Effects of *Striga lutea* (Lour) infestation on tolerant maize hybrids (*Zea mays* L) in southern Guinea savanna

S. A. OLAKOJO & G. OLAOYE
(S. A. O.: Institute of Agricultural Research and Training, Obafemi Awolowo University, P. M. B. 5029, Moor Plantation, Ibadan, Nigeria; G. O.: Department of Crop Production, University of Ilorin , P. M. B. 1515, Ilorin, Nigeria)

ABSTRACT

Twenty-four maize inbred lines were screened for tolerance to *Striga lutea* (Lour) in Temidire (a striga-endemic area of Eruwa in Ibarapa East Local Government Area of Oyo State) in 1995 and 1996 under artificial striga inoculation with about 44 000 striga seeds per hill. Ten of the maize inbred lines with varied levels of tolerance were used in diallel crosses to generate 45 F_1 hybrids. The resultant hybrids and two check entries (resistant and susceptible varieties) were evaluated in Temidire, Eruwa Farm settlement, and Ilora in 1998 cropping season under artificial striga infestation to ascertain the effects on grain production, striga tolerance, and maize agronomic characteristics. They were evaluated on four-row plots of three replicates, in a randomised complete block design. The results showed that three of the maize inbred lines were highly tolerant, four were moderately tolerant, one was moderately susceptible, while two were highly susceptible to striga infestation. Mean striga count and rating and days to anthesis (silking and tasselling) were significantly reduced in the hybrid maize compared to inbred parents. Plant and ear heights increased significantly in the hybrid maize. Kernel rows/cob and grain yield increased significantly by 25 and 124 per cent, respectively, over parent inbred. Striga rating, tolerance index, plant aspect, and grain yield differed significantly from one location to another. Similarly, plant and ear heights and husk tip cover differed significantly ($P<0.05$) among locations. The results of this study suggest a promising future for breeding of striga-resistant hybrid maize with yield advantage of over 124 per cent.

RÉSUMÉ

OLAKOJO, S. A. & OLAOYE, G.: *Effets de l'infestation de* Striga lutea *(Lour) sur les hybrides de maïs tolérant (*Zea mays *L.) au sud de la savane guinéenne.* Infestation de *Striga* devient petit à petit un problème grave en Afrique. Il attire aussi des efforts considérables de recherche pour une solution possible aux niveaux nationaux et internationaux, L'étude présente est probablement l'un de tels efforts. Vingt-quatre souches de croisements consanguins de maïs ont subi un test de despistage de la tolérance à la *Striga lutea* (Lour) à Termidire (une zone endémique d'Eruwa du district du gouvernement local de l'est d'Ibarapa de l'Etat d'Oyo) en 1995 et 1996 sous l'inoculation artificielle de *Striga* avec 44,000 de graines de *Striga* par colline. Dix les souches de croisements consanguins de maïs ayant des niveaux variés de tolérance étaient utilisées aux croisements diallèles pour produire 45 F_1 hybrides. Les hybrides résultants et deux entrées de contrôle (variété résistante et variété prédisposée) étaient évaluées à Temidire, aux habitation de champs d'Eruwa et à Ilora pendant la saison de culture de 1998 sous l'infestation de *Striga* artificielle pour la production de grain, tolérance à la striga et les caractéristiques agronomes de maïs. L'évaluation était faite sur les lots en quatre rangées de trois replicatifs dans un dessin de bloc complet choisi au hasard. Les résultats montraient que trois de souches de croisements consanguins de maïs étaient hautement tolérantes, quatre étaient modérément tolérants, une était modérément susceptible, alors que deux étaient hautement susceptibles à l'infestation de *Striga*. Le compte et l'indice moyens de *Striga* et les jours avant l'anthèse (apparition de soies et de pompon) étaient considérablement réduits dans les maïs de hybrides par comparaison avec les parents de croisements consanguins. D'autre part les tailles de plante et d'épi augmentaient considérablement dans les hybrides de maïs.

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Alors que les rangées de grains/épi et le rendement de grain augmentaient considerablement par 25 et 124 % respectivement au-dessus de parents de croisements consanguins. L'indice de *Striga*, l'index de tolérance, aspect de plante et le rendement de grain différaient considérablement d'un emplacement à l'autre. De la même façon, les tailles de plante et d'épi et les couvertures de la pointe de l'enveloppe différaient considérablement ($P < 0.05$) parmi les emplacements. Les résultats de cette étude suggèrent un avenir prometteur pour la reproduction de hybrides de maïs résistant à la *Striga* avec un avantage de rendement au-dessus de 124 %.

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Introduction

Striga is a parasitic weed commonly called witch weed. It is an obligate parasite belonging to the family Scrophulariaceae. Although, they are chlorophyllous, they require a host to complete their life cycle (Musselman, 1987). About 30 or more species have been described, but only five have been classified to be of economic importance in Africa (Ramaiah *et al.,* 1983). These include *Striga hermonthica* (Del) Benth, *S. asiatica* (L.) Kuntz (which had been re-classified as *S. lutea* by electrophoresis at IITA, Ibadan), *S. gesneriodes* (Willd) Vatke, *S. aspera* (Willd) Benth, and *S. forbesii* (Benth). Recently, *S. lutea* has been found endemic to some areas in Oyo and Ogun States of Nigeria, while some southern and northern Guinea savanna of Nigeria were also highly endemic to *S. hermonthica*. Maize is one of the cereal crops seriously affected by striga. Yield losses of between 70 and 90 per cent have been reported by many workers, including Kim & Tanimonure (1993), Lagoke (1986), Olakojo & Kogbe (1999), and Olakojo *et al.* (2001). Hence, the need for effective control of this parasite for enhanced higher yield.

Several control measures that have been suggested include cultural practices, use of biological agents, chemicals and stimulants, and use of nitrogen fertilizer. The use of resistant crop species seems the cheapest, most affordable, and most convenient for the use of African farmers.

The objectives of this study were, therefore, to identify striga-tolerant maize inbred lines for the development of F_1 hybrids, evaluate the resultant hybrids under artificial inoculation for yield potential, and to identify tolerant genotypes for release to farmers in *S. lutea*-endemic areas of southern and northern Guinea savanna for enhanced higher yield.

Materials and methods

Twenty-four maize inbreds (Table 1) with varied tolerance levels to *S. hermonthica* were screened for tolerance to *Striga lutea* in 1995 and 1996. Ten of the maize inbreds were identified and selected for use to study the genetics of *S. lutea* tolerance in maize. The selected inbred lines were subjected to half diallel crosses to generate F_1 hybrids. The 45 F_1 hybrids and two check entries were later evaluated in three striga-endemic locations of the southern Guinea savanna, namely Temidire, Eruwa and Ilora axis of Oyo State in Nigeria. Table 2 shows the description of the trial locations. Land was prepared mechanically and was ridged to avoid striga inoculum being eroded away. Other weeds were culturally controlled, while striga plants were left to infest maize plants. The use of herbicides was avoided for enhanced striga emergence.

Planting was done on 4-row plots of 3 m × 5 m with a spacing of 75 m × 50 m, at three seeds per hill, under artificial striga inoculum of about 44 000 germinable striga seeds per hill. This was done 14 days before maize planting so as to allow striga to condition itself to the new environment. Each entry was planted to a corresponding uninfested plot as control experiment. The seedlings were thinned to two per hill 3 weeks

TABLE 1

List of Maize Inbreds Used for Preliminary Screening for Striga lutea *Tolerance*

S/N	*Inbred line*	*Source/Origin*	*+Tolerance to (S. hermonthica)*
1.	TzLi 57	Côte d' Ivoire	Tolerant
2.	TzLi 55	Côte d' Ivoire	Moderately tolerant
3.	TzLi 100	Côte d' Ivoire	Tolerant
4.	Tzpi 9	Côte d' Ivoire	Highly tolerant
5.	Tzpi 260	Côte d' Ivoire	Tolerant
6.	Tzpi 97	Côte d' Ivoire	"
7.	Tzpi 43-22	Côte d' Ivoire	Moderately tolerant
8.	TzLi 6-1	Côte d' Ivoire	"
9.	TzLi 6-2	Côte d' Ivoire	"
10.	Tzi 4	IITA	Tolerant
11.	Tzi15	IITA	"
12.	TzLi 10	Côte d' Ivoire	"
13.	Tzi 25	IITA	Fairly tolerant
14.	Ku 1414	IITA	Susceptible
15.	Tzmi 105	IITA	Moderately tolerant
16.	Tzmi 104	IITA	Moderately susceptible
17.	9071 STR	IITA	Tolerant
18.	1368 STR	IITA	Highly tolerant
19.	9050 STR	IITA	Moderately susceptible
20.	Tzmi 407	IITA	Moderately tolerant
21.	9450 STR	IITA	Tolerant
22.	WHTPOP 13	Côte d'Ivoire	Moderately tolerant
23.	SLK 1	IAR & T	Susceptible
24.	SLK 2	IAR & T	"

+ Source: IITA, Côte d' Ivoire records 1995 and 1996

after planting (3 WAP) to obtain 53 333 plants ha^{-1}. Chemicals were not used to enhance good striga emergence, while highly reduced quantity of inorganic fertilizer (40 kg N, 20 kg P and 20 kg K ha^{-1}) was used to minimise nitrogen-supressing effect on striga emergence.

The data, which were collected from the two middle rows, included striga emergence count 10 WAP; striga syndrome rating (using scale 1-9, where 1was normal plant growth and no visible damage symptom, 9 was complete scorching of leaves, premature death or collapse of host plant, and no ear formation); days to 50 per cent anthesis (silking and tasselling emergence); striga tolerance index (grain yield of infested/ grain yield of non-infested maize); plant and ear heights (cm) from soil surface to the tassel and from soil surface to the primary ear, respectively; husk tip cover (using a scale 1-5, where 1= complete husk tip cover and 5 = poorly covered husk tip); ear aspect (1-5, where 1= excellent and 5 = very poor in general agronomic outlook); and kernels/row and grain yield (t/ha) at the adjusted moisture of 150 g/kg according to Kim (1994).

The data were statistically analysed by the New Duncan Multiple Range Test (Duncan, 1955) at 5 per cent level of significance ($P<0.05$) to determine means and ranges. The frequency distribution of maize hybrids were carried out for striga and maize agronomic parameters across locations.

Results

The results from the 2-year screening exercise showed that inbred lines Tzli 100, Tzpi 43-22, and Tzmi104 were highly tolerant to the effects of *Striga lutea* infestation, with syndrome ratings of 2.0 to 3.0. Tzmi 105, Tzi 4, Tzpi 260, and Tzli 57 were moderately tolerant with syndrome ratings of 4.0 to 6.0, while Tzpi 97 was moderately

TABLE 2

Description of Trial Locations

Location	*Agroecology*	*Longitude*	*Latitude*	*Average annual rainfall (mm)*
Temidire	Derived savanna	3° 21'E	7° 23'N	1020.0
Eruwa	Southern Guinea savanna	3° 24'E	7° 25'N	985.0
Ilora	Forest / savanna transition	3° 55'E	7° 45'N	973.4

susceptible with a rating of 7.0. Inbred lines Tzli 6-1 and Tzi 10 were highly susceptible to *S. lutea* infestation, with a rating of 9.0 (Table 3). From these results, Tzpi 97 which was tolerant to *S. hermonthica* was moderately susceptible to *S. lutea*, while Tzpi 43-22 which was also susceptible to *S. hermonthica* was highly resistant to *S. lutea*.

Table 4 shows the character means and ranges of striga and maize agronomic parameters across locations. Plant and ear heights, kernels/row as

TABLE 3

Agronomic and Striga-related Parameters of Maize Inbred Lines Selected for Use in Diallel Crosses

Code no.	*Maize parent inbred*	*Origin*	*Seed texture*	*+Tolerance to* S. hermonthica	*Days to tasselling*	*Days to silking*	*Mean striga rating (1-9)*	*Tolerance to* S. lutea
1.	Tzpi 97	Côte d' Ivoire	Dent	Tolerant	60	63	7.0	Moderately susceptible
2.	TzLi 100	"	Dent	Highly tolerant	62	65	2.0	Highly tolerant
3.	Tzpi 43-22	"	Flint/dent	Moderately susceptible	62	66	3.0	Highly tolerant
4.	Tzmi 104	IITA, Ibadan	Flint	Moderately susceptible	65	68	3.0	Highly tolerant
5.	Tzmi 105	"	Flint	Moderately susceptible	67	64	4.0	Moderately tolerant
6.	TzLi 57	Côte d' Ivoire	Flint/dent	Susceptible	67	72	5.0	Moderately tolerant
7.	TzLi 10	IITA, Ibadan	Flint	Very susceptible	58	62	9.0	Highly susceptible
8.	TzLi 6-1	Côte d'Ivoire	Dent	Tolerant	58	60	9.0	Highly susceptible
9.	Tzi 4	IITA, Ibadan	Flint/dent	Susceptible	59	59	6.0	Moderately tolerant
10.	Tzpi 260	Côte d'Ivoire	Dent	Susceptible	59	66	5.0	Moderately tolerant

+IITA, Côte d'Ivoire record (1995 and 1996)

TABLE 4

Means and Ranges (Across Locations) for Striga-related Parameters and Maize Agronomic Characters in Tested Maize Genotypes

Parameter	*Mean*		*Range*		*Character advantage over parent (%)*
	Parent	*Hybrid*	*Parent*	*Hybrid*	
Striga count	6.16[b]	4.45[a]	5.33 - 8.00	1.60 - 9.66	28.0[d]
Striga rating	5.76[a]	5.66[a]	5.33 - 9.00	3.66 - 8.30	2.0[f]
Days to tasselling	118.19[a]	110.06[b]	108.00 - 125.55	103.33 - 105.00	7.0[e]
Days to silking	128.93[a]	121.45[b]	122.00 - 139.00	115.88 - 125.23	5.8[e]
Plant height	197.47[b]	319.63[a]	192.00 - 296.66	282.66 - 356.00	75.3[b]
Ear height	97.80[b]	139.20[a]	72.33 - 109.00	115.00 - 160.66	42.3[c]
Husk tip cover	3.31[a]	2.59[b]	2.66 - 5.00	2.10 - 3.33	21.8[d]
Ear aspect	2.45[a]	2.34[a]	1.50 - 3.83	1.63 - 3.33	4.5[e]
Kernel rows/cob	20.01[a]	24.98[a]	19.33 - 22.66	22.33 - 28.00	25.0[d]
Yield t/ha	1.41[b]	3.16[a]	0.47 - 2.39	1.78 - 4.69	124.0[a]

Figures in the same row with different alphabets are significantly different at 5 % level of probability well as grain yields were significantly higher in hybrids compared to the parent inbreds, due to their heterotic effects. Striga count, striga rating as well as ear aspect were slightly lower in values for hybrids, showing better tolerance to *S. lutea* artificial infestation. Days to 50 per cent anthesis (silking and tasselling) were also reduced significantly ($P<0.05$) in the hybrids compared to the parent inbreds, showing earliness in maturity. Striga count and rating ranged from 5.0 to 8.0 and 5.0 to 9.0, respectively, in parent inbreds as against the hybrids with range of 1.0 to 9.0 and 3.0 to 4.0, respectively. Days to 50 per cent tasselling ranged from 108 to 125 in the parent inbreds as compared to 103 to 105 in hybrids, while days to silking ranged from 122 to 139 in the parent inbreds as against 115 to 125 in the hybrids.

Plant height was in the range of 192 and 297cm in the inbred parents compared to 282 and 356 cm in the hybrids. Ear height also ranged from 72.3 to 109 cm in the parent inbreds while hybrids had a range of 115 to 160.6 cm. The differences in husk tip cover between the parents and the hybrids were not significant. Kernel rows/ear ranged from 19 to 23 in the parent compared to a range of 22 to 28 in the hybrids. Grain yield for the parent inbreds ranged from 0.47 to 2.39 t/ha and for the hybrids from 1.78 to 4.69 t/ha (Table 4).

Table 5 shows the means and ranges of the striga-related characters at individual locations. Mean syndrome rating, tolerance index (mean grain yield of infested/mean grain yield of uninfested), plant aspect, and grain yield differed significantly from one location to another at $P<0.05$ for infested and uninfested maize plants. Grain yields, which were similar for Eruwa and Temidire, were significantly higher at Ilora, suggesting differential performance of the genotypes in different locations. Ranges from the character means were not markedly different among locations (Table 5). Table 6 shows the means and ranges of maize agronomic characters in the three locations. Plant height and husk tip cover differed significantly from one location to another while other agronomic characters did not differ significantly ($P<0.05$).

Tolerant check entry (9846) recorded striga emergence count (5.0), tolerant rating (4.5), and

TABLE 5

Means and Ranges in Striga-related Characters and Grain Yield of S. lutea-*tolerant Hybrid Maize Varieties Evaluated in Temidire, Eruwa, and Ilora*

Character	Mean			Range		
	Temidire	Eruwa	Ilora	Temidire	Eruwa	Ilora
Plant stand	16.21[a]	14.06[a]	14.50[a]	12.00 - 21.00	9.00 - 20.00	13.00 - 18.00
	13.24[a]	14.31[a]	14.80[a]	9.33 - 16.67	9.00 - 20.00	13.00 - 19.33
Striga count	2.878[b]	2.03[b]	10.48[b]	0.067 - 19.00	0.00 - 10.00	0.00 - 12.00
	0.24[c]	0.40[c]	0.00[d]	0.00 - 2.33	0.00 - 1.33	0.00 - 2.30
Striga rating	3.80[b]	2.97[b]	3.60[c]	1.67 - 5.00	1.67 - 5.00	2.00 - 6.33
Tolerance index	1.28[c]	1.31[b]	0.87[d]	0.30 - 2.00	0.64 - 2.79	0.65 - 1.15
Plant aspect	2.16[b]	1.80[b]	1.60[c]	1.33 - 3.67	1.00 - 5.00	1.06 - 2.30
	2.08[b]	1.00[b]	1.30[c]	10.00 - 3.67	1.00 - 5.00	1.30 - 1.67
Yield t/ha	2.09[b]	2.50[b]	2.62[c]	0.62 - 4.00	0.27 - 3.47	1.35 - 4.33
	2.33[b]	1.02[b]	3.01[c]	0.87 - 4.52	0.45 - 1.69	2.06 - 5.13
S E			0.22			

Values at lower portions represent uninfested plot

Figures not followed by the same letter are significantly different at 5 % level of probability

TABLE 6

Means and Ranges of Maize Agronomic Characters of Striga-tolerant Hybrids Tested in Temidire, Eruwa, and Ilora

Character	*Temidire*		*Eruwa*		*Ilora*	
	Mean	*Range*	*Mean*	*Range*	*Mean*	*Range*
Plant height (cm)	180.05[a] (161.75[a])	123.6 - 186.00 (126.00 - 156.33)	158.78[b] (153.12[a])	142.36 - 179.67 (134.33 - 178.33)	109.59[b] (112.00[b])	73.3 - 175.33 (61.00 - 176.33)
Ear height (cm)	72.68[a] (72.51[a])	53.00 - 97.67 (53.00 - 81.33)	69.16[a] (64.02[a])	54.67 - 84.00 (49.33 - 79.33)	56.87 (57.15[ba])	42.67 - 95.33 (44.33 - 79.00)
Flag leaf length (cm)	27.93[a] (28.18[a])	16.00 - 38.00 (12.00 - 43.00)	27.10[a] (27.10[a])	24.33 - 30.67 (21.67 - 31.33)	27.13[a] (26.61[a])	18.00 - 34.00 (18.53 - 34.20)
Days to silking	61.95[a] (62.06[a])	55.33 - 73.3 (55.67 - 66.33)	57.92[a] (60.33[a])	56.33 - 62.00 (57.33 - 63.00)	60.83[a] (60.82[a])	55.30 - 68.00 (55.00 - 70.67)
Days to tasselling	56.31[a] 56.25[a]	49.33 - 66.33 (52.67 - 61.33)	54.01[a] (54.24[a])	52.00 - 57.33 (51.33 - 57.33)	55.86[a] (56.19[a])	49.33 - 70.67 (52.33 - 58.00)
Husk tip cover	1.27[a] (1.37[a])	1.00 - 1.67 (1.00 - 2.67)	1.64[b] (1.01[a])	1.00 - 1.33 (1.00 - 1.33)	1.66[b] (1.60[b])	1.00 - 2.00 (1.00 - 26.67)
S E			0.31			

Figures in the same rows with different alphabets are significantly different at 5 % level of probability
Values in parentheses are for uninfested maize plants

tolerance index (0.68), compared to the susceptible check (9847) with striga count of 20.0 as well as striga rating and tolerance index of 8.5 and 0.51, respectively. The two checks (tolerant and susceptible) also recorded yields of 2.0 and 0.7 t ha^{-1}, respectively. However, the new hybrids were significantly better than the tolerant check in these parameters, especially mean yield (3.16 t ha^{-1}), giving a yield advantage of 50.0 per cent over the tolerant check.

Discussion

Results from this study showed that inbred parents Tzli100, Tzpi 43-22, and Tzmi104 were highly tolerant to the effects of artificial *S. lutea* infestation, with striga syndrome rating of 2-3. Hence, they could serve as promising sources of tolerant genes for the development of tolerant genotypes. This confirms the report of Kim & Adetimirin (1997) that genotypes Ev 25-SR-100-1-2 STR and 9044-3 showed percent tolerance of 92 and 83, respectively..Similarly, the performance of the resultant F_1 hybrids was significantly better than the inbred parents in plant height, kernels/row, and grain yield which are yield-contributing components of striga-tolerant maize genotypes.

Although Olakojo, Ogunbodede & Kogbe (1999) reported yield increase of between 10 and 59 per cent in such hybrids over their parent inbreds, the hybrids were highly susceptible to striga. Therefore, they should be converted to striga-tolerant genotypes to enhance their yield potential in striga-endemic areas. Reduction in crop plant height and vigour has been associated with striga infestation as reported by many workers including Nagawa (1991), Reda & Kebebe (1994), and Mbasa (1994). In this study, increase in plant height, kernel row/ear, and grain yield under artificial striga infestation seems encouraging.

Conversely, reduction in days to anthesis enhances earliness in the tolerant hybrid maize, thereby reducing striga-supressing effect (8-19 WAP) and consequently enhancing higher grain yield. Although Adeosun *et al.* (2001) had described striga emergence count as a parameter to assess the tolerance level of crop genotypes, Kim (1994) recommended the use of striga rating in assessing crop genotypes for tolerance to striga infestation. In this study, mean striga rating, tolerance index, plant height, and grain yield differed significantly from one location to another, indicating differences in the performance of maize hybrids in different locations for these striga agronomic traits. This perhaps suggests the need to select maize-tolerant genotypes for different agroecologies under artificial striga infestation rather than breeding for striga tolerance in a particular environment and testing them in many locations.

Generally, the F_1 hybrids performed relatively better than the parent inbreds, with character advantages of between 2.0 and 124.0 per cent. The hybrids were better than the parent inbreds with 28.0 per cent reduction advantage for striga count, 2.0 per cent tolerance rating advantage, 75.3 and 42.3 per cent plant and ear height advantages, as well as 21.0 and 25.0 per cent husk tip cover and kernel row advantages, respectively. A grain yield advantage of about 124.0 per cent of hybrids over parent inbreds in this study, therefore, seems encouraging.

Conclusion

The results of this study offer a promising future for the development of *S. lutea*-resistant hybrids, thereby enhancing higher grain yield/ha and consequently boosting maize productivity in *S. lutea*-endemic areas.

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