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Development of *Striga asiatica* tolerant hybrid maize (*Zea mays* L.), varieties

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ABSTRACT

Eighteen maize (*Zea mays* L.) Lines including nine *Striga asiatica* tolerant inbreds and nine agronomically desirable (but not necessarily tolerant) inbreds were used in a non-reciprocal diallel cross. The selected F1 hybrids were evaluated twice in the *Striga asiatica* endemic area under artificial infestation. Significant differences were recorded in plant and ear heights, silking and tasselling days under infestation and non-count infestation. Striga emergence count ranged between 0.62 and 1.69, while, tolerance rating varied between 3.0 and 4.17. Tolerance advantages of between 0.12 and 0.25 have resulted in a yield increase of between 13.4% and 27.8%. Yield advantage, tolerance index and, tolerance advantages were also found to be reliable parameters for the assessment of striga tolerance in maize.

High mid-parent heterosis of between 76.0 and 88% was obtained for seed yield, especially in hybrids 9601, 9602 and 9618. From this study, five striga tolerant hybrid maize varieties were identifed. The hybrids (9601, 9602, 9603, 9605 and 9607 exhibited tolerance index of above 0.75, with % yield increase of 13.4, 19.24, 14.1, 27.8 and 13.4 respectively. These hybrids may be desirable for cultivation in the striga endemic areas of South Western Nigeria.

Key words: Heterosis, *Zea mays*, *Striga asiatica*, tolerance index, tolerance advantage

INTRODUCTION

Maize constitutes a major component of the diet of people in the subsaharan tropical region, especially in the Northern and Southern Guinea Savanna. Its production capability and utilization potential are also assuming greater proportions in recent times as the crop is now dominating the farming system in the Northern Guinea Savanna. In the same vein however, effects of production constraints such as downy mildew disease, streak, insect and vertebrate pests are also on the increase. For example in Nigeria, Lagoke (1980) reported the effect of *S. hermonthica* in Northern Guinea Savanna on sorghum and millet, while Omidiji *et al.* (1992) reported infestation of *Striga asiatica* on maize in Southern Guinea Savanna.

Recently, striga parasitic weed commonly called witch weed has reached epidemic status in Northern Guinea Savanna and some parts of derived and Southern Guinea ecologies. Although, striga has been reported to occur in more than 25 countries, surviving on several wild grasses and on major cereals (Omidiji *et al.* 1992), the occurrence, spread and distribution of striga indicate some host and ecological preference. Striga attacking cereals are distinct from those of legumes.

Yield losses due to striga infestation on crops is enormous in countries where it is a serious production stress. Kim *et al.* (1986) reported loss of between 30-90% in maize due to *S. hermonthica* infestation. In fact, total farmland abandonment by 60-70% of the farming population have been reported by Mboob (1985) due to striga infestation, threatening the livehood of about 300 million people in 42 countries. Striga is prolific in seed setting, producing about 500,000 seeds per plant, it is capable of being viable in the soil for about 20 years thus making its control extremely difficult.

Available information on striga assessment indicates that no linear relationship exists between the density of striga seed inoculum used and emergence count (Weber *et al.* 1995). It was also reported by Andrews (1945) that only small portion of striga seed present in the soil attach to the root of host and emerge above ground, and that striga emergence was usually low in maize as against sorghum. This makes a fair assessment of striga tolerance more difficult.

Various control measures such as cultural, chemical and combination of both, have been suggested. Host plant resistance breeding has been identified to be cheaper, most affordable and feasible approach to control striga (Olakojo and Kogbe 1988). The main objectives of the research were: the development of *S. asiatica* tolerant hybrid maize varieties as well as to develop effective striga assessment strategies.

MATERIALS AND METHODS

Twenty-four maize genotypes were screened for tolerance to *S. asiatica* in 1995 and 1996 following the procedures outlined by Berner *et al.* 1995. Nine maize inbreds (Table 1) were identified to be fairly tolerant to artificial infestation with *Striga asistica.* Non-reciprocal diallel crosses were carried out in all possible combinations among the *S. asiatica* tolerant inbreds and nine agronomically desirable maize inbreds.

Table 1. Yield, striga count, striga rating and % tolerance of 18 striga tolerant maize inbreds evaluated at Temidire - Eruwa Oyo State, Nigeria 1996.

Inbred	Yield, t ha^{-1} infested	Non infested	Striga tolerance index	Striga emergence count	Striga rating 1-9	Ranking based on yield and tolerance
TZLi100	1.30	1.40	0.92	1.30	2.0	1
TZLi9	0.85	3.10	0.18	0.00	9.0	16
TZLi57	1.23	3.10	0.40	1.7	5.0.	13
CSP-SR	1.36	2.58	0.53	2.0	5.0	10
TZLi10	0.82	3.37	0.24	1.0	9.0	17
Tzpi97	1.33	2.70	0.49	0.0	7.0	12
TZLi6-1	0.22	3.86	0.57	1.7	9.0	11
Tli57	1.20	2.40	0.50	1.7	5.0	9
Tzpi260	1.30	1.40	0.92	1.8	5.0	6
Tzi4	0.95	1.00	0.95	3.5	6.0	15
Coca SR	1.29	1.36	0.94	1.2	3.0	5
TZLi55	1.35	2.00	0.67	1.5	2.0	3
Tzmi 103	2.0	2.50	0.98	2.0	4.0	8
Tzpi 43-44	2.13	1.32	0.98	1.3	3.0	2
TZLi 11.24	1.24	1.60	0.77	2.0	4.0	7
TZLi 9-1	1.63	2.00	0.81	1.5	2.0	4
Tzpi87	1.23	3.10	0.40	1.7	7.0	14
MKP 10	0.45	0.8	0.40	1.3	9.0	18
Mean	0.65	1.22	2.14	1.83	5.33	
CV	39.83	54.94	41.60	49.82	29.36	
LSD (0.05)	-	-	-	1.56	2.68	

Striga tolerance index = yield of infested/yield of non infested.

Table 2. Pedigree and grain texture of the 22F_1 Striga asiatica tolerant white hybrid maize varieties, tested in Temidire-Eruwa Oyo State, Nigeria in 1996 an d1997.

Hybrid	Pedigree	Grain texture
9601	TZLi 57 x Tli 155	Flint
9602	Tzi4 xTZLi 100	Flint/Dent
9603	TZPi 260 x Tzpi 9	Dent
9604	TZPi97 x Tzpi 9	Dent
9605	Tzi4 x coca - SR(OP)	Flint/Dent
9606	Tzpi 9 x Tzpi 43-44	" "
9607	TZLi 57 x Coca-SR	"
9608	TZLi 15 x TZMi 103	"
9609	TZLi 57 x TZMi 103	"
9610	TZLi 155 x Tzi 100	Flint
9611	Tzi 15 x TZLi 57	Flint/Dent
9612	TZL1 57 x TZLi 100	Flint
9613	TZLi 100 x Tzi 15	Flint
9614	TZLi 5 xTZLi 10	Dent
9615 Check 1 (Res)	TZLi 5 x TZLi 1	"
9616 Check 2 (Sus)	TZLi 1 x TZLi 9	"
9617	TZLi 1 x TZLi 10	"
9618	Tzpi 44 x Tzpi 22	"
9619	Tzpi 22 xTzpi 43	"
9620	Tzpi 44 x Tzpi 87	"
9621	Tzpi 44 x Tzmi 103	Flint
9622	Tzpi 87 x MKP 10	Dent

The resultant F_1 (Table 2) were tested for tolerance to *S. asiatica* during the preliminary evaluation. Twenty promising hybrids were further evaluated in complete randomized blocks with three replications alongside the two check entries (Table 3) under artificial inoculation of about 4000 seeds of *Striga asiatica,* 6-14 days before planting. Each hybrid was planted on ridges at 75x50 cm of four-row plots at two plants per stand giving a population of 53333 plants per hectare. Low dosage of NPK 20-10-10 fertilizer (50 kg ha^{-1}) was applied by broadcast before ridging during land preparation, so as to reduce suppressing effect of nitrogen on striga. Herbicide was not used, to allow full striga emergence.

Data were collected on striga tolerance related parameters, such as striga emeregence count/m^2: tolerance rating using 1-9 scale according to Kim (1995), where 1 = normal plant growth, no visible symptoms 9 = complete scorching of all leaves causing premature death or collapse of host plant and no ear formation). Others include striga tolerance index (i.e. Yield of infested/yield of uninfested), tolerance advantage (tolerance index of variety-tolerance index of the best check entry)/ (tolerance index of check) and yield advantage (Yield of variety - Yield of best check/Yield of best check x 100).

Data were statistically analyzed using analysis of variance and mean separation was done by New Duncan Multiple Range Test (NDMRT). Mid-parent heterosis was computed for grain yield.

RESULTS AND DISCUSSION

Striga infestation reduced plant and ear heights. Significant differences were observed in plant height and the values ranged between 72.0 (9621) and 14.4cm (9601) in the infested maize plants and between 77.2 and 148.0 cm in the uninfested maize plants. A similar trend was also observed in ear height and means of 65.7 and 68.4 cm were recorded in the infested and uninfested maize plants respectively (Table 3). Days to silking and tasselling also varied between 29 and 57, and 28 and 53 in infested and uninfested maize plants respectively (Table 3).

Yield varied between (2.5 and 3.4 t ha^{-1}) and between (2.5 and 3.3 t ha^{-1})in the infested and non-infested maize in 1996. Similar trend was observed in the second evaluation, where yield ranged between (2.66 and 3.53 t ha^{-1}) and between (4.66 and 3.90 t ha^{-1}) the two treatments indicating yield stability under artificial infestation. Significant yield increase was not recorded in the uninfested maize entries. Striga has been reported to be capable of survival in the soil for about 20 years, only to become more active in the presence of susceptible host plants (M'boob 1985).

Striga mean count varied between 0.62 and 1.69 m-1 in the first evaluation and between 0.60 and 1.69 m-2 in the second evaluation. This trait is influenced by striga seed viability, germinability, seedling survival and attachment to the host. These factors may be responsible for low emergence count recorded in this trial. Our observation in Moor Plantation, however indicates low emergence but virulent attack on maize, whereby a single stand of

Table 3. Some agronomic traits of *S. asiatica* tolerant white hybrid maize varieties tested under striga infestation in 1996 and 1997 at Temidire Eruwa, Oyo State, Nigeria.

Variety	Plant height (cm)		Ear height (cm)		Days to 50% silking		Days to 50% tasseling		Stem lodging	
	+	-	+	-	+	-	+	-	+	-
9601	142.4	148.0	68.3	69.8	52	50	53	52	4	4.0
9602	93.8	96.8	60.5	63.5	51	50	49	48	3	3.0
9603	84.4	122.0	66.0	67 3	53	52	53	52	3	3.5
9604	103.0	114.0	80.0	85.6	55	53	54	53	3	3.0
9605	102.2	117.4	79.5	82.0	29	28	30	30	3	3.5
9606	91.2	98.8	62.0	65.3	47	45	47	45	3	3.0
9607	119.4	126.8	80.2	83.0	53	53	54	52	3	3.0
9608	100.6	130.47	70.2	72.3	53	50	54	53	3	3.0
9609	86.6	93.5	50.3	53.4	55	53	54	52	4	4.0
9610	11.0	114.8	86.3	88.2	56	53	54	52	3.0	3.0
9611	111.0	114.8	86.3	88.2	56	53	54	52	3.0	3.0
9612	85.4	114.8	86.3	88.2	56	52	54	52	3.0	4.0
9613	107.0	118.8	81.2	85.9	47	46	47	46	3.5	4.0
9614	101.75	106.0	79.8	54.0	53	56	53	4.0	3.5	4.0
9615 Check 1 (Res)	103.6	106.6	60.2	62.3	55	53	53	52	4.0	3.5
9616 Check 2 (sus)	94.0	90.4	82.4	86.0	29	27	30	28	4.0	3.5
9617	107.2	109.6	54.3	54.3	57	54	58	56	3	3.5
9618	88.8	95.75	50.3	55.0	50	56	54	3.0	3.0	3
9619	88.0	89.7	49.7	52.0	52	51	51	50	3.0	3.0
9620	77.8	86.0	49.9	52.0	54	52	54	52	3.0	3.3
9621	77.8	86.0	49.9	52.0	54	52	54	52	3.0	3.5
9622	72.0	77.0	44.2	45.0	56	54	55	52	3.0	3.0
Mean	98.89	106.12	65.74	68.4	50.0	48.0	50	48.0	3.23	3.32
CV (%)	14.8	16.12	20.87	20.0	17.98	17.94	17.10	16.98	12.4	11.89
LSD (0.05)	6.49	7.58	6.08	6.19	3.99	3.82	3.79	3.61	0.18	NS

Note: + = infested with *Striga asiatica*; - = uninfested with *Striga asiatica*.
9615 = Resistanat check; 9616 =susceptible check

Table 4. Yield, striga count, striga rating and % tolerance of 22F, hybrids evaluated in Temidire-Eruwa, Oyo State, Nigeria in 1996 and 1996.

Hybrid	Mean yield, t ha^{-1} Infested 1996	non inf. 1996	Non infested 1997	1997	Mean striga Count/m^2 1996	1997	Striga rating (1-9) 1996	1997
9601	3.4a	3.39a	3.20a	3.27a	1.73	0.78	1.73c	1.73c
9602	3.31a	3.17a	3.64a	3.90a	1.82	1.11	1.91abc	1.86abc
9603	3.20a	3.20a	3.43a	3.38a	1.77	0.83	1.99ab	1.73c
9604	3.01a	303a	2.98a	3.03a	1.82	1.12	1.91abc	1.77bc
9605	3.54a	3.57a	3.90a	3.71a	1.87	1.24	1.99a	1.77bc
9606	2.94a	2.93a	3.33a	3.25a	1.91	1.12	1.82abc	1.82abc
9607	3.40a	3.34a	3.15a	3.38a	1.82	1.05	1.82abc	1.73c
9608	3.2a	3.05a	3.20a	3.18a	1.73	1.09	1.95ab	1.86abc
9609	2.94a	3.01a	3.10a	3.17a	1 86	0.96	1.86abc	1.91ab
9610	2.64a	2.67a	2.70a	2.86a	1.91	1.02	1.73c	1.94ab
9611	2.50b	2.54b	2.70a	2.79a	2.00	1.25	1.91abc	1.94ab
9612	2.60a	2.54b	2.80a	2.69a	2.03	2.09	1.86abc	1.90ab
9613	2.94a	2.91a	3.20a	3.32a	1.86	0.92	1.82abc	1.73c
9614	2.60a	2.92a	2.63a	3.25a	1.91	1.63	1.82abc	1.73c
9615	2.90a	2.53b	3.42a	2.64a	1.77	0.89	1.77bc	1.82abc
9616	3.01a	2.67a	2.80a	3.30a	1.96	1.63	1.83abc	1.73c
9617	2.80a	2.97a	2.85a	3.20a	1.77	1.29	1.91abc	1.78bc
9618	2.60a	2,97a	3.53a	3.22a	1.95	1.09	1.77bc	1.83abc
9619	2.63a	2.60a	2.90a	2.95a	2.00	1.08	1.90abc	1.95a
9620	2.60a	2.64a	2.95a	3.02a	2.00	1.27	1.77bc	1.86abc
9621	2.60a	2.56b	2.70a	2.88a	2.00	1.28	0.90b	1.94ab
9622	2.72a	2.56b	2.66a	2.66a	2.00	0.96	0.96d	1 95a
Mean	2.91	2.90	3.07	3.12	1.88	1.01	0.97	1.81
SE Mean	0.162	0.158	0.58	0.165	0.060	0.05	0.09	0.05
CV (%)	9.67	9.47	8.93	918	5.52	90	17.11	5.01

Table 5. Striga tolerance index, mean tolerance index, tolerance advantage, mean yield and % yield increase.

Variety	Striga tolerance index 1996	1997	Mid parent heterosis, %	Mean striga count	Tolerance advantage, %	Mean yield, t ha^{-1}	% yield increase or decrease over best check
9601	1.06	1.03	76.0	1.04	25.0	3.30	13.4
9602	0.91	0.90	85.0	0.90	8 0	3.47	13.24
9603	0.93	0.95	62.0	0.94	13.0	3.32	14.10
9604	1.01	1.01	60.0	1.01	2.20	3.00	3.10
9605	0.91	0.96	60.0	0.93	12.20	3.72	27.80
9606	0.88	0.90	55.0	0.89	7.0	3.72	27.80
9607	1.08	0.99	60.0	1.03	24.0	3.14	7.80
9608	1.00	0.96	60.0	0.98	18.0	2.98	2.40
9609	0.95	0.95	56.3	0.95	14.0	3.02	3.70
9610	0.97	0.93	57.4	0.96	16.0	2.67	8.20
9611	0.93	0.94	58.3	0.93	12.0	2.60	10.60
9612	0.92	0.91	60.0	0.91	10.8	2.70	7.20
9613	0.92	0.87	60	0.89	7.0	3.06	5.20
9614	0.92	0.90	50.0	0.91	10.0	2.62	9.90
9615	0.98	0.96	85.0	0.97	17.0	3.16	8.60
9616 (check)	0 85	0.81	45.8	0.83	0.00	2.91	0.00
9617	0.93	0.94	48.3	0.93	13.0	2.83	4.70
9618	0.98	0.92	88.0	0.95	14.0	3.07	5.50
9619	0.66	0.88	52.0	0.77	7.0	2.76	5.20
9620	0.91	0.88	60.0	0.89	6.0	2.78	4.50
9621	0.88	0.89	52.8	0.88	6.0	2.65	8.90
9622	0.96	0.96	54.8	0.96	20.0	2.68	77.90
LSD (0 05)	0.04	0.02	2.21	0.03	2.86	0.13	4.63

yellow flowered *S. asiatica* can cause serious damage to susceptible maize plants.

Striga ratings varied between 3.0 (varieties 9601, 9608) and 4.17 (variety 9612) in the first evaluation as against 3.0 and 3.83 in the second evaluation. Kim (1995) had affairmed that different genes control striga rating and emergence count, thereby providing opportunity to plant breeders for easy genetic manipulation. It has also been found that, yield of individual maize plant is significantly related to incidence and severity of sympotoms (Oikeh *et al.* 1991). Similar results were obtained in this trial as well. Thus varieties 9601 and 9608 with striga rating 3.0 recorded grain yields of 3.4 and 3.20 t ha^{-1}, respectively in 1996 as against varieties 9602 and 9621 with striga rating 4.0 and yield of 2.6 t ha^{-1} in each of the variety. Tolerance advantages of 25, 13, 24 and 12% have resulted in corresponding yield increase of 13.4, 14.0, 13.4 and 27.8% respectively in varieties 9601, 9603, 9607 and 9605 (Table 5). Hence, striga ratings and tolerance index appear more relevant in striga tolerance assessment. For example varieties 9601, 9604, 9607 and 9608 (with tolerance indices 1.04, 1.03, 1.01 and 0.98) recorded striga tolerance ratings of 3.0, 3.3, 3.3 and 3.5 respectively. Whereas striga counts (0.66, 1.07, 1.53 and 1.66) were not directly related to either yield or striga tolerance index. Tolerance index, tolerance and yield advantages, as well as striga ratings appeared to be better parameters for the assessment of striga tolerance.

Kim (1995), Oikeh *et al.* (1991) and Steward *et al.* (1991) have suggested use of striga rating (which is related to individual plant yield), in the assessment of maize plants for striga tolerance level.

The results of mid-parent heterosis of the hybrids are presented in Table 5. Hybrids 9601, 9602 and 9618 recorded very high heterosis for grain yield having 76.0, 85.0 and 88.0% respectively, while moderate heterosis of 52 to 62% were obtained for other hybrids except hybrids 9616 and 9617 with relatively low heterosis of 45.0 and 48.3%. The importance of heterotic pattern for yield and other agronomic characters including days to maturity had been reported by Crossal *et al.* (1989) and Ajala (1992). Large heterosis observed in hybrids 9601 9602 and 9618 produced using inbreds Tzli57, Tzli55, Tzli100 and Tzpi22, suggests that, they are more genetically diverse compared to parents Tzli1, Tzli9 and Tzli10, which produced hybrids having low heterosis for seed yield. High heterosis for seed yield in parents of diverse Baker (1978). It was observed that high heterosis enhance rapid progress in selection especially in the development of F_1 hybrids. The recent increase of maize (Smith *et al.* 1994) cropping in the savanna is coupled with increased cost of chemicals for the control of striga. Cultivation of outstanding striga tolerant varieties such as 9602, 9602, 9603, 9605 and 9607 is highly desirable in the control of striga in the Northern Guinea Savanna of Nigeria.

REFERENCES

Andrews FW 1945 The parasitim of *Striga hermonthica* L. Benth under irrigation 1. Preliminary results and effect of heavy light irrigation on striga attack. Ann. Appl. Biol. 32: 139-200

Berner DK, Winslow MD, Awad AE, Cardwell KFD, Mohanraji KE and Kim stock 1995 Striga Research Methods - Manual of Striga Research, 2nd Edition. PASCON Publication, Ibadan, Nigeria. pp. 1-80

Doggett H 1965 *Striga hermonthica* in Sorghum East J. Agric. Sci. 65: 183

Dogget H 1984 Striga - Its biology and control. Proc. Workshop on the Biology and Control of Stirga. Dankar, Senegal 14-17 Nov., 1983. ICSU Press pp. 26-27.

Eplee RE and Norris RS 1987 Chemical control of Striga. In: parasitic Weeds in Agriculture. Vol. 1, L.J. Mkusselman

Igbinnosa I, Cardwell KE and Okonkwo SNC 1992 Effect of inorganic nitrogen nutrition on germinated embryos of the giant witch weed *Striga hermonthica* Benth. cultured *in vitro*. Nation-wide conference on maize. Ile-Ife, Nigeria, March, 1986.

Kim SK 1991 Breeding maize for striga tolerance and the development of a field infestation technique. In: Combating Striga in Africa. Edited by S.K Kim (Ed.) IITA, Ibadan, Nigeria. pp. 96-108.

Kim SK and Tanimonire F 1993 Relationship between water and striga emergence. Striga Newsletter, 4. July, 1993 p. 9.

Kim SK 1995 Genetics of maize tolearance of *Striga hermmonthica*. Crop Sci. 34 (4) : 900-907.

Lagoke STO 1986 Striga in Nigeria. In: proceedings of the FAO/OAU All African Government Consultation on Striga Control 20-24 Oct., 1986. Maroua Cameroon. pp. 68-75.

M'boob SS 1986 A regional programme for West and Central Africa. In: Proceedings of the FAO/OAU, All - African Government Consultation on Striga Control 20-24. Oct., 1986. Marouva Cameroom. pp. 190-194.

Mussellmon LJ, Ayansu ES and Okwonkwo SNC 1984 Taxonomy and biosystematics of striga. Paper presented at workshop on striga biology and control held in Dakar, Senegal 14-17 Nov., 1983.

Oikeh S, Weber G, Lagoke STO and Awad A 1991 Estimation of yield losses from *Striga hermonthica* in farmers fields in the northern Guinea savanna of Nigeria. Paper presented at the 19th Annual Conference of the Weed Society of Nigeria 1-5 December 1991, Zaria, Nigeria.

Omidiji MO, Kogbe JOS, Shoyinka SA, Olunuga BA, Salawu RA and Somuji O 1993 Striga on maize in Ogun State, Nigeria. Maize Newsletter. Vol. 1 No. 2.

Parker C 1984 The physiology of *Striga* spp: Present state of knowledge and priorities for future research: Paper presented at a workshop on Biology and control of striga Dakar, Senegal. Nov. 14-17, 1988. ICSU Press. pp. 179-194.

Olakojo SA and Kogbe JOS 1998 Reaction of some maize genotypes to infestation with *Striga asiatica*. Bioscience Research Communication (in Press).

Safa SB, Jones BMG and Musselmen LJ 1984 Mechanism Farming outbreeding on *Striga hermonthica*. New Phytol. 96: 279-305.

Smith J, Barau AD, Goldman A and Mareck JH 1994 The role of technology in agricultural intensification: The evolution of maize production in the Northern Guinea Savanna of Nigeria. Economic Development and Cultural Change 42: 537-554.

Weber G, Elemo K, Award A, Lagoke STO and Oikeh S 1995 Striga infestation in farmers' fields. In: *Striga hermonthic* in cropping systems of the Northern Guinea Savanna pp 7-30.