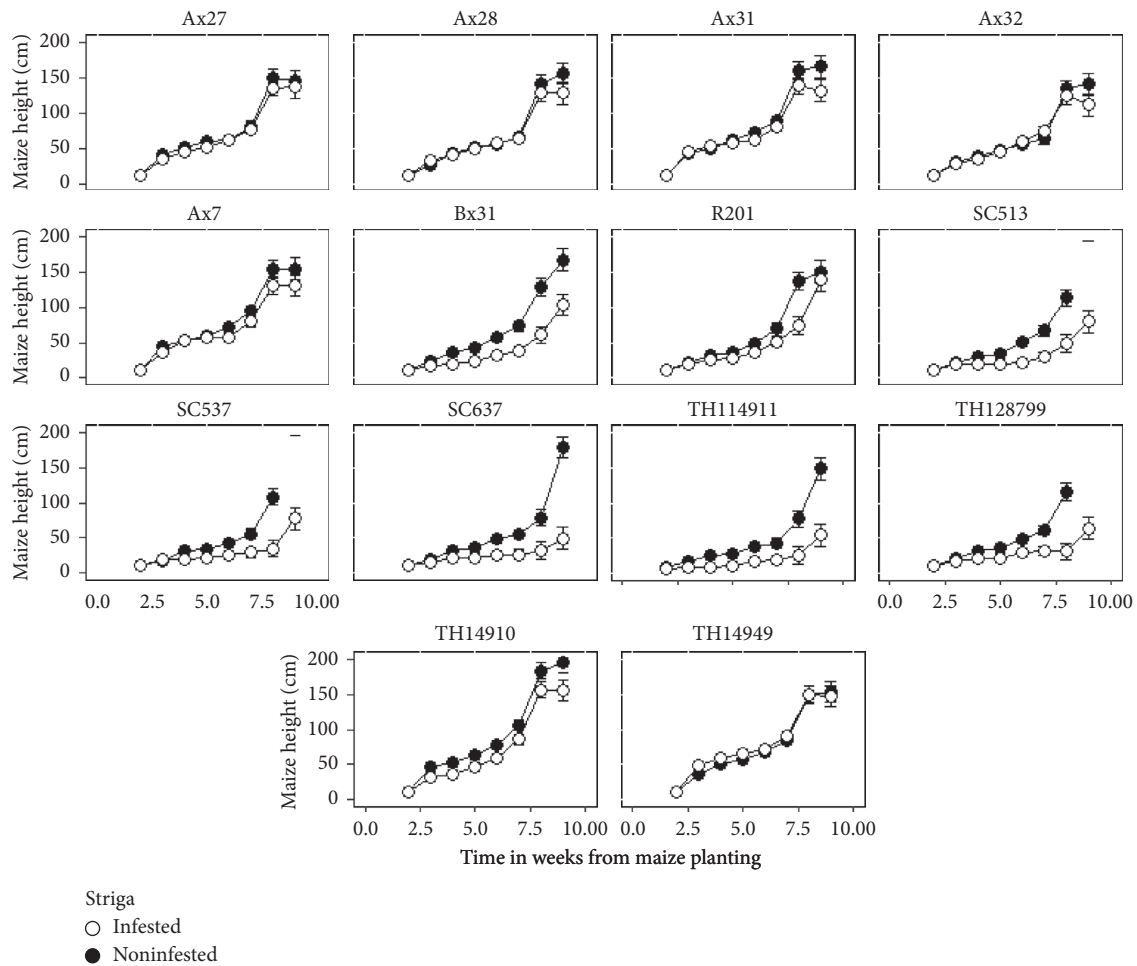


FIGURE 4: Maize plant heights recorded from 2nd WACE up to 9th WACE. Error bars indicate the standard errors shared between four replications.

4. Discussion

Generally, the University of Zimbabwe hybrids bred from IITA *S. hermonthica* resistant varieties proved to be resistant and tolerant to *S. asiatica* compared to local checks. This is not surprising as IITA and partner organizations such as CIMMYT have been rigorously working towards the breeding of *Striga* resistant varieties derived from wild maize relatives, which are naturally resistant to *S. hermonthica* [49]. One such example of the successful *S. hermonthica* resistant genotype by the IITA is the ZD05 [10, 49]. According to Barker et al. [61], Frost et al. [62], and Gurney et al. [63], biomass accumulation and allocation particularly stem biomass and plant height have been used as indicators to assess the tolerance of genotypes to *S. asiatica*. In line with that, the University of Zimbabwe bred genotypes (Figure 1) showed insignificant sensitivity to *S. asiatica* in terms of biomass accumulation and allocation as compared to checks with the only exception of R201 (Figures 1–3). This shows that the University of Zimbabwe bred genotypes using the IITA *S. hermonthica* resistant genotypes can tolerate *S. asiatica* infestation. These findings are in agreement with those reported by Kim and Adetimirin [64] and Gethi and

Smith [65] that *S. hermonthica* resistant and tolerant genotypes also exhibit comparable resistance and tolerance to *S. asiatica*. The University of Zimbabwe bred genotypes, Ax31, Ax28, and Ax7 (Figure 4), did not show any significant differences in terms of height of *S. asiatica* infested and noninfested levels, indicating that they are able to tolerate the negative effects of the parasite. Several researchers including Press and Stewart [66], Taylor et al. [67], and Chitagu et al. [68] reported that, among other parameters, plant height is a good measure of varieties' tolerance to *S. asiatica*. This is mainly because the witchweed had phytotoxic effects and it is also a strong sink for mineral nutrients and carbohydrates which in most cases outcompetes the host crop leaving it stunted [63, 69–71]. Moreover, it was evident from the results that the University of Zimbabwe developed genotypes that did not suffer significantly reduced stem biomass to *Striga asiatica*, the explanation being that these varieties were again able to withstand *Striga* effects. *Striga* is known to affect biomass accumulation and allocation in susceptible plants; one example is reduced biomass allocation to the stems [72, 73]. Stem biomass has been explained by Gurney et al. [74] as a parameter which indicates tolerance levels to *S. asiatica* in sorghum varieties.

TABLE 6: Analysis of variance for *Striga* counts recorded from 42nd day after planting (DAP) to 72nd DAP.

Source of variation	Degrees of freedom	Weekly counts
Replication	3	737.47
Genotype	13	995.47
Residual	36	735.94
Time	5	2553.97***
Time × genotype	49	219.64***
Residual	127	18.87
Total	233	

The symbols *, **, and *** represent significance at 0.5, 0.01, and 0.001 probability levels.

TABLE 7: Analysis of variance for *Striga* germination percentage and furthest germination distance (mm).

Source of variation	Degrees of freedom	Germination distance	Germination percentage
Replication	3	34.83	329.7
Genotype	13	351.68***	945.1***
Residual	39	32.9	232
Total	55		

The symbols *, **, and *** represent significance at 0.5, 0.01, and 0.001 probability levels.

TABLE 8: Germination percentages and furthest germination distance means of IITA and local checks recorded under laboratory conditions.

Genotype	Germination percentage	Genotype	Germination distance (mm)
Ax31	12.8	Ax31	1.5
Ax28	18.0	TH114911	5.0
TH14949	21.5	Bx31	6.3
Bx31	22.9	R201	8.0
R201	23.9	TH14949	8.5
Ax32	25.2	Ax27	9.8
Ax27	32.1	Ax28	10.0
Ax7	35.5	Ax32	12.5
TH114911	40.6	Ax7	14.8
SC637	46.0	TH14910	17.5
TH14910	51.4	TH128799	22.0
SC513	54.6	SC637	24.8
SC537	56.0	SC513	30.3
TH128799	57.2	SC537	31.0
Mean	35.6		14.4
<i>p</i> value	<0.001		<0.001
Least significant difference at 5%	11.3		4.2

So given that most of the University of Zimbabwe bred varieties were not sensitive to *S. asiatica* in terms of plant height and stem biomass, these varieties are highly tolerant to the parasite.

The University of Zimbabwe bred genotypes, Ax31, Bx31, Ax27, and Ax28, had the least furthest *S. asiatica* germination distances, which are less than 10 mm, the index that denotes resistance as described by Hess et al. [75]. Interestingly, some of these genotypes such Ax31, which had furthest *S. asiatica* germinating distances of less than 10 mm also had comparably low *Striga* seed germination percentage, confirming low germination stimulant production, hence resistance to *S. asiatica*. However, those found to be resistant only exhibited preattachment mechanism of resistance based on low germination stimulant production; no postattachment resistance was noted since all the genotypes were not significantly different in terms of *S. asiatica* counts,

which was high in the pot experiment. These findings are in line with studies conducted by Oswald and Ransom [76], which revealed no postattachment resistance to *S. hermonthica* in maize genotypes.

Despite the fact that these materials were developed using *S. hermonthica* resistance/tolerance, they also proved to be able to withstand *S. asiatica* infestation as well. These findings are in line with Gethi and Smith [65], who conveyed that the TZL pools were good sources of *S. asiatica* resistance/tolerance. It was found that though the two *Striga* species are different, similarities exist in the way they respond to germination stimulation, how they attach their haustoria to the host crop, and the host defense mechanisms exhibited against these parasitic weeds [77]. Hence, this study provides a detailed insight into the similarity of host resistance to these two *Striga* species. This information on the relative similarity of host resistance/tolerance to

S. asiatica and *S. hermonthica* is good news to breeders and farmers, as these genotypes will be a two in one approach for the control of the two *Striga* species. That is, the University of Zimbabwe bred genotypes will be a fit in all as they can be grown in both *S. asiatica* and *S. hermonthica* endemic areas without any significant yield losses incurred. These genotypes are a testimony to the amount of work which has been conducted by the IITA and partner organizations such as CIMMYT. This is because the genotypes, which were bred by CIMMYT also showed significant resistance/tolerance to *S. asiatica* even though they were advanced from inbred parents developed for *S. hermonthica* resistance by the IITA. Basically, most checks succumbed to *Striga* with the only exception of R201. This local check, R201, displayed desirable levels of resistance/tolerance, which is comparable to the University of Zimbabwe hybrids bred from IITA resistance sources. Previous research reveals that this genotype (R201) is resistant/tolerant to *S. asiatica* [68]; however, its response to *S. hermonthica* is still to be determined. This is because genetic variations naturally exist even among these local checks. It is important to note that CIMMYT and IITA parent materials are used by many seed houses during their breeding programs and hence the exhibition of resistance/tolerance of these genotypes to *Striga* is a welcome development in the fight against *Striga*. This *Striga* resistant/tolerant characteristic of the developed genotypes can be a major boost to local breeding programs if incorporated to produce locally adapted *Striga* resistant genotypes. *Striga* resistant/tolerant genotypes will provide a lifeline to resource-limited smallholder farmers in their effort to curb the *Striga* scourge endemic in their arable lands. The integration of resistant/tolerant genotypes and other low-cost *Striga* control methods, either cultural or mechanical methods, will be of great agronomic advantage to the African farmer.

5. Conclusion

The University of Zimbabwe maize hybrids bred from IITA germplasm with resistance to *S. hermonthica* resistant/tolerant genotypes displayed desirable resistance/tolerance to *S. asiatica* relative to local commercial checks. Examples of such genotypes are Ax31, Ax28, Ax7, and Ax32. This clearly highlights the similarity of host genetic resistance/tolerance to the two *Striga* species. Hence, these genotypes of the University of Zimbabwe can be used in the breeding programs of seed houses to breed *Striga* resistant/tolerant genotypes for a better and feasible *Striga* control option if integrated together with other *Striga* control strategies for smallholder farmers in *Striga* rife areas.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Supplementary Materials

Table S1 shows the nutritional composition of the soil used in the pot experiments. Fertilizer rates were applied in all the pots used in this study to achieve an application rate of 11.2 kg-N·ha⁻¹, 9.8 kg-P·ha⁻¹, and 9.3 kg-K·ha⁻¹. (*Supplementary Materials*)

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